

DESCRIPTION

CATHETER BALLOON AND BALLOON CATHETER

Technical Field

[0001] The present invention relates to a
5 catheter balloon and a balloon catheter.
Particularly, the present invention relates to a
balloon and a balloon catheter inserted into lumens
in the body.

Background Art

10 [0002] A catheter equipped with a balloon
(balloon catheter) is used for body organ dilation,
which is performed for maintaining a luminal space
by means of placing a stent in a stenosed site of
lumens in the body, such as blood vessels, the bile
15 duct, the esophagus, the trachea, the urethra, and
other organs. Moreover, the catheter is also being
used for treating ischemic heart diseases or for
urethral catheterization for patients having a
difficulty in urination.

20 [0003] Accordingly, the balloon catheter is
required to have properties including (1)
trackability (a property that enables the balloon to
move along the tortuous blood vessels and the like),
(2) an ability to pass through stenosed sites of
25 blood vessels and the like, (3) an ability to dilate
stenosed sites of calcified blood vessels and the
like, (4) compliance (an appropriate degree of non-
extensibility by which the balloon catheter does not
inflate any further once it has dilated up to a
30 desired diameter), (5) a sufficient degree of

strength and pressure resistance that enables the balloon catheter to endure the internal pressure or impact caused at the time of balloon dilation, and the like.

5 [0004] Particularly, the balloon portion is required to have compliance, pressure resistance, and flexibility and to be formed of a thin membrane. As materials of the catheter balloon satisfying such properties, polyethylene terephthalate, polyolefins, 10 polyamide, and the like have been conventionally used.

For example, the conventional balloon, which is obtained as disclosed in JP-A-2008-253786 by means of selecting aliphatic-aromatic polyamide as a base 15 polymer and making the aliphatic polyamide having a short carbon chain into a polymer alloy to improve compliance or pressure resistance, has aromatic rings in the main chain, and hence the pressure resistance and compliance thereof can be improved. 20 However, this balloon is inferior to a balloon made of polyethylene terephthalate (PET) and the flexibility thereof is poorer than that of aliphatic polyamide.

For this reason, the JP-A-2008-253786 discloses a 25 technique relating to a balloon obtained by adding inorganic crystals to the polymer.

[0005] Moreover, as another technique of improving pressure resistance and flexibility, JP-A-2005-319289 can be exemplified.

The JP-A-2005-319289 discloses a technique of producing a balloon by means of biaxial stretch blow molding by using a block polymer, which includes a polyamide-based hard segment and a glycol-based soft segment, as a material of the balloon membrane such that a calculated elastic modulus under a pressure caused at the time of balloon dilation becomes 1,300 MPa or higher.

Summary of Invention

[0006] If inorganic crystals are added to the polymer as described in the JP-A-2008-253786, pressure resistance or compliance of the balloon are definitely improved. However, the improvement in the flexibility or a property of thin membrane cannot be expected.

Moreover, the catheter balloon repeatedly dilates and contracts by medical practice. In the balloon which is disclosed in the JP-A-2008-253786 and formed of a membrane that is merely a mixture of inorganic crystals and a polymer, the adhesion force between the polymer and the inorganic crystals is weak, and the inorganic crystals themselves do not easily dilate or contract. Consequently, when the balloon dilates, delamination occurs in the

interface between the polymer and the inorganic crystal inside the membrane, and gaps are formed. These gaps act as cracks in the entire membrane as a mixture of the inorganic crystals and the polymer, hence rupture of the balloon membrane may start from the gaps.

Particularly, the balloon is generally in the form of a cylinder and has a structure that dilates due to the internal pressure thereof. Therefore, from a dynamic viewpoint, a maximum stress is applied to the innermost circumference thereof, and this leads to a problem that balloon membrane easily ruptures from the direction of the inner circumference if there are gap inside the membrane.

[0007] Furthermore, through the biaxial stretch blow molding that is performed as described in the JP-A-2005-319289 by using the block copolymer, which includes a polyamide-based hard segment and a glycol-based soft segment, as a material of the balloon membrane, sufficient pressure resistance is not obtained.

Particularly, as described above, from a dynamic viewpoint, a maximum stress is applied to the innermost circumference of the balloon, hence the problem that the balloon membrane easily ruptures from the direction of the inner circumference thereof cannot be resolved.

[0008] In order to solve the above problem, the present invention is focused on the orientation of polymers in the balloon membrane, and aims to provide a catheter balloon with improved pressure resistance of the entire membrane and a balloon catheter by converting the maximum stress applied to the innermost circumference into extensibility.

[0009] In order to achieve the above object, the present inventors found that the above problems can

be solved by a cylindrical catheter balloon formed of a membrane as a laminate of at least two or more layers including a polyamide elastomer layer and a polyamide layer, in which the polyamide elastomer layer is disposed at the inner side of the polyamide layer, a refractive index n_{r1} in the circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide layer is greater than a refractive index n_{r2} in the circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide elastomer layer, and a difference between the refractive index n_{r1} and the refractive index n_{r2} is 0.01 or greater.

[0010] If the following description and preferable embodiments illustrated in the attached drawings are taken into consideration, other objects, properties, and characteristics of the present invention will become obvious.

Brief Description of Drawings

[0011] [Fig. 1A] Fig. 1A is a schematic view showing an example of a catheter balloon according to the present invention.

[Fig. 1B] Fig. 1B is a schematic view showing another example of the catheter balloon according to the present invention.

[Fig. 2] Fig. 2 is a schematic view for illustrating a mold for molding the catheter balloon according to the present invention.

[Fig. 3] Fig. 3 is a schematic view showing an example of a balloon catheter according to the present invention.

[Fig. 4] Fig. 4 is a view illustrating examples and showing experimental data of the present invention.

[Fig. 5] Fig. 5 is a view showing experimental data of examples of the present invention.

[Fig. 6] Fig. 6 is a view showing experimental data of examples of the present invention.

[Fig. 7] Fig. 7 is a view showing experimental data of examples of the present invention.

[Fig. 8] Fig. 8 is a view showing experimental data of examples of the present invention.

Description of Embodiments

[0012] Hereinafter, embodiments of the present invention will be described in detail.

[0013] In addition, the present application is based on Japanese Patent Application No. 2011-0214496 filed September 29, 2011, the entire content of which is incorporated herein as reference.

[0014] A first aspect of the present invention is a cylindrical catheter balloon formed of a membrane as a laminate of at least two or more layers including a polyamide elastomer layer and a polyamide layer, in which the polyamide elastomer layer is disposed at the inner side of the polyamide layer, a refractive index n_{r1} in the circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide layer is greater than a refractive index n_{r2} in the

circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide elastomer layer, and a difference between the refractive index n_{r1} and the refractive index n_{r2} is 0.01 or greater.

[0015] According to the above aspect, a catheter balloon that has been further improved in terms of pressure resistance compared to the conventional catheter balloon can be provided.

Moreover, it is possible to inhibit the balloon portion from dilating due to pressurization while maintaining flexibility and pass-through ability that the conventional balloon has. Furthermore, it is possible to reliably dilate a lesion and to prevent the mucous membrane or the inner lining of blood vessels from being damaged.

Accordingly, if the balloon according to the present invention is used, it is possible to obtain a balloon catheter which exhibits excellent trackability at the time of the balloon dilation, inhibits cracking or crazing as a starting point of rupture, and has excellent mechanical strength and flexibility.

[0016] In addition, a compliance, which shows how easily the diameter can be increased, of the balloon of the present invention is as low as 0.012 mm/atm or less. Therefore, it is possible to dramatically inhibit the balloon portion from stretching due to the pressurization while maintaining flexibility and

pass-through ability that the conventional balloon has.

[0017] The structure of the catheter balloon according to the present invention will be described first by using drawings, and then the properties and each constituent of the balloon will be described below. However, each of Figs. 1A and 1B is merely an example of the catheter balloon, and the scope of the present invention is not limited thereto.

10 [0018] Fig 1A is a cross-sectional view showing an example of the catheter balloon according to the present invention that has a two-layer structure consisting of a polyamide layer and a polyamide elastomer layer. Fig. 1B is a cross-sectional view showing an example of the catheter balloon of the present invention that has a three-layer structure in which a polyamide elastomer layer 8, a polyamide layer 9, and the polyamide elastomer layer 8 are laminated on each other in this order.

20 [0019] It is preferable for a catheter balloon 11 according to the present invention to be constituted with a cylindrical membranous body 2 that can dilate or contract by fluid supplied from a catheter and connection portions 7a and 7b that extend from both ends in the axial direction of the membranous body and are connected to the catheter.

25 In the respective connection portions 7a and 7b at both ends, opening portions 3a and 3b through which a catheter is inserted are formed.

It is preferable for the opening portion 3b of one of the connection portions to have a diameter larger than that of the opening portion 3a of the other connection portion.

5 Moreover, the catheter balloon 11 has a cylindrical portion which is for dilating stenosed portions of lumens in the body, such as blood vessels, the ureter, and the bile duct, and has a practically uniform outer diameter.

10 [0020] As shown in Figs. 1A and 1B, each of both ends of the cylindrical membranous body 2 may have a tapered shape (portion with a gradient).

That is, it is preferable for the balloon according to the present invention to have the cylindrical
15 membranous body 2 including tapered portions 6a and 6b that have the shape of an (approximately) truncated cone (or the shape of an approximately truncated pyramid) becoming narrow toward the both ends thereof, and the connection portions 7a and 7b
20 that are linked respectively to the tapered portions 6a and 6b and are connected to the catheter extending out of the axial direction.

Further, in the connection portions 7a and 7b at the both ends, opening portions 3a and 3b through which
25 the catheter is inserted are respectively formed.

[0021] When both ends of the cylindrical membranous body have a tapered shape, the portion where the diameter of the balloon is maximized continues in the central portion of the cylindrical
30 membranous body. Moreover, the tapered portions 6a

and 6b continue from the central portion of the cylindrical membranous body and show the change in which the diameter continuously decreases toward the end thereof.

5 [0022] The connection portions 7a and 7b connected to the catheter continue respectively from the tapered portions 6a and 6b, and have small outer diameters of almost the same size. A balloon is mounted on the catheter in the connection portions 7a
10 and 7b, and the opening portions 3a and 3b are formed respectively in these portions. In addition, the tapered portions 6a and 6b and the connection portions 7a and 7b connected with the catheter are respectively positioned in both ends of
15 the cylindrical membranous body of the balloon. The shapes of the respective tapered portions and connections portions may be different from each other.

[0023] The catheter balloon according to the
20 present invention is formed of a membrane having a multi-layer structure as a laminate of at least two or more layers including a polyamide elastomer layer and a polyamide layer. The catheter balloon is preferably formed of a membrane having one to three
25 polyamide elastomer layers and one to two polyamide layers, and more preferably formed of a membrane having two polyamide elastomer layers and one polyamide layer.

[0024] If the polyamide elastomer is laminated on
30 the polyamide as described above, a parison, which

will be described later, can be easily molded by coextrusion. Moreover, flexibility and pass-through ability required for a catheter balloon as well as pressure resistance can be established

5 simultaneously.

[0025] Regarding the order of laminating the polyamide elastomer layer 8 and the polyamide layer 9, as long as a laminate structure, in which the polyamide elastomer layer 8 is disposed at the
10 innermost side and the polyamide layer 9 is laminated on the outer surface of the polyamide elastomer layer 8, is established, other layers may be laminated in any order without particular limitation.

15 [0026] It is particularly preferable for the catheter balloon according to the present invention to be constituted with a membrane having a three-layer structure in which the polyamide elastomer layer 8, the polyamide layer 9, and the polyamide
20 elastomer layer 8 are laminated on each other in this order.

[0027] If the polyamide elastomer layer is formed as an outermost layer, the balloon exhibits flexibility when being inserted into the body by
25 being mounted on a catheter. Accordingly, the balloon excellently passes through lumens in the body, such as blood vessels.

[0028] Moreover, the surface of the polyamide elastomer layer provided as an outermost layer or

the polyamide layer may be optionally coated with a biocompatible material or an antithrombotic material. As the biocompatible material or the antithrombotic material, one kind among various known polymers may
5 be used alone, or a mixture thereof may be used.

For example, natural polymers (collagen, gelatin, chitin, chitosan, cellulose, polyaspartic acid, polyglutamic acid, polylysine, casein, and the like), synthetic polymers (phosphatide polymers and

10 Methacryloyloxyethyl Phosphorylcholin (MPC) block polymers having a phosphoric acid group on the side chain thereof), polyhydroxyethyl methacrylate, hydroxyethyl methacrylate-styrene copolymers (for example, a HEMA-St-HEMA block copolymer), polymethyl
15 methacrylate, polylactic acid, polyglycolic acid, a lactic acid-glycolic acid copolymer, polyethylene, polypropylene, and the like can be preferably used.

[0029] In order to make it easy to insert the catheter balloon according to the present invention
20 into blood vessels or a guide catheter, it is preferable to treat the outer surface of the balloon or the membranous body such that the outer surface of the balloon or the membranous body exhibits lubricity when coming into contact with blood and
25 the like.

Examples of the above treatment include a method of coating the surface with hydrophilic polymers such as poly(2-hydroxyethylmethacrylate), polyhydroxyethyl acrylate, hydroxypropyl cellulose,
30 methyl vinyl ether-maleic anhydride copolymers,

polyethylene glycol, polyacrylamide, polyvinyl pyrrolidone, and random or block copolymers of dimethylacrylamide-glycidyl methacrylate, a method fixing these polymers onto the surface, and the like.

5 [0030] It is preferable for the polyamide elastomer layer to be formed while being in close contact with the surface of the polyamide layer. Furthermore, it is preferable for the polyamide elastomer layer to be formed while being in close
10 contact with the entire surface of the polyamide layer.

In this manner, a catheter balloon with improved pressure resistance can be provided.

[0031] As described above, the catheter balloon
15 according to the present invention is a cylindrical membranous body in which a polyamide elastomer layer is disposed at the inner side of a polyamide layer, in which a refractive index n_{r1} in the circumferential direction of a cross-section
20 perpendicular to the axis in the surface of inner side of the polyamide layer is greater than a refractive index n_{r2} in the circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide elastomer
25 layer, and a difference between the refractive index n_{r1} and the refractive index n_{r2} is 0.01 or greater. The difference between the refractive index n_{r1} in the circumferential direction of a cross-section perpendicular to the axis in the surface of inner
30 side of the polyamide layer and the refractive index

n_{r2} in the circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide elastomer layer is preferably from 0.01 to 0.02 and more preferably from 0.01 to 0.015.

[0032] As described above, if the polyamide elastomer layer is disposed at the inner side of the polyamide layer, and the difference between the refractive index n_{r1} in the circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide layer and the refractive index n_{r2} in the circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide elastomer layer is 0.01 or greater, the number of the polyamide elastomer molecules in the polyamide elastomer layer that are oriented in the circumferential direction becomes relatively small. Consequently, the polyamide elastomer layer obtains a margin for stretching.

It is considered that for this reason, the stress applied to the innermost circumference can be converted into extensibility of the polyamide elastomer layer.

[0033] To described in more detail, it is known that in the system in which internal pressure is applied to a cylindrical substance such as a catheter balloon, theoretically, a maximum stress is applied to the innermost circumference of the cross-section perpendicular to the axis of the cylindrical

substance, and the stress decreases toward the radial direction of the cross-section perpendicular to the axis (cylinder model). Actually, it has been confirmed that when internal pressure is applied to the catheter balloon, rupture of the balloon starts from the side of the innermost circumference in many cases.

In the present invention, a flexible polyamide elastomer layer, in which a relatively small number of polymers are oriented in the circumferential direction, is disposed at the side of the innermost circumference to which a maximum stress is applied, whereby the maximum stress applied to the innermost circumference is converted into extensibility of the flexible polyamide elastomer layer. It is considered that for this reason, the internal pressure applied to the balloon can be effectively absorbed in the system of the catheter balloon.

[0034] On the other hand, it is considered that since a hard polyamide layer, in which the number of polymers oriented in the circumferential direction is relatively larger than that of the flexible polyamide elastomer layer, is disposed at the outside of the polyamide elastomer layer, the strength of the entire catheter balloon can be maintained.

Moreover, in the balloon membrane according to the present invention, a large number of polymer chains are crystallized in the hard polyamide layer in which a relatively large number of polymers are

oriented in the circumferential direction.
Accordingly, an effect that results in excellent compliance is also obtained.

[0035] From the above facts, it is considered
5 that by controlling the orientation state of polymer chains in each layer of the membrane as a laminate of at least two layers including a polyamide layer and a polyamide elastomer layer constituting the balloon catheter, the pressure resistance that makes
10 the rupture starting from the inner side occur less compared to the conventional catheter balloon is improved.

[0036] The orientation state of the polymer chains can be confirmed by measuring birefringence
15 in general.
For example, in a uniaxially stretched polymer film, the molecular chains are oriented in the stretch direction. Accordingly, there is a difference between a refractive index in the stretch direction
20 and a refractive index in a direction perpendicular to the stretch direction. This results in anisotropy of the refractive index of light, and can be measured as birefringence.

As methods of measuring birefringence described
25 above, there are (1) an intensity method, (2) a compensation method, (3) observation of polarization color, and the like.

In the present invention, birefringence is measured by the (2) compensation method as follows, and then
30 a refractive index (n_r) in the circumferential

direction of a cross-section perpendicular to the axis of the balloon, a refractive index (n_l) in the long axis direction of the balloon, and a refractive index (n_d) in a radial direction of the cross-section perpendicular to the axis of the balloon are calculated.

[0037] A relative refractive index used in the present invention is calculated by three-dimensional analysis by using a polarization microscope.

10 The cross-section of a fragment having a thickness of 16 μm that is sliced from the central portion of the straight tube portion of the balloon and the cross-section of a fragment that is sliced in the long axis direction were observed with a
15 polarization microscope, and retardation thereof was measured using a compensator to calculate a birefringence Δn of the cross-section and a birefringence Δn of the long axis by the following Formulae (1) to (3).

20

[0038] [Math. 1]

Formula (1)

$$\Delta n = R \div t$$

Formula (2)

$$R = C \times f(i)$$

25

Formula (3)

$$f(i) = \sin^2 i (1 + 0.2041 \times \sin^2 i + 0.0627 \times \sin^4 i)$$

[0039] (In the Formulae (1) to (3), $9R$ indicates retardation (nm), t indicates the thickness $16\text{ }\mu\text{m}$ of a sample, C indicates a constant of 0.822×10^4 that depends on the thickness of a crystal mounted
 5 on the compensator, and i indicates a correction angle (Radian) of the compensator.)

Subsequently, the birefringence Δn of the cross-section and the birefringence Δn of the long axis calculated by the Formulae (1) to (3) are assigned
 10 to the following Equations (1) to (3) to calculate solutions of a refractive index (n_r) in the circumferential direction of the cross-section perpendicular to the axis, a refractive index (n_L) in the long-axis direction, and a refractive index
 15 (n_d) in the radial direction (thickness direction) of the cross-section perpendicular to the axis respectively.

[0040] [Math. 2]

Equation (1):

$$\Delta n(\text{Cross-section}) = |n_r - n_d|$$

Equation (2):

$$\Delta n(\text{Long axis}) = |n_L - n_d|$$

Equation (3):

$$n^2 = (n_r^2 + n_L^2 + n_d^2) \div 3$$

Solution:

$$n_r = (-b + \sqrt{b^2 - 12c}) \div 6$$

$$n_L = n_d + \Delta n(\text{Long axis})$$

$$n_d = n_r - \Delta n(\text{Cross-section})$$

$$b = 2\Delta n(\text{Long axis}) - 4\Delta n(\text{Cross-section})$$

$$c = 2(\Delta n(\text{Cross-section}))^2 + (\Delta n(\text{Long axis}))^2 - 2\Delta n(\text{Cross-section}) \times \Delta n(\text{Long axis}) - 3n^2$$

[0041] (In the Equations (1) to (3) and solutions, $\Delta n(\text{cross-section})$ indicates a birefringence in the slicing direction, $\Delta n(\text{long axis})$ indicates a

birefringence in the long-axis direction, n_r indicates a refractive index in the circumferential direction, n_L indicates a refractive index in the long-axis direction, n_d indicates a refractive index
5 in the thickness direction, and n is 1.51 (average refractive index.))

In this manner, as described in the experimental results which will be shown later in examples, it is possible to calculate the refractive index (n_r) in
10 the circumferential direction of the cross-section perpendicular to the axis, the refractive index (n_L) in the long-axis direction, and the refractive index (n_d) in the radial direction of the cross-section perpendicular to the axis in any position in each
15 layer of the catheter balloon having the multi-layer structure, by means of the above measurement method using a polarization microscope.

[0042] Moreover, by calculating the refractive index (n_r) in the circumferential direction of the
20 cross-section perpendicular to the axis, the refractive index (n_L) in the long-axis direction, and the refractive index (n_d) in the radial direction of the cross-section perpendicular to the axis by means of the above method, the orientation
25 state of polymer chains in each direction can be specified.

For example, the larger the value of n_r is, the more the polymer chains are likely to be oriented in the circumferential direction, and the larger the value
30 of n_L is, the more the polymer chains are likely to

be oriented in the long-axis direction. Furthermore,
the smaller the value of n_d is, the more the polymer
chains are likely to exhibit plane orientation, and
if n_r and n_L have the same value, the polymer chains
5 may be oriented in an isotropic state.

In the present invention, n_{r2} of the polyamide
elastomer layer is smaller than n_{r1} of the polyamide
layer by 0.01 or a larger value. Accordingly, in
the polyamide elastomer layer, the degree of
10 orientation in the circumferential direction is low,
hence the innermost circumference of the balloon
obtains a margin for stretching.

[0043] In the present specification, regarding
each of the refractive indices of the surface of
15 inner side of the polyamide elastomer layer that is
disposed at the innermost side of the balloon, a
refractive index in the circumferential direction of
the cross-section perpendicular to the axis is
denoted as n_{r2} , a refractive index in the long-axis
20 direction is denoted as n_{L2} , and a refractive index
in the radial direction of the cross-section
perpendicular to the axis is denoted as n_{d2} .

Moreover, regarding each of the refractive indices
of the surface of inner side of the polyamide layer
25 that is laminated on the surface of the polyamide
elastomer layer, a refractive index in the
circumferential direction of the cross-section
perpendicular to the axis is denoted as n_{r1} , a
refractive index in the long-axis direction is
30 denoted as n_{L1} , and a refractive index in the radial

direction of the cross-section perpendicular to the axis is denoted as n_{d1} .

[0044] Herein, each of the refractive indices of the surface of inner side of the polyamide layer refers to a refractive index in the area of the polyamide layer near the inner surface (interface between the polyamide layer and the polyamide elastomer layer) of the polyamide layer. For example, the refractive index in the circumferential direction of the cross-section perpendicular to the axis of the surface of inner side of the polyamide layer refers to a refractive index in the circumferential direction that is found in an area which starts from the inner surface of the polyamide layer and is equal to or smaller than one third of the thickness of the entire polyamide layer.

[0045] Furthermore, herein, each of the refractive indices of the surface of inner side of the polyamide elastomer layer refers to a refractive index in the area of the polyamide elastomer layer near the inner surface of the polyamide elastomer layer. For example, the refractive index in the circumferential direction of the cross-section perpendicular to the axis of the surface of inner side of the polyamide elastomer layer refers to a refractive index in the circumferential direction that is found in an area which starts from the inner surface of the polyamide elastomer layer and is equal to smaller than a half the thickness of the entire polyamide elastomer layer.

[0046] Regarding the size of the catheter balloon according to the present invention, the outer diameter of the cylindrical membranous body is preferably 1 mm to 35 mm and preferably 1.5 mm to 30 mm when the balloon dilates. Moreover, the length of the cylindrical membranous body in the long-axis direction is 3 mm to 80 mm and preferably 10 mm to 75 mm, and the full length of the balloon (total length of the cylindrical membranous body and the connection portions in the long-axis direction) is 5 mm to 120 mm and preferably 15 mm to 100 mm.

[0047] The shape of the cross-section perpendicular to the axis of the balloon according to the present invention is not particularly limited and may be a circle, an ellipse, an approximately elliptic shape, an approximately circular shape, or a polygonal columnar shape. It is preferable for the balloon according to the present invention to have a cylindrical shape.

[0048] When the catheter balloon according to the present invention contracts, the average thickness (thickness) thereof is preferably 5 μm to 50 μm and more preferably 10 μm to 30 μm .

[0049] If the average thickness of the catheter balloon is within a range of 5 μm to 50 μm at the time of contraction, this is preferable in view of trackability or the ability to pass through stenosed portions of blood vessels and the like.

[0050] The connection portions of the catheter balloon of the present invention may be integrated (monolithically molded) with the membranous body 2 as described in Fig. 1A or 1B shown above, or may be
5 separately bonded to the membranous body, in the form of a membranous substance which has a diameter smaller than that of the membranous body 2 and an approximately cylindrical shape.

In a normal state, the average thickness of the
10 connection portions according to the present invention is preferably 5 μm to 50 μm and more preferably 10 μm to 30 μm .

[0051] The catheter balloon according to the present invention includes a membranous body that
15 can dilate or contract by fluid supplied from a catheter. Therefore, the catheter balloon is foldable and can contract in a state of being folded around the outer circumference of the body of the catheter.

20 [0052] The average thickness of the polyamide layer constituting the catheter balloon according to the present invention is preferably 0.5 μm to 49.5 μm and more preferably 5 μm to 25 μm .

This is because flexibility and pass-through ability
25 required for a catheter balloon as well as pressure resistance can be established simultaneously.

[0053] The polyamide layer according to the present invention contains polyamide and may optionally contain known additives or radiopaque

substances. Alternatively, the polyamide layer may be constituted only with polyamide. If the polyamide layer contains polyamide in an amount of 50% by weight to 100% by weight, pressure resistance or compliance required for a catheter balloon can be secured.

[0054] The polyamide that can be preferably used for the polyamide layer according to the present invention is not particularly limited as long as it has an acid amide bond ($-\text{CO}-\text{NH}-$) on a main chain, and is produced by polymerization (homopolymerization) of lactam or amino acid having a cyclic structure or condensation polymerization of dicarboxylic acid and diamine in general. Therefore, it is preferable to use homopolyamide as the polyamide.

Examples of homopolymerizable monomers include ϵ -caprolactam, aminocaproic acid, enantholactam, 7-aminoheptanoic acid, 11-aminoundecanoic acid, 12-aminododecanoic acid, 9-aminononanoic acid, piperidone, and the like.

[0055] Examples of the dicarboxylic acid to be subjected to condensation polymerization together with diamine include adipic acid, sebacic acid, dodecanedicarboxylic acid, glutaric acid, terephthalic acid, 2-methylterephthalic acid, isophthalic acid, naphthalene dicarboxylic acid, and the like.

Examples of the diamine include tetramethylenediamine, hexamethylenediamine, nonamethylenediamine, decamethylenediamine, undecamethylenediamine, dodecamethylenediamine, 5 paraphenylenediamine, metaphenylenediamine, and the like.

[0056] As the polyamide, those having other segments such as polyester and polyether are preferable. The polyamide may be used in the form 10 of a commercially available product or may be synthesized. Examples of commercially available polyamide include nylon 4, 6, 7, 8, 11, 12, 6.6, 6.9, 6.10, 6.11, 6.12, 6T, 6/6.6, 6/12, 6/6T, 6T/6I, and the like.

15 Moreover, the terminal of the polyamide may be sealed with a carboxyl group, an amino group, or the like.

One kind of the polyamide resin may be used alone, or two or more kinds thereof may be used in 20 combination.

Among the above, nylon 11 and nylon 12 are particularly preferable as the polyamide according to the present invention.

[0057] The weight average molecular weight of the 25 polyamide according to the present invention is preferably 10,000 to 500,000, more preferably 15,000 to 400,000, and even more preferably 20,000 to 300,000.

[0058] If the molecular weight of the polyamide 30 used for the polyamide layer according to the

present invention is 10,000 to 500,000, mechanical strength sufficient for improving pressure resistance is obtained.

[0059] The weight average molecular weight of the polyamide according to the present invention can be measured by known methods such as MS spectrometry, a light scattering method, liquid chromatography, and gas chromatography. In the present specification, a molecular weight measured by gel permeation chromatography is used.

The measurement conditions are as follows. Mobile phase: hexafluoroisopropanol (including 5 mmol/L of additive CF_3COONa); standard substance: standard PMMA/dimethyl terephthalate; injection amount: 100 μL ; a flow rate: 1 mL/min, column temperature: 40°C, concentration: 0.1 w/v% DS-4; column: Shodex GPC HFIP-806M-2 + HFIP-803, detector: Shodex RI-71

[0060] Regarding each of the refractive indices in the surface of inner side of the polyamide layer (interface between the polyamide layer and the polyamide elastomer layer) according to the present invention, the refractive index (n_{r1}) in the circumferential direction of the cross-section perpendicular to the axis is preferably 1.520 to 1.540, the refractive index (n_{L1}) of the long-axis direction is preferably 1.500 to 1.520, and the refractive index (n_{d1}) in the radial direction of the cross-section perpendicular to the axis is preferably 1.480 to 1.510. The refractive index (n_{r1}) in the circumferential direction of the cross-

section perpendicular to the axis is more preferably 1.525 to 1.535, the refractive index (n_{L1}) in the long-axis direction is more preferably 1.505 to 1.515, and the refractive index (n_{d1}) in the radial
5 direction of the cross-section perpendicular to the axis is more preferably 1.485 to 1.500.

[0061] Each of the refractive indices of the surface of inner side of the polyamide layer (inner circumferential surface of the polyamide layer) is
10 obtained by the compensation method and calculation method described above.

Accordingly, needless to say, the above refractive index may be different from each of refractive indices obtained by other methods in some cases.

15 [0062] Examples of the additives that are optionally added to the polyamide layer include higher alcohols, hydroxybenzoic acid ester, aromatic sulfonamide, and the like, but the present invention is not limited to these.

20 [0063] Furthermore, in the present invention, the radiopaque substances that are optionally added to the polyamide layer are not particularly limited as long as they do not transmit X rays, and known radiopaque substances can be used.

25 Specific examples thereof include iodine, barium, bismuth, boron, bromine, calcium, gold, platinum, silver, iron, manganese, nickel, gadolinium, dysprosium, tungsten, tantalum, stainless steel, nitinol, barium sulfate, compounds of these, and
30 solution/dispersion (for example, a physiological

salt solution); amidotrizoic acid (3,5-diacetamino-2,4,6-triiodobenzoic acid), meglumine sodium amidotrizoate, meglumine amidotrizoate, sodium iothalamate, meglumine iothalamate, meglumine iotroxate, iotrolan, ioxaglic acid, ioxalan, iopamidol, iopromide, iothexol, ioversol, iomeprol; fatty acid ethyl esters of iodized poppy oil (for example, LipiodolTM as poppy seed oil having iodized carbon atoms); and the like.

One kind of the radiopaque substance may be used alone, or two or more kinds thereof may be used in the form of a mixture.

Alternatively, a contrast layer containing the above substance as a base may be further laminated on the membranous body.

[0064] In this manner, how the balloon has dilated can be confirmed by radioscopy, and accordingly, the position of the balloon can be clearly and easily confirmed.

[0065] The polyamide elastomer layer according to the present invention contains a polyamide elastomer. The polyamide elastomer layer may optionally contain known additives or radiopaque substances or may be constituted only with at least one or more kinds of polyamide elastomers.

Therefore, one kind of polyamide elastomer may be used alone, or two or more kinds thereof may be used in combination.

If the polyamide elastomer layer contains the polyamide elastomer in an amount of 50% by weight to

100% by weight, trackability required for a catheter balloon, an ability to pass through stenosed portions of blood vessels and the like, and flexibility necessary for an ability to dilate
5 stenosed portions of calcified blood vessels and the like can be secured.

[0066] The average thickness of the polyamide elastomer layer constituting the catheter balloon according to the present invention is preferably 0.5
10 μm to 10 μm and more preferably 1 μm to 5 μm .

If the average thickness is 0.5 μm to 10 μm , flexibility and pass-through ability required for a catheter balloon as well as pressure resistance can be established simultaneously.

15 [0067] The polyamide elastomer that is preferably used for the polyamide elastomer layer according to the present invention is preferably a polyamide block copolymer and more preferably a diblock copolymer consisting of a hard segment and a soft
20 segment.

Examples of the diblock copolymer include polyamide (hard segment)-polyether (soft segment) block copolymers, which specifically include a nylon 11-polytetramethylene glycol block copolymer and a
25 nylon 12-polytetramethylene glycol block copolymer.

[0068] The content of the soft segment in the polyamide elastomer according to the present invention is preferably 1 wt% to 50 wt% and more preferably 10 wt% to 30 wt%.

[0069] The shore D hardness of the polyamide elastomer according to the present invention is preferably 50 to 80 and more preferably 55 to 63.

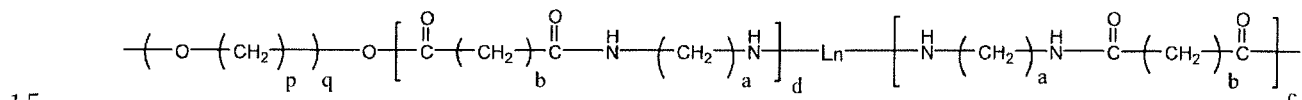
[0070] The tensile modulus of the polyamide elastomer according to the present invention is preferably 200 MPa to 600 MPa and more preferably 230 MPa to 500 MPa.

It is preferable for the polyamide elastomer according to the present invention to have a block copolymer represented by the following Chemical formula (1) or (2) on the polymer chain.

[0071]

[Chem. 1]

Chemical formula (1)



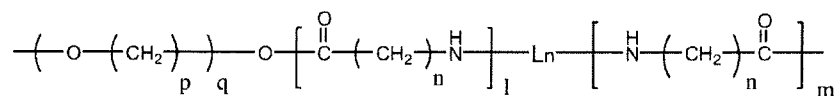
15

[0072] (In the Chemical formula (1), a is an integer of 4 to 12, b is an integer of 4 to 10, c is an integer of 0 to 100, d is an integer of 0 to 100, p is an integer of 2 to 4, q is an integer of 1 to 100, Ln is a linker site which is $-\text{C}(\text{O})-\text{R}-\text{O}-\text{C}(\text{O})-$, and R is an alkylene group having 2 to 12 methylene groups.)

20

[0073] [Chem. 2]

Chemical formula (2)



25

[0074] (In the Chemical formula (2), n is an integer of 5 to 11, l is an integer of 0 to 100, m

is an integer of 0 to 100, p is an integer of 2 to 4, q is an integer of 1 to 100, Ln is a linker site which is $-C(O)-R-O-C(O)-$, and R is an alkylene group having 2 to 12 methylene groups.)

5 That is, the polyamide elastomer according to the present invention may be the polyamide block copolymer itself represented by the Chemical formula (1) or (2) or a substance which is obtained by further polymerizing the polyamide block copolymer
10 represented by the Chemical formula (1) or (2) by means of melt polymerization. However, the polyamide elastomer according to the present invention is preferably a substance which is obtained by further polymerizing the polyamide block
15 copolymer represented by the Chemical formula (1) or (2) by means of melt polymerization. Accordingly, when the polyamide elastomer is further polymerized by means of melt polymerization, the polyamide block copolymer represented by the
20 Chemical formula (1) or (2) becomes, so to speak, a "repeating unit".

[0075] Moreover, R in the Chemical formulae (1) and (2) is not particularly limited and may be linear, branched, or cyclic, as long as R is an
25 alkylene group having 2 to 12 methylene groups. Specific examples thereof include a tetramethylene group, a 2-methylpropyl group, a 1,1-dimethylethylene group, an n-pentylene group, an n-hexylene group, an n-nonylene group, a 1-
30 methyloctylene group, a 6-methyloctylene group, a 1-

ethylheptylene group, a 1-(n-butyl)pentylene group, a 4-methyl-1-(n-propyl)pentylene group, a 1,5,5-trimethylhexylene group, a 1,1,5-trimethylhexylene group, an n-decylene group, a 1-methylnonylene group, a 1-ethyloctylene group, a 1-(n-butyl)hexylene group, a 1,1-dimethyloctylene group, a 3,7-dimethyloctylene group, an n-undecylene group, a 1-methyldecylene group, and the like.

[0076] The polyamide elastomer that is further polymerized as described above can be obtained by performing melt polymerization on the polyamide elastomer of which both terminals are not sealed. The melt polymerization can be performed by conducting heating for a certain time (12 to 96 hours) under vacuum by using a vacuum drier (VOS301SD manufactured by EYELA) having a cooling function (cooling machine; UT-4000L manufactured by EYELA) and a vacuum pump (GCD136XN manufactured by ULVAC KIKO, Inc.).

[0077] When the polyamide block copolymer represented by the Chemical formula (1) or (2) is used for the polyamide elastomer layer according to the present invention, one kind of the polyamide block copolymer represented by the Chemical formula (1) or (2) may be used alone, or two or more kinds thereof may be used in combination.

[0078] The weight average molecular weight of the polyamide elastomer according to the present invention is preferably 10,000 to 500,000, more

preferably 15,000 to 400,000, and even more preferably 20,000 to 300,000.

Moreover, the molecular weight of the polyamide elastomer is measured by the same method as the
5 method used for polyamide.

[0079] If the weight average molecular weight of the polyamide elastomer is 10,000 to 500,000, extensional viscosity increases, and stretching caused by pressurization is suppressed. Accordingly,
10 a degree of the overall compliance of the balloon decreases.

[0080] The polyamide elastomer according to the present invention may be synthesized, or a commercially available product may be purchased as
15 the polyamide elastomer. Examples of the polyamide elastomer usable in the present invention include ELG5660 (manufactured by EMS-GRIVORY, trade name; Grilflex), ELG6260 (manufactured by EMS-GRIVORY, trade name; Grilflex), a high-molecular weight
20 substance (having a melt viscosity of 1,260 Pa·s to 3,489 Pa·s) obtained by performing melt polymerization on the ELG5660, a high-molecular weight substance (having a melt viscosity of 5,282 Pa·s to 7,391 Pa·s) obtained by performing melt
25 polymerization on the ELG6260, and the like.

[0081] Furthermore, the terminal of the polyamide elastomer according to the present invention may be sealed with a carboxyl group, an amino group, and the like.

[0082] The melt viscosity of the polyamide elastomer according to the present invention is preferably 500 or higher and more preferably 500 Pa·s to 20,000 Pa·s.

5 This is because stretching caused by pressurization is suppressed, and a degree of the overall compliance of the balloon decreases.

In the present invention, the melt viscosity is measured using a flow tester "CFT-500D manufactured
10 by Shimadzu Corporation".

[0083] The additives or radiopaque substances that the polyamide elastomer layer may optionally contain are the same as those that the polyamide layer may contain. Accordingly, description thereof
15 will not be repeated herein.

[0084] In a particularly preferable embodiment of the material of the catheter balloon according to the present invention, the weight average molecular weight of the polyamide is 20,000 to 50,000, and the
20 weight average molecular weight of the polyamide elastomer is 20,000 to 500,000. Moreover, if nylon 12 is selected as the polyamide, and a nylon 12-polytetramethylene glycol block copolymer is selected as the polyamide elastomer, the difference
25 in the refractive index can be easily controlled to be 0.01 or greater.

[0085] [Production method for catheter balloon]

Hereinafter, a preferable embodiment of a production method for the catheter balloon according to the present invention will be described.

It is preferable for the production method for the catheter balloon according to the present invention to include a step 1 in which a dichroic (two-layered) or trichroic (three-layered) polymer tube (parison) is formed by coextrusion of a polyamide layer and a polyamide elastomer layer; a step 2 in which the parison is stretched in the axial direction at a temperature within a range from a secondary transition temperature to a primary transition temperature of both the polymers, and the stretched parison is biaxially stretched by being caused to expand in the radial direction; and a step 3 in which the expanded parison is cooled to a temperature equal to or lower than the secondary transition temperature of both the polymers to form a biaxially stretched balloon including a cylindrical membranous body that has a practically uniform inner diameter, tapered portions that are respectively disposed in the front and back of the membranous body, and connection portions that are respectively disposed in the front and back of the tapered portions and connected to a catheter.

[0086] Hereinafter, each of the steps will be described.

(Step 1)

The step 1 in which a tube-like parison is formed of a stretchable polymer can be performed by a general-purpose extruder equipped with a dice.

The polyamide elastomer, which is obtained by

5 polymerizing a polyamide elastomer by the method described above by means of melt polymerization, or the polyamide elastomer itself having not undergone polymerization, and polyamide are used as polymers for molding. The polymers for molding are
10 respectively heated and melted in the extruder and subjected to coextrusion to form a tube-like parison 27 by the dice.

The temperature at the time of the extrusion molding is not particularly limited as long as the polymers
15 can be melted. However, the temperature is preferably 180°C to 300°C and more preferably 200°C to 280°C.

(Step 2)

Then, the tube 27 is put into a mold 20 shown in Fig.
20 2, and one end of the tube 27 is blocked.

The blocking is performed by heating and melting or sealing by high frequency or by using a clamp or the like.

Fig. 2 is a cross-sectional view of the mold 20 for
25 molding a balloon. The mold 20 includes heaters 22 as heating means and cooling tubes 23 as cooling means.

Moreover, the mold 20 consists of separable molds 25 and 26. The shape of the inner surface that is

formed when the separable molds 25 and 26 are combined with each other becomes the basic shape of the outer surface of the balloon to be formed.

[0087] Subsequently, as shown in Fig. 2, the
5 heaters 22 are operated such that the tube 27 in the portion for forming a balloon 11 is heated at a temperature within a range from a secondary transition temperature to a primary transition temperature of the polymers (the polyamide and
10 polyamide elastomer that form the tube 27), specifically, at a temperature slightly exceeding the secondary transition temperature.

While being kept in a heated state, the tube 27 is stretched in the direction of the arrows X and Y.
15 Moreover, gas is supplied in a pressurized state into the tube 27 in the direction of the arrow Z, such that the tube 27 of the heated portion in the mold 20 is caused to come into close contact with the inner wall surface of the separable molds 25 and
20 26.

(Step 3)

Thereafter, a coolant is circulated inside a cooling tube 23 to cool the tube 27 to a temperature equal to or lower than the secondary transition
25 temperature.

The tube may be naturally cooled simply by being left as is without performing circulation of the coolant.

Then, the internal pressure of the tube 27 is controlled to be normal pressure, and then the tube 27 is pulled out of the mold 20.

Subsequently, the tube 27 is cut in the distal end portion and the proximal end portion thereof, whereby the basic shape of a balloon as shown in Fig. 1 is formed.

The above stretching treatment may be performed twice or more to form a balloon having a desired thickness.

[0088] As a preferable embodiment of the present invention, the balloon catheter according to the present invention will be described below, but the present invention is not limited to the following embodiment.

In the description of drawings, the same constituents are marked with the same signs so as not to repeat the same description.

In addition, the dimensional ratio of the drawings has been exaggerated for the convenience of description and may be different from the actual ratio in some cases.

[0089] [Balloon catheter]

The balloon catheter of the present invention will be described by using drawings.

Fig. 3 is a schematic view showing an example of the balloon catheter according to the present invention. In Fig. 3, a three-layer lamination-type balloon shown in Fig. 1B is described as an example of the balloon 11. However, the balloon having a two-layer

structure shown in Fig. 1A or other balloons according to the present invention can also be preferably used, and accordingly, the scope of the balloon catheter according to the present invention is not limited thereto.

[0090] As shown in Fig. 3, a balloon catheter 10 according to the present invention includes a catheter body 1 that has a long outer tube 12 being able to transport fluid, the balloon 11 that is connected to the distal end of the catheter body 1, and a hub 13 that is mounted on the proximal end of the catheter body 1.

The catheter body 1 also includes an inner tube 14 that passes through a lumen 120 formed inside the outer tube 12 and a distal end member 15 that is disposed at the distal end of the inner tube 14. The distal end refers to an end portion positioned at the side to be inserted into the blood vessel at the time of use, and the proximal end refers to an end portion positioned at the side of an operator who operates the balloon catheter 10 at the time of use.

[0091] Fig. 3 shows a rapid exchange-type catheter in which a single lumen is formed at the side of the proximal end portion of the catheter and which includes a wire port into which a guide wire is inserted between the distal end and the proximal end thereof. However, the catheter may be an over-the-wire type in which a double-lumen may be formed around the same axis at the side of the proximal end

portion of the catheter, and the inner tube extends to the hub.

[0092] The balloon catheter 10 is an example applied to a vasodilating catheter. The balloon and
5 the balloon catheter of the present invention can also be applied to other catheters such as a urethral catheter.

[0093] Examples of the fluid supplied into the balloon from the catheter include known substances
10 such as contrast media, helium gas, a physiological salt solution, CO₂ gas, O₂ gas, N₂ gas, and the air.

[0094] The structure of the balloon catheter 10 of the present invention will be described in more detail. As shown in Fig. 3, the balloon catheter 10
15 includes the inner tube 14 that has a first lumen 150 having opened distal end; the outer tube 12 that is disposed in a position, which is away from the distal end of the inner tube 14 toward the proximal end by a predetermined length, while sharing the
20 same axis with the inner tube 14 and forming the second lumen 120 between the outer tube 12 and the outer surface of the inner tube 14; the foldable balloon 1 that has a connection portion (at the side of distal end portion of the balloon) 7a connected
25 to and mounted on the inner tube 14 and a connection portion (at the side of proximal end portion of the balloon) 7b connected to and mounted on the outer tube 12, and is communicated with the second lumen 120 near the proximal end portion; and the hub 13

that includes an opening portion communicated with the second lumen.

[0095] The balloon catheter 10 of the present invention is constituted with the catheter balloon
5 body 1, which includes the inner tube 14 and the outer tube 12, the hub 13, and the balloon 11. The inner tube 14 includes a first lumen 150 (outer lumen at the inner side) having an opened distal end. The first lumen 150 is a lumen for inserting a guide
10 wire and is communicated with a wire port 18 as an opening portion forming a guide wire port. A guide wire 17 can be inserted through the wire port 18.

[0096] The outer diameter of the inner tube 14 is
15 0.30 mm to 2.50 mm and preferably 0.40 mm to 2.00 mm, and the inner diameter thereof is 0.20 mm to 2.35 mm and preferably 0.25 mm to 1.70 mm.

It is preferable for the material for forming the inner tube 24 to be flexible to some extent. For
20 example, polyolefins such as polyethylene, polypropylene, an ethylene-propylene copolymer, and an ethylene-vinyl acetate copolymer, and thermoplastic resins such as polyvinyl chloride, polyurethane, polyamide, polyamide elastomer, and
25 polyester elastomer can be used.

[0097] Into the outer tube 12, the inner tube 14 is inserted. The distal end of the outer tube 12 is placed in a position that slightly recedes from the distal end of the inner tube. By the inner surface

of the outer tube 12 and the outer surface of the inner tube 14, the second lumen 120 is formed.

Accordingly, the second lumen 120 can become a lumen having a sufficient volume.

5 Moreover, the distal end of the second lumen 120 is communicated with the inside of the aforementioned balloon 11 in the distal end portion of the balloon. The proximal end of the second lumen 120 is communicated with an opening portion 130 of the hub
10 13 that forms an injection port for injecting fluid (for example, contrast media, helium gas, a physiological salt solution, CO₂ gas, or O₂ gas) for expanding the balloon.

The outer diameter of the outer tube 12 is 0.50 mm
15 to 4.30 mm and preferably 0.60 mm to 4.00 mm, and the inner diameter thereof is 0.40 mm to 3.80 mm and preferably 0.50 mm to 3.00 mm.

[0098] In addition, the aforementioned radiopaque substances may be optionally injected into the
20 balloon at the time of balloon dilation.

[0099] It is preferable for the material for forming the outer tube 12 to be flexible to some extent. For example, polyolefins such as polyethylene, polypropylene, an ethylene-propylene
25 copolymer, and an ethylene-vinyl acetate copolymer and thermoplastic resins such as polyvinyl chloride, polyurethane, polyamide, polyamide elastomer, and polyester elastomer can be used.

[0100] In Fig. 3, it is preferable that the
30 distal end of the balloon catheter 10 of the present

invention be provided with the distal end member 15 having a spherical surface that plays a role of assisting the catheter to move along the blood vessel and prevents the blood vessel wall from being damaged.

[0101] The balloon 11 is foldable. When being in a state of not being dilated, the balloon can be folded around the outer periphery of the inner tube 14.

Moreover, the balloon 11 is foldable balloon having a cylindrical body with practically uniform diameter, in which at least a portion thereof has a cylindrical shape so as to easily dilate stenosed portions of blood vessels or body cavities.

In addition, the connection portion 7b of the balloon 11 is fixed in a liquid-tight manner to the distal end portion of the outer tube 12 by an adhesive or heat-sealing.

The connection portion 7a is also fixed in a liquid-tight manner to the distal end portion of the inner tube 14 in the same manner as described above.

[0102] As shown in Fig. 3, in the balloon 11, a space 112 is formed between the inner surface of the balloon 11 and the outer surface of the inner tube 14 at the time of dilation.

The entire circumference of the proximal end of the space 112 is communicated with the second lumen 120. As described above, since the proximal end of the balloon 11 is communicated with the second lumen having a relatively large volume, it is easy to

inject fluid into the balloon 11 from the second lumen.

As the balloon 11, the balloon described above is used.

5 In Fig. 3, the balloon 11 is constituted with three layers. However, the constitution is not particularly limited as long as the balloon is constituted with at least two or more layers including the polyamide layer and the polyamide
10 elastomer layer as described above.

[0103] In order to make it possible to confirm the position of the cylindrical membranous body of the balloon 11 by means of radiography, it is preferable to place one or more X-ray markers 44 on
15 the outer surface of the inner tube 14.

As shown in Fig. 3, it is preferable that the X-ray markers 44 be placed in a position that is closer to the proximal end of the balloon 11 than to the portion where the balloon 11 is fixed to the inner
20 tube 14 and a position that is closer to the distal end of the balloon 11 than to the portion where the balloon is fixed to the outer tube 12. In other words, it is preferable that the markers be placed at sites positioned in both ends of the cylindrical
25 membranous body 2 of the balloon 11.

[0104] It is preferable for the X-ray markers 44 to be formed of a radiopaque substance (for example, gold, platinum, iridium, tungsten, or an alloy of these).

[0105] The hub 13 according to the present invention includes the opening portion 130 which is communicated with the second lumen 120 and forms an injection port as an inlet of a path through which
5 fluid is injected or discharged.

Accordingly, the opening portion 130 plays a role of a flow path and is communicated with a portion for supplying and discharging fluid (not shown in the drawing), for example, an inflator, a syringe, or
10 a pump.

In this manner, fluid is supplied to the balloon 11 through the opening portion 130 and the second lumen 120 and discharged out of the balloon 11.

That is, the opening portion 130 and the lumen 120
15 function as a pathway for supplying and discharging drive fluid which causes the balloon 11 to dilate or contract.

[0106] As materials for forming the hub according to the present invention, thermoplastic resins such
20 as polycarbonate, polyamide, polysulfone, polyarylate, and a methacrylate-butylene-styrene copolymer can be preferably used.

Examples

[0107] Hereinafter, specific examples of the
25 present invention will be described.

[0108] (Example 1)

A polyamide elastomer (melt viscosity of 1,260 Pa·s) resin (PAE1) which was obtained by performing melt polymerization on polyamide elastomer (Grilamide
30 ELG5660 manufactured by EMS-GRIVORY, shore D

hardness of 56) was prepared, and a three-layered tube (magnification of inner diameter expansion; 8.2-fold, ϕ 0.37 × 0.47 × 0.82 × 0.88 mm) using PAE1 for the inner and outer layers and polyamide (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer was molded.

Thereafter, dry nitrogen was blown into the obtained tube for 30 seconds at a pressure of 3.9 MPa at 110°C to perform blow molding, thereby preparing a balloon having an outer diameter of 3.00 mm and a thickness of 22.4 μ m. A withstanding pressure (burst pressure of the balloon) was 37.1 atm, and a compliance thereof was 0.010 mm/atm.

[0109] The term "compliance", which is used in the present invention and indicates how easily the diameter expands, is represented by the slope of a compliance curve that shows the relationship established between pressure and the increase in the outer diameter of the balloon when internal pressure in an operation range of 12 atm to 22 atm is applied to the balloon.

[0110] The obtained balloon was cut into slices and cut in the long-axis direction. The cross-section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the birefringence.

As a result of assigning the calculated birefringence to the aforementioned Equations (1) to

(3), the refractive index n_{r1} in the circumferential direction of the surface of inner side of the polyamide layer as the interlayer was 1.532, and the refractive index n_{r2} in the circumferential direction of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.517.

[0111] Fig. 4(a) shows the sites for measuring each of the refractive indices in Examples and Comparative examples.

For the balloon formed of three-layered membrane, retardation was measured in each of five sites shown in Fig. 4(a). For the balloon formed of two-layered membrane, retardation was measured in each of four sites shown in Fig. 4(a).

Moreover, the graphs of Examples and Comparative examples shown in Fig. 4(b) to Fig. 8 show the relationship between the position of the five or four sites in the balloon and the refractive indices in those positions. n_r indicates a refractive index in the circumferential direction, n_l indicates a refractive index in the long-axis direction, and n_d indicates a refractive index in the thickness direction.

That is, as shown in Fig. 4(a), for the balloon formed of three-layered membrane, five sites in total, which include a site that is assigned with 0 and corresponds to the vicinity of the surface of inner side of the polyamide elastomer layer forming the innermost circumference of the cross-section of the catheter balloon, a site that is assigned with 1

and corresponds to the vicinity of the surface of inner side of the polyamide layer adjacent to the polyamide elastomer layer as the innermost

circumference, a site that is assigned with 2 and

5 corresponds to the vicinity of the surface of outer side of the polyamide layer, a site that is assigned with 1.5 and interposed between the surface of inner side and the surface of outer side of the polyamide layer, and a site that is assigned with 3 and

10 corresponds to the vicinity of the surface of outer side of the polyamide elastomer layer forming the outermost circumference of the cross-section of the catheter balloon, are defined as distances from the inner circumferential surface of the catheter

15 balloon of Examples 1 to 9 and Comparative examples 1 and 2.

Moreover, for the balloon formed of two-layered membrane, four sites in total, which include a site that is assigned with 0 and corresponds to the

20 vicinity of the surface of inner side of the polyamide layer forming the innermost circumference of the cross-section of the balloon, a site that is assigned with 1 and corresponds to the vicinity of the surface of outer side of the polyamide layer, a

25 site that is assigned with 1.5 and interposed between the surface of inner side and the surface of outer side of the polyamide layer, and a site that is assigned with 2 and corresponds to the vicinity of the surface of outer side of the polyamide

30 elastomer layer forming the outermost circumference

of the cross-section of the catheter balloon, are defined as distances from the inner circumferential surface of the catheter balloon of Comparative examples 3 and 4.

5 [0112] (Example 2)

A polyamide elastomer (melt viscosity of 1,260 Pa·s) resin (PAE1) which was obtained by performing melt polymerization on polyamide elastomer (Grilamide ELG5660 manufactured by EMS-GRIVORY, shore D
10 hardness of 56) was prepared, and a three-layered tube (magnification of inner diameter expansion; 8.6-fold, ϕ 0.35 × 0.46 × 0.77 × 0.83 mm) using PAE1 for the inner and outer layers and polyamide (Grilamide L25 manufactured by EMS-GRIVORY) for the
15 interlayer was molded. Thereafter, dry nitrogen was blown into the obtained tube for 120 seconds at a pressure of 3.9 MPa at 110°C to perform blow molding, thereby preparing a balloon having an outer diameter of 3.00 mm and a
20 thickness of 22.1 μ m. A withstanding pressure (burst pressure of the balloon) was 36.8 atm, and a compliance thereof was 0.010 mm/atm.

[0113] The obtained balloon was cut into slices and cut in the long-axis direction. The cross-
25 section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the birefringence.

As a result of assigning the calculated birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of the surface of inner side of the polyamide layer as the interlayer was 1.533, and the refractive index n_{r2} in the circumferential direction of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.520.

[0114] (Example 3)

10 A polyamide elastomer (melt viscosity of 3,489 Pa·s) resin (PAE1) which was obtained by performing melt polymerization on polyamide elastomer (Grilamide ELG5660 manufactured by EMS-GRIVORY, shore D hardness of 56) was prepared, and a three-layered
15 tube (magnification of inner diameter expansion; 8.6-fold, ϕ 0.35 × 0.47 × 0.82 × 0.88 mm) using PAE1 for the inner and outer layers and polyamide (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer was molded.
20 Thereafter, dry nitrogen was blown into the obtained tube for 30 seconds at a pressure of 4.0 MPa at 100°C to perform blow molding, thereby preparing a balloon having an outer diameter of 3.00 mm and a thickness of 22.6 μ m. A withstanding pressure
25 (burst pressure of the balloon) was 32.7 atm, and a compliance thereof was 0.009 mm/atm.

[0115] The obtained balloon was cut into slices and cut in the long-axis direction. The cross-section thereof was observed with a polarization

microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the birefringence.

As a result of assigning the calculated
5 birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of the surface of inner side of the polyamide layer as the interlayer was 1.531, and the refractive index n_{r2} in the circumferential direction
10 of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.517.

[0116] (Example 4)

A polyamide elastomer (melt viscosity of 5,282 Pa·s) resin (PAE1) which was obtained by performing melt
15 polymerization on polyamide elastomer (Grilamide ELG6260 manufactured by EMS-GRIVORY, shore D hardness of 62) was prepared, and a three-layered tube (magnification of inner diameter expansion;
8.6-fold, ϕ 0.35 × 0.47 × 0.82 × 0.88 mm) using PAE1
20 for the inner and outer layers and polyamide (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer was molded.

Thereafter, dry nitrogen was blown into the obtained tube for 120 seconds at a pressure of 3.7 MPa at
25 110°C to perform blow molding, thereby preparing a balloon having an inner diameter of 3.00 mm and a thickness of 22.8 μm . A withstanding pressure (burst pressure of the balloon) was 29.9 atm, and a compliance thereof was 0.011 mm/atm.

[0117] The obtained balloon was cut into slices and cut in the long-axis direction. The cross-section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the birefringence.

As a result of assigning the calculated birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of the surface of inner side of the polyamide layer as the interlayer was 1.530, and the refractive index n_{r2} in the circumferential direction of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.516.

[0118] (Example 5)

A polyamide elastomer (melt viscosity of 5,282 Pa·s) resin (PAE1) which was obtained by performing melt polymerization on polyamide elastomer (Grilamide ELG6260 manufactured by EMS-GRIVORY, shore D hardness of 62) was prepared, and a three-layered tube (magnification of inner diameter expansion; 7.7-fold, ϕ 0.39 × 0.50 × 0.82 × 0.92 mm) using PAE1 for the inner and outer layers and polyamide (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer was molded.

Thereafter, dry nitrogen was blown into the obtained tube for 30 seconds at a pressure of 3.2 MPa at 130°C to perform blow molding, thereby preparing a balloon having an outer diameter of 3.00 mm and a

thickness of 21.9 μm . A withstanding pressure (burst pressure of the balloon) was 28.1 atm, and a compliance thereof was 0.010 mm/atm.

The obtained balloon was cut into slices and cut in
5 the long-axis direction. The cross-section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the birefringence.

As a result of assigning the calculated
10 birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of the surface of inner side of the polyamide layer as the interlayer was 1.530, and the refractive index n_{r2} in the circumferential direction
15 of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.517.

[0119] (Example 6)

A polyamide elastomer (melt viscosity of 7,391 Pa·s) resin (PAE1) which was obtained by performing melt
20 polymerization on polyamide elastomer (Grilamide ELG6260 manufactured by EMS-GRIVORY, shore D hardness of 62) was prepared, and a three-layered tube (magnification of inner diameter expansion;
8.6-fold, ϕ 0.35 $\times$ 0.47 $\times$ 0.82 $\times$ 0.88 mm) using PAE1
25 for the inner and outer layers and polyamide (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer was molded.

Thereafter, dry nitrogen was blown into the obtained tube for 30 seconds at a pressure of 3.6 MPa at

110°C to perform blow molding, thereby preparing a balloon having an outer diameter of 3.00 mm and a thickness of 22.2 μm . A withstanding pressure (burst pressure of the balloon) was 30.9 atm, and a compliance thereof was 0.011 mm/atm.

[0120] The obtained balloon was cut into slices and cut in the long-axis direction. The cross-section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the birefringence.

As a result of assigning the calculated birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of the surface of inner side of the polyamide layer as the interlayer was 1.531, and the refractive index n_{r2} in the circumferential direction of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.517.

[0121] (Example 7)

A three-layered tube (magnification of inner diameter expansion; 8.5-fold, ϕ 0.36 $\times$ 0.50 $\times$ 0.84 $\times$ 0.88 mm) using polyamide elastomer (Grilamide ELG5660 manufactured by EMS-GRIVORY, shore D hardness of 56) for the inner and outer layers and polyamide (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer was molded. Thereafter, dry nitrogen was blown into the obtained tube for 30 seconds at a pressure of 4.2 MPa at 90°C

to perform blow molding, thereby preparing a balloon having an outer diameter of 3.00 mm and a thickness of 20.4 μm . A withstanding pressure (burst pressure of the balloon) was 33.1 atm, and a compliance thereof was 0.013 mm/atm.

[0122] The obtained balloon was cut into slices and cut in the long-axis direction. The cross-section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the birefringence.

As a result of assigning the calculated birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of the surface of inner side of the polyamide layer as the interlayer was 1.526, and the refractive index n_{r2} in the circumferential direction of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.514.

[0123] (Example 8)

A three-layered tube (magnification of inner diameter expansion; 8.2-fold, ϕ 0.37 $\times$ 0.51 $\times$ 0.84 $\times$ 0.88 mm) using polyamide elastomer (Grilamide ELG5660 manufactured by EMS-GRIVORY, shore D hardness of 56) for the inner and outer layers and polyamide (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer was molded. Thereafter, dry nitrogen was blown into the obtained tube for 30 seconds at a pressure of 4.2 MPa at 90°C

to perform blow molding, thereby preparing a balloon having an outer diameter of 3.00 mm and a thickness of 19.6 μm . A withstanding pressure (burst pressure of the balloon) was 33.3 atm, and a compliance
5 thereof was 0.016 mm/atm.

The obtained balloon was cut into slices and cut in the long-axis direction. The cross-section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was
10 measured to calculate the birefringence.

As a result of assigning the calculated birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of inner side of the polyamide layer as
15 the interlayer was 1.528, and the refractive index n_{r2} in the circumferential direction of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.513.

[0124] (Example 9)

20 A three-layered tube (magnification of inner diameter expansion; 7.9-fold, ϕ 0.38 $\times$ 0.52 $\times$ 0.85 $\times$ 0.89 mm) using polyamide elastomer (Grilamide ELG5660 manufactured by EMS-GRIVORY, shore D hardness of 56) for the inner and outer layers and
25 polyamide (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer was molded. Thereafter, dry nitrogen was blown into the obtained tube for 30 seconds at a pressure of 4.0 MPa at 100°C to perform blow molding, thereby preparing a

balloon having an outer diameter of 3.00 mm and a thickness of 19.4 μm . A withstanding pressure (burst pressure of the balloon) was 33.0 atm, and a compliance thereof was 0.015 mm/atm.

5 [0125] The obtained balloon was cut into slices and cut in the long-axis direction. The cross-section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the

10 birefringence.

As a result of assigning the calculated birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of inner side of the polyamide layer as
15 the interlayer was 1.525, and the refractive index n_{r2} in the circumferential direction of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.515.

[0126] (Comparative example 1)

20 A three-layered tube (magnification of inner diameter expansion; 8.2-fold, ϕ 0.37 $\times$ 0.48 $\times$ 0.82 $\times$ 0.90 mm) using polyamide elastomer (PEBAX5533 manufactured by ARUKEMA K.K., shore D hardness of 55) for the inner and outer layers and polyamide
25 (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer was molded.

Thereafter, dry nitrogen was blown into the obtained tube for 30 seconds at a pressure of 3.0 MPa at 110°C to perform blow molding, thereby preparing a

balloon having an outer diameter of 3.00 mm and a thickness of 22.3 μm . A withstanding pressure (burst pressure of the balloon) was 26.0 atm, and a compliance thereof was 0.018 mm/atm.

5 [0127] The obtained balloon was cut into slices and cut in the long-axis direction. The cross-section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the

10 birefringence.

As a result of assigning the calculated birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of the surface of inner side of the polyamide layer as the interlayer was 1.528, and the refractive index n_{r2} in the circumferential direction of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.522.

[0128] (Comparative example 2)

20 A three-layered tube (magnification of inner diameter expansion; 8.6-fold, ϕ 0.35 $\times$ 0.47 $\times$ 0.82 $\times$ 0.88 mm) using polyamide elastomer (Grilamide ELG5930 manufactured by EMS-GRIVORY, shore D hardness of 59) for the inner layer, polyamide
25 (Grilamide L25 manufactured by EMS-GRIVORY) for the interlayer, and polyamide elastomer (Grilamide ELG5660 manufactured by EMS-GRIVORY, shore D hardness of 56) for the outer layer was molded.

Thereafter, dry nitrogen was blown into the obtained tube for 30 seconds at a pressure of 4.2 MPa at 90°C to perform blow molding, thereby preparing a balloon having an outer diameter of 3.00 mm and a thickness of 23.2 μm . A withstanding pressure (burst pressure of the balloon) was 21.3 atm, and a compliance thereof was 0.015 mm/atm.

[0129] The obtained balloon was cut into slices and cut in the long-axis direction. The cross-section thereof was observed with a polarization microscope, and retardation at five sites shown in Fig. 4(a) was measured to calculate the birefringence.

As a result of assigning the calculated birefringence to the aforementioned Equations (1) to (3), the refractive index n_{r1} in the circumferential direction of the surface of inner side of the polyamide layer as the interlayer was 1.532, and the refractive index n_{r2} in the circumferential direction of the surface of inner side of the polyamide elastomer layer as the inner layer was 1.527.

[0130] (Comparative example 3)

The cross-section of a balloon Hiryu (ϕ 3.00 mm $\times$ 15 mm, membrane thickness of 19.8 μm , withstanding pressure of 28.0 atm, compliance of 0.016 mm/atm) manufactured by Terumo Corporation (two-layered balloon constituted with an inner layer formed of polyamide and an outer layer formed of polyamide elastomer) was observed with a polarization

microscope, and retardation at four sites shown in Fig. 4(a) was measured. As a result, a refractive index in the circumferential direction (n_r) of the surface of inner side of the polyamide layer was 1.531, and n_r of the surface of innermost layer where polyamide elastomer did not exist was less than 1.520.

[0131] (Comparative example 4)

The cross-section of a balloon Kongou (ϕ 3.00 mm $\times$ 15 mm, membrane thickness of 23.4 μm , withstanding pressure of 27.9 atm, compliance of 0.015 mm/atm) manufactured by Terumo Corporation (two-layered balloon constituted with an inner layer formed of polyamide and an outer layer formed of polyamide elastomer) was observed with a polarization microscope, and retardation at four sites shown in Fig. 4(a) was measured. As a result, a refractive index in the circumferential direction (n_r) in the surface of inner side of the polyamide layer was 1.529, and n_r of the surface of the innermost layer where polyamide elastomer did not exist was less than 1.520.

[0132] Experimental data showing the relationship between the respective refractive indices of Examples 1 to 9 as well as Comparative examples 1 to 4 and the distance from the inner circumferential surface of the balloon are shown in Fig. 4(b) to Fig. 8.

[0133] The refractive index n_r in the circumferential direction of Examples 1 to 9 and Comparative examples 1 to 4 are shown below.

5 [0134]
[Table 1]

Table 1

	nr2 of surface of inner side of inner layer (A)	nr1 of surface of inner side of inter layer (B)	(B) - (A)
Example 1	1.517	1.532	0.015
Example 2	1.520	1.533	0.013
Example 3	1.517	1.531	0.014
Example 4	1.516	1.530	0.014
Example 5	1.517	1.530	0.013
Example 6	1.517	1.531	0.014
Example 7	1.514	1.526	0.012
Example 8	1.513	1.528	0.015
Example 9	1.515	1.525	0.010
Comparative example 1	1.522	1.528	0.006
Comparative example 2	1.527	1.532	0.005
Comparative example 3	No PAE layer	1.531	Failure of calculation
Comparative example 4	No PAE layer	1.529	Failure of calculation

[0135] Reference Signs List

- 10 1 catheter body
2 cylindrical membranous body

3a, 3b opening portions
7a, 7b connection portions connected to catheter
8 polyamide elastomer layer
9 polyamide layer
5 10 balloon catheter
11 catheter balloon
3412 outer tube
13 hub
14 inner tube
10 130 opening portion (injection port)
120 second lumen
150 first lumen

CATHETER BALLOON AND BALLOON CATHETER

CLAIMS

[Claim 1]

5 A cylindrical catheter balloon formed of a membrane as a laminate of at least two or more layers which include a polyamide elastomer layer and a polyamide layer,

 wherein the polyamide elastomer layer is
10 disposed at the inner side of the polyamide layer, a refractive index n_{r1} in the circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide layer is greater than a refractive index n_{r2} in the
15 circumferential direction of a cross-section perpendicular to the axis in the surface of inner side of the polyamide elastomer layer, and a difference between the refractive index n_{r1} and the refractive index n_{r2} is 0.01 or greater.

20

[Claim 2]

 The catheter balloon according to Claim 1,
 wherein the refractive index n_{r2} in the circumferential direction of the cross-section
25 perpendicular to the axis in the surface of inner side of the polyamide elastomer layer is 1.520 or less.

[Claim 3]

30 The catheter balloon according to Claim 1 or 2,

wherein the refractive index n_{r1} in the circumferential direction of the cross-section perpendicular to the axis in the surface of inner side of the polyamide layer is 1.520 to 1.540.

5

[Claim 4]

The catheter balloon according to any one of Claims 1 to 3,

wherein one more polyamide elastomer layer is
10 disposed at the outer side of the polyamide layer.

[Claim 5]

A balloon catheter comprising the catheter
balloon according to any one of Claims 1 to 4.

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