(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 202 759 A1

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

(43) Date of publication:
**30.06.2010 Bulletin 2010/26**

(21) Application number: **08764615.4**

(22) Date of filing: **23.05.2008**

(51) Int Cl.:
***H01B 11/18*** *(2006.01)* ***H01B 3/44*** *(2006.01)*
***H01B 7/02*** *(2006.01)*

(86) International application number:
**PCT/JP2008/059569**

(87) International publication number:
**WO 2009/041116 (02.04.2009 Gazette 2009/14)**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT RO SE SI SK TR**
Designated Extension States:
**AL BA MK RS**

(30) Priority: **25.09.2007 JP 2007247652**

(71) Applicant: **Polyplastics Co., Ltd.**
**Tokyo 108-8280 (JP)**

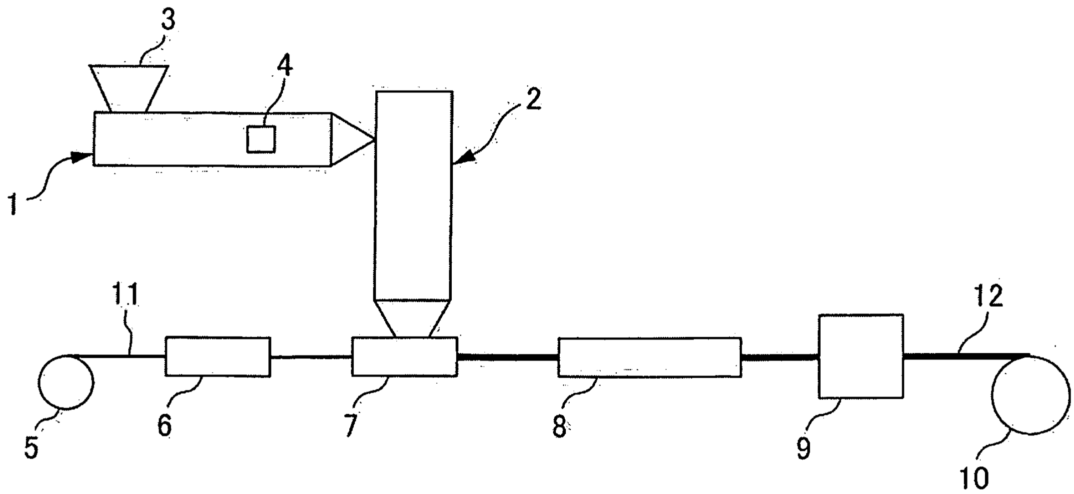
(72) Inventors:
- **TANIKITA, Masumi**
  **Tokyo 108-8280 (JP)**
- **SERIZAWA, Hajime**
  **Tokyo 108-8280 (JP)**

(74) Representative: **Ackermann, Joachim**
**Postfach 11 13 26**
**60048 Frankfurt am Main (DE)**

# (54) COAXIAL CABLE

(57) To provide a coaxial cable for high frequency transmission in which an insulator layer formed to cover the inner conductor in the coaxial cable has sufficient lateral pressure resistance, and low attenuation in transmission. [Means for Solving the Problem] Foam molding of a resin composition containing a cyclic olefin-based resin, and a low density polyethylene and/or a linear low-density polyethylene enables formation of an insulating layer that has a high extent of foaming, and is excellent in mechanical strength, as compared with conventional insulating layers. Consequently, the insulator layer formed by covering the inner conductor in a coaxial cable will have a low dielectric dissipation factor and relative permittivity, whereby a coaxial cable for high frequency transmission that is excellent in transmission characteristics and mechanical characteristics can be provided.

FIG. 2






Printed by Jouve, 75001 PARIS (FR)

## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to a coaxial cable in which a cyclic olefin-based resin is used.

### BACKGROUND ART

**[0002]** In recent years, there are increasingly higher demands for broadband capability of communications such as mobile phones, Internet, wireless LANs, and the like. Additionally, for transmitting information of larger amounts at higher speed, shifting of electric signal to a higher frequency range has been significantly in progress. Under such circumstances, coaxial cables accompanied by lower attenuation and less signal delay in a high frequency band have been desired.

**[0003]** Meanwhile, coaxial cables are constituted mainly with a center conductor, an insulator layer provided thereon, and an outer conductor provided therearound. Importance has been placed on lower attenuation in a high frequency band, and lowering of a dielectric dissipation factor of the insulator layer is most effective for achieving a high-frequency coaxial cable. Moreover, foaming is effective for further lowering the attenuation. However, foaming may result in deterioration of lateral pressure resistance of the insulating layer, and thus a problem of difficulty in maintaining the shape of the foam may be caused.

**[0004]** It has been known that a relative permittivity of the insulating layer can be effectively lowered by increasing an extent of foaming of the insulating layer. In addition, as an insulating material having a low dielectric dissipation factor, cyclic olefin-based resins may be exemplified. The cyclic olefin-based resins exhibit satisfactory foam moldability, and also characteristics superior in the lateral pressure resistance derived from high rigidity may be thereby expected.

**[0005]** In this respect, Patent Document 1 discloses a coaxial cable for high frequency transmission in which a norbornene resin is used. Additionally, Patent Document 2 discloses an insulating material that is superior in the lateral pressure resistance by blending a cyclic olefin-ethylene copolymer with polyolefin or the like.

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2000-297172
Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2000-311519

### DISCLOSURE OF THE INVENTION

#### Problems to be Solved by the Invention

**[0006]** However, a coaxial cable accompanied by still lower attenuation in a high frequency band has been desired, and improvement that allows a coaxial cable having a performance higher than those of Patent Document 1 and Patent Document 2 to be provided has been demanded. As is evident from Examples of Patent Document 1 and Patent Document 2, the extent of foaming of the insulator layer is about 62% in the former document, and about 72% in the latter document. Therefore, for achieving a coaxial cable having a lower attenuation in a high frequency band, improvement by increasing the extent of foaming of the insulator layer may be conceived. However, in general, when the extent of foaming increases, the lateral pressure resistance deteriorates due to expansion of foam cells, and furthermore, breakage of the foam cells leads to failure in obtaining an insulating layer having a low relative permittivity. Therefore, a coaxial cable having lateral pressure resistance which allows for satisfactory use as a coaxial cable through keeping independency of the foam cells even though the extent of foaming is increased has been desired.

**[0007]** The present invention was made in order to solve the problems as described above, and an object of the invention is to provide a coaxial cable in which an insulator layer has sufficient lateral pressure resistance which allows for satisfactory use as a coaxial cable, and has a higher extent of foaming.

**[0008]** The present invention was made in order to solve the problems as described above, and an object of the invention is to provide a coaxial cable in which an insulator layer has sufficient lateral pressure resistance which allows for satisfactory use as a coaxial cable, and has a higher extent of foaming.

#### Means for Solving the Problems

**[0009]** The present inventors found that the aforementioned problems can be solved by foam molding of a resin composition including a cyclic olefin-based resin, and a low density polyethylene and/or a linear low-density polyethylene. Accordingly, the present invention was achieved. More specifically, the present invention provides the following.

**[0010]** According to a first aspect of the present invention, a coaxial cable is provided which includes a layer, as an insulating layer, formed by foam molding of a resin composition containing a cyclic olefin-based resin, and at least one of a low density polyethylene and a linear low-density polyethylene, in which the extent of foaming of the insulating layer is from 80% to 90%.

**[0011]** According to the first aspect of the invention, the insulating layer in the coaxial cable of the present invention includes a cyclic olefin-based resin. The cyclic olefin resin has a low dielectric dissipation factor, a low relative permittivity and satisfactory foam moldability, and improvement of the lateral pressure resistance of the foam molded product may be expected by virtue of its features having an even higher modulus of elasticity. Therefore, the coaxial cable of the present invention can be preferably used as one for high frequency transmission since the insulating layer in the coaxial cable of the present invention has these characteristics. On the other hand, the cyclic olefin-based resins are disadvantageous in that they lack in flexibility. However, the insulating layer in the coaxial cable of the present invention includes a low density polyethylene and/or a linear low-density polyethylene being superior in flexibility. Thus, the disadvantage of the cyclic olefin-based resin can be compensated, thereby enabling formation of an insulating layer that is superior in flexibility.

**[0012]** In addition, the low density polyethylene and the like are preferably included also in view of increase in the extent of foaming of the insulating layer since they also have satisfactory foam moldability.

**[0013]** The extent of foaming indicates an extent of foam included in the insulating layer. When the foam is included in a greater amount, the ratio of a gas having a low relative permittivity occupying the insulating layer increases. Therefore, the higher extent of foaming results in lowering of the dielectric dissipation factor and the relative permittivity of the insulating layer in a coaxial cable, whereby a coaxial cable accompanied by a lower attenuation even in a high frequency range can be obtained. The insulating layer in the coaxial cable of the present invention can realize a higher extent of foaming than conventional ones. Favorable lateral pressure resistance of the cyclic olefin-based resin, and satisfactory foam moldability of the cyclic olefin-based resin and the low density polyethylene and/or the linear low-density polyethylene account for such advantages. When the foam moldability is favorable, foam cells can be present independently even though the extent of foaming is increased. It should be noted that the extent of foaming as used herein means an extent of foaming determined by the following formula (1).

$$\text{Extent of foaming (\%)} = 100 - (\text{specific gravity after foaming})/(\text{specific gravity before foaming}) \times 100 \quad (1)$$

**[0014]** According to a second aspect, the resin composition in the coaxial cable of the first aspect includes: from 20% by weight to 50% by weight of the cyclic olefin-based resin; and from 50% by weight to 80% by weight of at least one of the low density polyethylene and the linear low-density polyethylene in terms of the total amount.

**[0015]** According to the second aspect of the invention, by virtue of the content of the cyclic olefin-based resin included in the insulating layer in a coaxial cable falling within the above range, effects of the cyclic olefin-based resin such as satisfactory foam moldability, a low relative permittivity and lateral pressure resistance can be sufficiently exhibited. In addition, since the content of the cyclic olefin-based resin falls within the above range, the disadvantage of some lack in flexibility can be compensated enough with the polyethylene. Thus, by using the insulating layer described above in a coaxial cable, a coaxial cable further suitable for high frequency transmission can be obtained.

**[0016]** Moreover, the low density polyethylene and/or the linear low-density polyethylene included in the insulating layer in the coaxial cable in a total amount falling within the above range enables the disadvantage of a high relative permittivity to be sufficiently compensated with the cyclic olefin-based resin, while satisfactorily exhibiting the effect of the polyethylene being excellent in flexibility. Thus, a coaxial cable more suited for high frequency transmission can be obtained.

**[0017]** According to a third aspect, the insulating layer in the coaxial cable of the first or second aspect has a compressive strength of no less than 800 N/cm$^2$, and an attenuation of no greater than 27 dB/100 m.

**[0018]** According to the third aspect of the invention, even though the attenuation is kept at a level of no greater than 27 dB/100 m through lowering the relative permittivity of the insulating layer by increasing the extent of foaming of the insulating layer in the coaxial cable to increase pores in the insulating layer, a coaxial cable having sufficiently favorable mechanical strength can be obtained since the compressive strength is no less than 800 N/cm$^2$. In addition, the insulating layer in the coaxial cable of the present invention includes a low density polyethylene and/or a linear low-density polyethylene. Thus, since all materials in the coaxial cable are excellent in flexibility, the insulating layer becomes excellent in flexibility, whereby excellent flexibility is achieved as a whole of the coaxial cable, which is preferable as a coaxial cable.

**[0019]** The compressive strength refers to a maximum stress at which a material can endure against a compression load, and is one indicator that represents the lateral pressure resistance of an insulating layer in a coaxial cable. Because an insulating layer having a low compressive strength can be broken by a force imparted in production, use and the like of the coaxial cable, it is not preferred as an insulating layer for use in a coaxial cable for high frequency transmission. Since the insulating layer used in the present invention has a compressive strength of no less than 800 N/cm$^2$, it can be suitably used as an insulating layer for a coaxial cable.

**[0020]** The compressive strength of the insulating layer in the coaxial cable of the present invention is preferably no less than 800 N/cm$^2$. Since the compressive strength of no less than 800 N/cm$^2$ serves in attaining sufficient mechanical strength, such an insulating layer can be suitably used as an insulating layer for a coaxial cable.

**[0021]** The insulating layer in the coaxial cable of the present invention preferably has an attenuation of no greater than 27 dB/100 m. An attenuation of greater than 27 dB/100 m leads to large transmission loss, and thus correct operation of electronic instruments may fail.

**[0022]** In general, the signal is attenuated as the dielectric dissipation factor is higher. In particular, dielectric dissipation factor greatly influences attenuation in a high frequency band. Therefore, in order to lower the attenuation of a coaxial cable in a high frequency band, a low dielectric dissipation factor of the insulating layer is often desired.

**[0023]** According to a forth aspect, the insulating layer has a moisture permeability of no greater than 0.55 g/m$^2$·day·atm in the coaxial cable of any one of the first to third aspects.

**[0024]** According to the fourth aspect of the invention, the insulating layer in the coaxial cable of the present invention is hardly permeable to water molecules, and has a high relative permittivity that can be the cause of increase in attenuation; therefore, it is more suitable for use in high frequency transmission. Moreover, corrosion of the inner conductor due to permeation of moisture through the insulating layer can be prevented. Thus, a coaxial cable which can be used for a longer period of time can be obtained.

**[0025]** The insulating layer used in the coaxial cable of the present invention has a moisture permeability of preferably no greater than 0.55 g/m$^2$·day·atm. When the moisture permeability exceeds 0.55 g/m$^2$·day·atm, the moisture is more likely to be attached, and conductive failure may be caused through occurrence of corrosion in significant cases.

**[0026]** According to a fifth aspect, the insulating layer has a relative permittivity of no greater than 1.20 in a frequency domain of from 1 GHz to 10 GHz in the coaxial cable of any one of the first to forth aspects.

**[0027]** According to the fifth aspect of the invention, delay time of the signal in transmission in the coaxial cable is lessened by undergoing lowering of the relative permittivity of the insulating material used in the coaxial cable of the present invention, and thus a coaxial cable available in accelerated and increased capacity of communication can be obtained.

**[0028]** When the insulating layer in a coaxial cable has a low dielectric dissipation factor, the attenuation of the coaxial cable is lowered.

**[0029]** The insulating layer in the coaxial cable of the present invention has a relative permittivity in a frequency domain of from 1 GHz to 10 GHz of preferably no greater than 1.20. The relative permittivity in the aforementioned frequency domain being no greater than 1.20 is preferred since less delay of the signal is caused.

**[0030]** According to a sixth aspect, the cyclic olefin-based resin is a copolymer of cyclic olefin and $\alpha$-olefin, or a hydrogenated product thereof in the coaxial cable of any one of the first to fifth aspects.

**[0031]** According to the sixth aspect of the invention, since the cyclic olefin-based resin is constituted as described above, an effect having excellent balance of signal transmission characteristics, flexibility, compressive strength, moisture permeable characteristics and the like as a coaxial cable is achieved.

**[0032]** According to a seventh aspect of the present invention, the cyclic olefin-based resin has a relative permittivity of no greater than 2.3 in a frequency domain of from 1 GHz to 10 GHz, a dielectric dissipation factor of no greater than $4 \times 10^{-4}$, and a flexural modulus at room temperature of no less than 2.0 GPa in the coaxial cable of any one of the first to sixth aspects.

**[0033]** According to the seventh aspect of the invention, since the cyclic olefin-based resin included in the insulating layer in the coaxial cable of the present invention has a low dielectric dissipation factor, formation of an insulating layer having a low dielectric dissipation factor is enabled when this cyclic olefin-based resin is used. Low dielectric dissipation factor of the insulating layer results in lowering of the attenuation of the coaxial cable. Accordingly, the coaxial cable having such an insulating layer having a low dielectric dissipation factor is suited for high frequency transmission.

**[0034]** Furthermore, by using a cyclic olefin resin having a low relative permittivity, delay time of the signal is lessened, and a characteristic excellent as a coaxial cable for high frequency transmission is achieved.

**[0035]** The flexural modulus refers to an extent of deformation resistance of a material against bending stress. Materials having a higher flexural modulus are preferred since they have greater mechanical strength as they are more superior in resistance to bending stress. The bending stress referred to herein is a flexural modulus measured according to ISO 178. The insulating layer in the coaxial cable of the present invention includes a material having flexibility, such as a low density polyethylene. Thus, it can be prevented from becoming a fragile material.

**[0036]** The flexural modulus of the cyclic olefin-based resin is preferably no less than 2 GPa, and more preferably no less than 2 GPa and no greater than 3.5 GPa. When the flexural modulus is less than 2 GPa, the lateral pressure resistance is deteriorated, and the modulus of elasticity beyond 3.5 GPa may result in deterioration of flexibility and may narrow the range of blending.

Effects of the Invention

**[0037]** According to the present invention, a coaxial cable can be obtained which is provided with an insulator layer having sufficient lateral pressure resistance which allows for satisfactory use as a coaxial cable, and having a higher extent of foaming of the insulator layer. The higher extent of foaming of the insulating layer in the coaxial cable results in lowering of the dielectric dissipation factor and the relative permittivity of the insulating layer, whereby preferable use as a coaxial cable for high frequency transmission is enabled.

BRIEF DESCRIPTION OF THE DRAWINGS

**[0038]**

Fig. 1 shows a view illustrating an extrusion apparatus; and
Fig. 2 shows a view illustrating a coaxial cable manufacturing apparatus.

EXPLANATION OF REFERENCE NUMERALS

**[0039]**

| | |
|---|---|
| 1 | First extruder |
| 2 | Second extruder |
| 3 | Hopper |
| 4 | Foaming agent press-in port |
| 5 | Conductor delivery unit |
| 6 | Conductor heating unit |
| 7 | Crosshead die |
| 8 | Cooling system |
| 9 | Drawing unit |
| 10 | Rolling unit |
| 11 | Inner conductor |
| 12 | Electric wire |

DETAILED DESCRIPTION OF THE INVENTION

**[0040]** Hereinafter, one embodiment of the coaxial cable of the present invention is explained in detail, but the present invention is not in any way limited to the following embodiment. The present invention can be realized with appropriate modifications within the scope of the object of the invention. With respect to points the explanations of which overlap, the description may be appropriately omitted, but the gist of the invention is not limited thereto.

Cyclic Olefin-based Resin

**[0041]** Hereinafter, a cyclic olefin-based resin to be an essential component of the coaxial cable of the present invention is explained. Since cyclic olefin-based resins have properties such as a low dielectric dissipation factor, low relative permittivity, foam moldability, low water absorbing capacity, and lateral pressure resistance, they are preferred as a material to be included in an insulating layer for use in coaxial cables. The cyclic olefin-based resin used in the present invention contains a cyclic olefin component as a copolymer component, and is not particularly limited as long as it is a polyolefin resin containing a cyclic olefin component in the main chain thereof. For example,

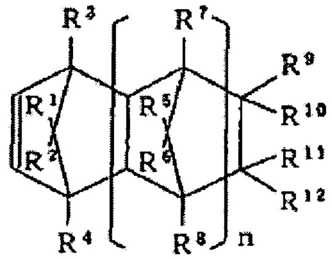
(a1) an addition polymer of cyclic olefin, or a hydrogenated product thereof,
(a2) an addition copolymer of cyclic olefin and $\alpha$-olefin, or a hydrogenated product thereof, and
(a3) a ring-opening (co)polymer of cyclic olefin, or a hydrogenated product thereof can be exemplified.
Moreover, the cyclic olefin-based resin containing a cyclic olefin component as a copolymer component used in the present invention includes
(a4) any of the resins of the above (a1) to (a3) being grafted and/or copolymerized with an unsaturated compound having a polar group.

**[0042]** The polar group may include, for example, carboxyl groups, acid anhydride groups, epoxy groups, amide groups, ester groups, hydroxyl groups, or the like. Examples of the unsaturated compound having a polar group include (meth)acrylic acid, maleic acid, maleic anhydride, itaconic anhydride, glycidyl (meth)acrylate, (meth)acrylic acid alkyl (1 to 10 carbon atoms) esters, maleic acid alkyl (1 to 10 carbon atoms) esters, (meth)acrylamide, 2-hydroxyethyl (meth) acrylate, and the like.

**[0043]** In the present invention, one kind alone or a mixture of two or more kinds of the cyclic olefin-based resins containing the cyclic olefin component described above (a1)-(a4) as a copolymer component may be used. In the present invention, the addition copolymer of cyclic olefin and α-olefin, or a hydrogenated product thereof (a2) can be preferably used.

**[0044]** In addition, a commercially available resin can be used for the cyclic olefin-based resin containing a cyclic olefin component as a copolymer component which may be used in the present invention. The commercially available cyclic olefin-based resins may include, for example, TOPAS (registered trademark, manufactured by TOPAS Advanced Polymers), Apel (registered trademark, manufactured by Mitsui Chemical Co.), ZEONEX (registered trademark, manufactured by ZEON Corp.), ZEONOR (registered trademark, manufactured by ZEON Corp.), ARTON (registered trademark, manufactured by JSR Corp.), and the like.

**[0045]** The addition copolymer of cyclic olefin and α-olefin (a2) preferably used in the composition of the present invention is not particularly limited. Particularly preferable examples include copolymers containing [1] an α-olefin component having 2 to 20 carbon atoms and [2] a cyclic olefin component represented by the following general formula (I):



(I)

wherein, $R^1$ to $R^{12}$ may be the same or different from one another, and are each selected from the group consisting of a hydrogen atom, a halogen atom and a hydrocarbon group; $R^9$ and $R^{10}$, and $R^{11}$ and $R^{12}$ may be combined to form a bivalent hydrocarbon group; $R^9$ or $R^{10}$ may form a ring with $R^{11}$ or $R^{12}$; and n represents 0 or a positive integer, and when n is two or more, $R^5$ to $R^8$ may each be the same or different, for each repeating unit.

[1] α-Olefin Component having 2 to 20 Carbon Atoms

**[0046]** The α-olefin having 2 to 20 carbon atoms preferably used in the present invention, which serves as a copolymer component of the addition polymer that is formed by copolymerization of the cyclic olefin component and other copolymer component such as ethylene, is not particularly limited. For example, ethylene, propylene, 1-butene, 1-pentene, 1-hexene, 3-methyl-1-butene, 3-methyl-1-pentene, 3-ethyl-1-pentene, 4-methyl-1-pentene, 4-methyl-1-hexene, 4,4-dimethyl-1-hexene, 4,4-dimethyl-1-pentene, 4-ethyl-1-hexene, 3-ethyl-1-hexene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-octadecene, 1-eicosene and the like can be included. These α-olefin components may be used alone, or two or more kinds thereof may be used simultaneously. Among these, use of ethylene alone is most preferred.

[2] Cyclic Olefin Component Represented by the General Formula (I)

**[0047]** The cyclic olefin component represented by the general formula (I) preferably used in the present invention, which serves as a copolymer component in the addition polymer that is formed by copolymerization of the cyclic olefin component and other copolymer components such as ethylene, are described.

**[0048]** $R^1$ to $R^{12}$ in the general formula (I) may be the same or different from one another, and are each selected from the group consisting of a hydrogen atom, a halogen atom, and a hydrocarbon group.

**[0049]** Specific examples of $R^1$ to $R^8$ may include, for example, a hydrogen atom; halogen atoms such as fluorine, chlorine and bromine; lower alkyl groups such as a methyl group, an ethyl group, a propyl group and a butyl group. These may be different from one another, partially different, or entirely the same.

**[0050]** Specific examples of $R^9$ to $R^{12}$ may include, for example, a hydrogen atom; halogen atoms such as fluorine, chlorine and bromine; alkyl groups such as a methyl group, an ethyl group, a propyl group, an isopropyl group, a butyl group, an isobutyl group, a hexyl group and a stearyl group; cycloalkyl groups such as a cyclohexyl group; substituted or unsubstituted aromatic hydrocarbon groups such as a phenyl group, a tolyl group, an ethylphenyl group, an isopropylphenyl group, a naphthyl group and an anthryl group; a benzyl group, a phenethyl group, and aralkyl groups formed by substitution of an alkyl group with an aryl group, and the like. These may be different from one another, partially different, or entirely the same.

**[0051]** Specific examples of the case in which $R^9$ and $R^{10}$, or $R^{11}$ and $R^{12}$ are combined to form a bivalent hydrocarbon group include, for example, alkylidene groups such as an ethylidene group, a propylidene group and an isopropylidene group, and the like.

**[0052]** When $R^9$ or $R^{10}$ forms a ring with $R^{11}$ or $R^{12}$, the resultant ring may be either monocyclic or polycyclic, may be polycyclic having crosslinking, may be a ring having a double bond, or may be a ring constituted with any combination of these rings. In addition, these rings may include a substituent group such as a methyl group.

**[0053]** Specific examples of the cyclic olefin component represented by the general formula (I) include bicyclic cycloolefins such as bicyclo[2.2.1]hept-2-ene (common name: norbornene), 5-methyl-bicyclo[2.2.1]hept-2-ene, 5,5-dimethyl-bicyclo[2.2.1]hept-2-ene, 5-ethyl-bicyclo[2.2.1]hept-2-ene, 5-butyl-bicyclo[2.2.1]hept-2-ene, 5-ethylidene-bicyclo[2.2.1]hept-2-ene, 5-hexyl-bicyclo[2.2.1]hept-2-ene, 5-octyl-bicyclo[2.2.1]hept-2-ene, 5-octadecyl-bicyclo[2.2.1]hept-2-ene, 5-methylidene-bicyclo[2.2.1]hept-2-ene, 5-vinyl-bicyclo[2.2.1]hept-2-ene and 5-propenyl-bicyclo[2.2.1]hept-2-ene; tricyclic cycloolefins such as tricyclo[4.3.0.$1^{2,5}$]deca-3,7-diene (common name: dicyclopentadiene), tricyclo[4.3.0.$1^{2,5}$]dec-3-ene; tricyclo[4.4.0.$1^{2,5}$]undeca-3,7-diene or tricyclo[4.4.0.$1^{2,5}$]undeca-3,8-diene, or tricyclo[4.4.0.$1^{2,5}$]undec-3-ene that is a partially hydrogenated product (or an adduct of cyclopentadiene and cyclohexene) thereof; 5-cyclopentyl-bicyclo[2.2.1]hept-2-ene, 5-cyclohexyl-bicyclo[2.2.1]hept-2-ene, 5-cyclohexenyl bicyclo[2.2.1]hept-2-ene, and 5-phenyl-bicyclo[2.2.1]hept-2-ene;

tetracyclic cycloolefins such as tetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$] dodec-3-ene (also simply referred to as tetracyclododecene), 8-methyltetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$]dodec-3-ene, 8-ethyltetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$]dodec-3-ene, 8-methylidenetetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$]dodec-3-ene, 8-ethylidenetetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$]dodec-3-ene, 8-vinyltetracyclo[4,4.0.$1^{2,5}\cdot1^{7,10}$] dodec-3-ene and 8-propenyl-tetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$]dodec-3-ene;

polycyclic cycloolefins such as 8-cyclopentyl-tetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$]dodec-3-ene, 8-cyclohexyl-tetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$]dodec-3-ene, 8-cyclohexenyl-tetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$]dodec-3-ene, 8-phenyl-cyclopentyl-tetracyclo[4.4.0.$1^{2,5}\cdot1^{7,10}$]dodec-3-ene; tetracyclo[7.4.$1^{3,6}\cdot0^{1,9}\cdot0^{2,7}$]tetradeca-4,9,11,13-tetraene (may be also referred to as 1,4-methano-1,4,4a,9a-tetrahydrofluorene), tetracyclo[8.4.$1^{4,7}0^{1,10}\cdot0^{3,8}$]pentadeca-5,10,12,14-tetraene (may be also referred to as 1,4-methano-1,4,4a,5,10,10a-hexahydroanthracene); pentacyclo[6.6.1.$1^{3,6}\cdot0^{2,7}\cdot0^{9,14}$]-4-hexadecene, pentacyclo[6.5.1.$1^{3,6}\cdot0^{2,7}0^{9,13}$]-4-pentadecene, pentacyclo[7.4.0.$0^{2,7}\cdot1^{3,6}\cdot1^{10,13}$]-4-pentadecene; heptacyclo[8.7.0.$1^{2,9}\cdot1^{4,7}\cdot1^{11,17}\cdot0^{3,8}\cdot0^{12,16}$]-5-eicosene, heptacyclo[8.7.0.$1^{2,9}\cdot0^{3,8}\cdot1^{4,7}\cdot0^{12,17}\cdot1^{13,16}$]-14-eicosene; and tetramers of cyclopentadiene, and the like.

**[0054]** These cyclic olefin components may be used alone or in combinations of two or more kinds thereof. Among them, use of bicyclo[2.2.1]hept-2-ene (common name: norbornene), or tetracyclododecene is preferable.

**[0055]** The method for polymerizing [1] an $\alpha$-olefin component having 2 to 20 carbon atoms and [2] a cyclic olefin component represented by the general formula (I), and the method for hydrogenating the resultant polymer are not especially limited, and can be carried out according to publicly known methods. Although it may be carried out by either random copolymerization or block copolymerization, random copolymerization is preferable.

**[0056]** In addition, the polymerization catalyst that may be used is not particularly limited, and the polymer can be obtained by using a conventionally well-known catalyst such as a Ziegler-Natta series, metathesis series, or metallocene series catalyst according to a well known process. The addition copolymer of cyclic olefin and $\alpha$-olefin or the hydrogenated product thereof that is favorably used in the present invention is preferably manufactured by use of a metallocene series catalyst or a Ziegler-Natta series catalyst.

**[0057]** An exemplary metathesis catalyst may be a molybdenum or tungsten series metathesis catalyst that is well-known as a catalyst for ring-opening polymerization of cycloolefin (for example, as described in Japanese Unexamined Patent Applications, First Publication Nos. S58-127728, S58-129013, etc.). In addition, the polymer obtained with the metathesis catalyst is preferably hydrogenated using a transition metal catalyst supported on an inorganic support, at a rate of no less than 90% of the double bond in the main chain, and at a rate of no less than 98% of the carbon-carbon double bond in the aromatic ring of the side chain.

Other Copolymer Component

**[0058]** The addition copolymer of cyclic olefin and $\alpha$-olefin (a2), particularly preferably used in the composition of the present invention, may contain, in addition to [1] the a -olefin component having 2 to 20 carbon atoms and [2] the cyclic olefin component represented by the general formula (I), other copolymerizable unsaturated monomer component as needed within a range not to impair the object of the present invention.

**[0059]** The unsaturated monomer, which may be optionally copolymerized, is not particularly limited, and for example, hydrocarbon based monomers including two or more carbon-carbon double bonds in one molecule and the like may be exemplified. Specific examples of the hydrocarbon based monomer including two or more carbon-carbon double bonds in one molecule include: linear unconjugated diene such as 1,4-hexadiene, 1,6-octadiene, 2-methyl-1,5-hexadiene, 4-methyl-1,5-hexadiene, 5-methyl-1,5-hexadiene, 6-methyl-1,5-heptadiene and 7-methyl-1,6-octadiene; cyclic unconjugated diene such as cyclohexadiene, dicyclopentadiene, methyltetrahydroindene, 5-vinyl-2-norbornene, 5-ethylidene-2-norbornene, 5-methylene-2-norbornene, 5-isopropylidene-2-norbornene, 6-chloromethyl-5-isopropenyl-2-norbornene and 4,9,5,8-dimethano-3a,4,4a,5,8,8a,9,9a-octahydro-1H-benzoindene; 2,3-diisopropylidene-5-norbornene; 2-ethylidene-3-isopropylidene-5-norbornene; 2-propenyl-2,2-norbornadiene; and the like. Among them, 1,4-hexadiene, 1,6-octadiene, and cyclic unconjugated diene, in particular, dicyclopentadiene, 5-ethylidene-2-norbornene, 5-vinyl-2-norbornene, 5-methylene-2-norbornene, 1,4-hexadiene, and 1,6-octadiene are preferable.

**[0060]** The content of the cyclic olefin-based resin in the insulating layer is preferably from 20% by weight to 50% by weight. When the content is less than 20% by weight, signal transmission characteristics, compressive strength, moisture permeability and the like for use in a coaxial cable may be inferior, and when the content is beyond 50% by weight, sufficient flexibility may not be attained.

Polyethylene

**[0061]** The low density polyethylene and the linear low-density polyethylene to be essential components of the coaxial cable of the present invention are explained below. The low density polyethylene and the linear low-density polyethylene are preferable materials for use in the insulating layer in the coaxial cable since they have flexibility.

**[0062]** The low density polyethylene, and the linear low-density polyethylene have MFR defined in JIS K6922-1 of preferably from 1.0 g/10 min to 10.0 g/10 min, and more preferably from 2.0 g/10 min to 8.0 g/10 min. Although flexibility can be attained when the MFR is lower than 1.0 g/10 min, the flowability can be deteriorated, whereby favorable processability may not be provided. In contrast, although favorable processability can be provided when the MFR exceeds 10.0 g/10 min, the flexibility may not be attained.

**[0063]** In particular, total content of the low density polyethylene and the linear low-density polyethylene is preferably 50% by weight to 80% by weight. When this content is less than 50% by weight, sufficient flexibility may not be achieved, and when this content is beyond 80% by weight, relative permittivity of the insulating layer may not be kept at a low level.

Other Components

**[0064]** To the insulating layer in the coaxial cable of the present invention can be added other thermoplastic resins, various compounding agents, and the like as needed, within a range not impairing its characteristics. Illustrative examples of the other resin include, for example, other polyolefin resins, polystyrene resins, fluorine resins, and the like. These other resins may be used alone or in a combination of two or more. Furthermore, when flexibility of the coaxial cable is required, an elastomer is preferably added to the cyclic polyolefin based resin. The elastomer which may be added is not particularly limited as long as it does not impair characteristics such as attenuation of the coaxial cable, and for example, a polyolefin based elastomer and a styrene based elastomer are preferred. Particularly, a polyolefin based elastomer is preferred for balancing the attenuation and the flexibility. In addition, illustrative examples of the compounding agent include stabilizers (antioxidant or anti-oxidizing agent, heavy metal resistant stabilizer, ultraviolet ray absorbing agent, heat stabilizer and the like), antistatic agents, fire retardants, retardant aids, colorants (dye, pigment and the like), wetting agents, plasticizers, lubricants, mold lubricants, crystal nucleating agents, dripping inhibitors, crosslinking agents, and the like. Since the insulating layer of a coaxial cable will be in contact with a metal such as copper that is a conductor, addition of a heavy metal resistant stabilizer is preferred. Illustrative examples of the heavy metal resistant stabilizer include salicylic acid derivatives (for example, trade name ADKSTAB CDA6), hydrazide derivatives (for example, trade name Irganox MD1024), oxalic amide derivatives (for example, trade name Naugard XL-1), sulfur-containing phosphite compounds (for example, trade name Hostanox OSP-1) and the like, and the type of the heavy metal resistant stabilizer is not particularly limited as long as characteristics of the coaxial cable are not impaired. Also, the amount of the heavy metal resistant stabilizer added is not particularly limited, and in general, the amount of addition of no greater than 0.3% by weight based on the resin component is preferably employed. Although the addition method is not particularly limited, it is more preferred to add beforehand to the cyclic polyolefin based resin, the polyethylene resin, other added resin, or the like.

Coaxial Cable

**[0065]** Although the constitution of the coaxial cable is not particularly limited, the most general examples include coaxial cables having an inner conductor, an insulating layer, an outer conductor and a sheath. The phrase "having a layer obtained by foam molding of a resin composition as an insulating layer" herein means to have an insulating layer formed to cover an inner conductor. In typical coaxial cables, an outer conductor is formed to cover the insulating layer for the purpose of electromagnetic shielding and the like, and further a sheath is formed to cover thereon.

**[0066]** The inner conductor is not particularly limited as long as it has electric conductivity, and for example, an electrically conductive metal such as copper or a copper alloy may be exemplified. It should be noted that a stranded wire produced by twisting multiple electrically conductive metal element wires may be used as the inner conductor.

**[0067]** The outer conductor is constituted as, for example, a conductor yarn braid produced by knitting multiple conductor element wires to form a mesh structure. As the conductor element wire for use in the outer conductor, for example, a copper wire or a copper alloy may be used. Examples of the procedure other than constituting in the form of a yarn braid include spiral winding, duplex winding and the like of a tape shaped conductor.

**[0068]** The method of foam molding of the resin composition in the present invention is not particularly limited as long as a desired extent of foaming can be achieved. A preferable method of foam molding may be exemplified by gas foaming.

**[0069]** The gas foaming refers to a method which includes pressing-in of a foaming agent into a melt extruder, covering a conductor with an insulating material, and allowing for foaming concomitantly with extrusion. Examples of the foaming agent include inert gases such as nitrogen, argon and carbon dioxide; and gases such as methane, propane, butane, pentane, hexane and fluorocarbon. In addition, a foaming auxiliary agent may be used in combination. Examples of the foaming auxiliary agent include urea, urea based compounds, zinc white, zinc stearate, and the like. The foaming agent and the foaming auxiliary agent are not limited to these exemplified compounds. Also, the foaming agent and the like may be used either alone, or in combination of two or more kinds thereof.

**[0070]** The foaming agent may be mixed with an organic polymer to be foamed beforehand, or may be supplied into an extruder from a foaming agent supply port provided on a barrel of the extruder.

**[0071]** The extent of foaming is preferably 80% to 90%. When the extent of foaming is less than 80%, the relative permittivity and the dielectric dissipation factor of the insulating layer may become so high that a characteristic as a high-frequency coaxial cable can be insufficient. When the extent of foaming exceeds 90%, it is probable that sufficient mechanical strength of the insulating layer may not be maintained.

Method for Manufacturing Coaxial Cable

**[0072]** A method for manufacturing the coaxial cable of the present invention is not particularly limited, and general method can be employed. For example, manufacture of a coaxial cable with an extruder may be included. With respect to the type of the extruder, for example, a twin screw extruder or a single screw extruder may be used, or these may be connected to impart functions of gas injection and covering.

**[0073]** In the manufacture of a coaxial cable, for example, extrusion foam molding on an inner conductor is carried out using a foaming agent in an extruder, and a foam insulating layer is formed to cover the outer periphery of the inner conductor. In covering the inner conductor with a foam insulating layer, a covering device such as a crosshead die is generally used. The coaxial cable can be manufactured without impairing the characteristics even though introduction of the inner conductor into the covering device is carried out in the air. In the case of manufacturing a coaxial cable having a very low attenuation, improvement of the covering device, for example, by filling a port for introducing the inner conductor with an inert gas such as nitrogen may be preferred in attempts to stabilize the characteristics since oxidation of the resin component which may result from the air can be inhibited. An outer conductor is further formed by covering the foam insulating layer with a common method, and finally a sheath is formed by covering the outer conductor by a common method.

EXAMPLES

**[0074]** The present invention is described in detail below with reference to Examples and Comparative Examples, but the present invention is not to be limited thereto.

Various Materials

Cyclic Olefin Resin

**[0075]**

Manufactured by TOPAS ADVANCED POLYMERS, trade name: TOPAS8007F-04; TOPAS6013S-04 and TOPAS6015S-04

Manufactured by ZEON Corp., trade name: ZEONOR 1060R

**[0076]** The modulus of elasticity, the specific gravity, the relative permittivity and the dielectric dissipation factor of the cyclic olefin resins described above were measured. The modulus of elasticity was measured in accordance with ISO178.

Dielectric characteristics (relative permittivity and dielectric dissipation factor) were determined using a network analyzer 8757D manufactured by Agilent Technologies, Inc., and a cavity resonator complex relative permittivity measurement apparatus manufactured by Kanto Denshi Co., Ltd., and the measurement of the relative permittivity was carried out at 1 GHz, 3 GHz and 10 GHz by a cavity resonator perturbation method at 23°C. Upon measurement, the insulating layer was formed to have a predetermined shape (φ: 2.5 mm, and length: 80 mm), and inserted into the cavity resonator. Each of the measurement results is shown in Table 1.

[Table 1]

| | | | 1 GHz. | | 3 GHz | | 10 GHz | |
|---|---|---|---|---|---|---|---|---|
| | Modulus of elasticity (GPa) | Specific gravity | Relative permittivity | Dielectric dissipation factor | elative permittivity | Dielectric dissipation factor | Relative permittivity | Dielectric dissipation factor |
| TOPAS8007F-04 | 2.4 | 1.02 | 2.26 | 0.0004 | 2.26 | 0.0002 | 2.22 | 0.0002 |
| TOPAS6013S-04 | 2.8 | 1.02 | 2.24 | 0.0003 | 2.23 | 0.0002 | 2.20 | 0.0002 |
| TOPAS6015S-04 | 2.9 | 1.02 | 2.23 | 0.0002 | 2.22 | 0.0002 | 2.20 | 0.0002 |
| ZEONOR 1060R | 2.1 | 1.01 | 2.30 | 0.0004 | 2.30 | 0.0003 | 2.30 | 0.0003 |

**[0077]** From Table 1, it was confirmed that the aforementioned cyclic olefins have sufficient lateral pressure resistance and appropriate flexibility since each had a modulus of elasticity of no less than 2.0 GPa and no greater than 3.5 GPa. In addition, since the relative permittivity was no greater than 2.3, and the dielectric dissipation factor was no greater than 4 x $10^{-4}$, the relative permittivity of the insulating layer after foam molding can be prevented from elevation due to the relative permittivity of the material portion.

Polyethylene

**[0078]**

Low density polyethylene; manufactured by Sumitomo Chemical Co., Ltd., trade name: Sumikasen G401, MFR: 4.0 g/10 min (JIS K6922-1)
Linear low-density polyethylene; manufactured by Sumitomo Chemical Co., Ltd., trade name: Sumikasen L GA401, MFR: 3.0 g/10 min (JIS K6922-1)

Measurement and Evaluation Method

**[0079]** The extent of foaming, the compressive strength, the moisture permeability, the relative permittivity and the attenuation were measured with the resin compositions shown in Table 2 below.

Measurement of Extent of Foaming

**[0080]** The extent of foaming was measured with a specific gravity method in a manufacturing step of the coaxial cable explained below. The resin density before foaming, and the density of the foam were measured, and the extent of foaming was determined using the above formula (1).

Compressive strength

**[0081]** The resin composition shown in Table 2 was blended, and extrusion molding of a sheet foamed with a nitrogen gas was conducted using an extrusion equipment in which the temperature of a cylinder C was set to be 200°C, and the temperature of a die D was set to be 195°C (Fig. 1). The blended composition was charged via a hopper A, and a nitrogen gas was injected from a mixing unit B in a middle region of the cylinder. The sheet was molded to have a thickness of 5 mm.

**[0082]** Thus obtained sheet having a thickness of 5 mm was cut into a piece of 30 mm x 100 mm, and a load was applied in the thickness direction to measure a compressive strength. The measurement was conducted using TENSILON UTA-50KN manufactured by Orientec Co., Ltd., at a test speed of 1 mm/min.

Measurement of Moisture Permeability

**[0083]** The moisture permeability was measured in accordance with ISO 10156-1 (differential pressure method) using a VAC-V2 Gas Permeability Tester for differential pressure method manufactured by Labthink as a measurement device.

Method for Manufacturing Coaxial Cable

**[0084]** Using a coaxial cable manufacturing apparatus shown in Fig. 2, a foam insulating layer was formed on an inner conductor (copper wire). First, an inner conductor insertion port of a crosshead die 7 on the side of a conductor heating unit 6 was closed, and each resin of a resin composition shown in Table 2 was charged into a hopper 3 of a first extruder. Then, a nitrogen gas was pressed-in from a foaming agent press-in port 4 while melt kneading of the resin is carried out, and the mixture was injected into a second extruder 2. The mixture further melt kneaded in the second extruder 2 was injected into the crosshead die 7, and a foam insulator not including an inner conductor was obtained after passing through a cooling system 8 and a drawing unit 9. The density of the foam insulator was measured, and the pressure of the nitrogen gas was regulated such that a predetermined extent of foaming was attained. Accordingly, foaming conditions of the foam insulator were determined. With respect to present temperatures of the first extruder 1 and the second extruder 2, the settings were: 200°C in the case of the resin blends containing TOPAS8007F-04 and ZEONOR 1060R, and in the case of Comparative Examples; 215°C in the case of the resin blend containing TOPAS6013S-04; and 230°C in the case of the resin blend containing TOPAS6015S-04, respectively. With respect to adjustment of the extent of foaming, setting of the extent of foaming of 80% to 90% was enabled except for Comparative Example 1 in which the high density polyethylene alone was used. In the case of Comparative Example 1, the extent of foaming could not be increased, and thus the extent of foaming of 40% was employed. The foam insulator without including an inner conductor obtained in this step was used for measurement of the relative permittivity.

**[0085]** Next, the inner conductor insertion port of the crosshead die 7 on the side of a conductor heating unit 6 was opened, and an inner conductor 11 (copper wire) having a diameter of 1.4 mm was lead out from a conductor delivery unit 5, and placed sequentially into the conductor heating unit 6, the crosshead die 7, the cooling system 8, and the drawing unit 9. The inner conductor 11 was covered with a mixture extruded under the same conditions as the extrusion conditions of the foam insulator determined in the above procedure by way of the crosshead die 7, and then transferred sequentially to the cooling system 8 and the drawing unit 9. The drawing speed was regulated such that an electric wire 12 including the inner conductor 11 covered by the insulating layer had an external diameter of 4.8 mm. After regulation, the electric wire 12 was wound up to the rolling unit. Thereafter, the electric wire 11 was covered with corrugated copper as an outer conductor, and further covered with a polyethylene sheath to obtain a coaxial cable. The attenuation of the resulting coaxial cable was measured. When the density of the foam insulating layer was measured after eliminating the inner conductor 11 of the electric wire 12, it was confirmed to be the same as the density of the foam insulator produced under the same extrusion conditions except that covering with the inner conductor was omitted.

[Table 2]

| | Comparative Example 1 | Comparative Example 2 | Comparative Example 3 | Example 1 | Example 2 | Example 3 | Example 4 | Example 5 | Example 6 | Example 7 |
|---|---|---|---|---|---|---|---|---|---|---|
| TOPAS8007F-04 | | | | 30 | 30 | 30 | 30 | | | |
| TOPAS6013S-04 | | | | | | | | 30 | | |
| TOPAS6015S-04 | | | | | | | | | 30 | |
| ZEONOR 1060R | | | | | | | | | | 30 |
| Low density polyethylene | 100 | | 50 | 70 | | | | | | |
| Linear low-density polyethylene | | 100 | 50 | | 70 | 70 | 70 | 70 | 70 | 70 |
| Extent of foaming (%) | 80 | 80 | 80 | 80 | 80 | 85 | 90 | 80 | 80 | 85 |
| Compressive strength (kPa) | 582 | 585 | 583 | 911 | 912 | 903 | 894 | 909 | 911 | 899 |
| Moisture permeability ($g/m^2$ · day · atm) | 0.62 | 0.61 | 0.61 | 0.45 | 0.45 | 0.44 | 0.45 | 0.44 | 0.45 | 0.45 |
| Relative permittivity (1 GHz) | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | 1.13 | 1.10 | 1.18 | 1.18 | 1.13 |
| Relative permittivity (3 GHz) | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | 1.13 | 1.10 | 1.18 | 1.18 | 1.13 |
| Relative permittivity (10 GHz) | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | 1.13 | 1.10 | 1.18 | 1.18 | 1.13 |
| Attenuation (db/100 m) | 32.4 | 27.4 | 29.9 | 26.8 | 23.1 | 17.6 | 12.3 | 23.1 | 23.1 | 24.5 |

| | Example 8 | Example 9 | Example 10 | Example 11 | Example 12 | Example 13 | Example 14 |
|---|---|---|---|---|---|---|---|
| TOPAS8007F-04 | 20 | 30 | 50 | 50 | 80 | 30 | 50 |
| Low density polyethylene | | | | 50 | | 35 | 25 |
| Linear low-density polyethylene | 80 | 70 | 50 | | 20 | 35 | 25 |
| Extent of foaming (%) | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| Compressive strength (kPa) | 874 | 912 | 963 | 975 | 1248 | 941 | 956 |
| Moisture permeability ($g/m^2 \cdot day \cdot atm$) | 0.47 | 0.45 | 0.41 | 0.40 | 0.25 | 0.45 | 0.40 |
| Relative permittivity (1 GHz) | 1.18 | 1.18 | 1.18 | 1.18 | 1.17 | 1.18 | 1.18 |
| Relative permittivity (3 GHz) | 1.18 | 1.18 | 1.18 | 1.18 | 1.17 | 1.18 | 1.18 |
| Relative permittivity (10 GHz) | 1.18 | 1.18 | 1.17 | 1.17 | 1.16 | 1.18 | 1.17 |
| Attenuation (db/100 m) | 24.6 | 23.1 | 20.2 | 22.9 | 15.5 | 25.0 | 21.5 |

**[0086]** From Table 2, the extent of foaming falling within the range of 80% to 90%, the compressive strength being no less than 800 (kPa), the moisture permeability being no greater than 0.55 ($g/m^2 \cdot day \cdot atm$), the relative permittivity being no greater than 1.20, and the attenuation being no greater than 27 (dB/100 m) were ascertained in Examples 1 to 14. Therefore, the coaxial cables of Examples 1 to 14 are coaxial cables suited for high frequency transmission. To the contrary, the coaxial cables of Comparative Examples 1, 2 and 3 without containing a cyclic olefin were confirmed to be unsuited for high frequency transmission due to the high attenuation and also due to the high moisture permeability. Furthermore, these were confirmed to be unsuitable as a coaxial cable owing to the lowered compressive strength.

## Claims

1. A coaxial cable comprising a layer, as an insulating layer, formed by foam molding of a resin composition containing a cyclic olefin-based resin, and at least one of a low density polyethylene and a linear low-density polyethylene, wherein
the extent of foaming of the insulating layer is from 80% to 90%.

2. The coaxial cable according to claim 1, wherein
the resin composition comprises:

   from 20% by weight to 50% by weight of the cyclic olefin-based resin; and
   from 50% by weight to 80% by weight of at least one of the low density polyethylene and the linear low-density polyethylene in terms of the total amount.

3. The coaxial cable according to either of claim 1 or 2, wherein
the insulating layer has a compressive strength of no less than 800 $N/cm^2$, and an attenuation of no greater than 27 dB/100 m.

4. The coaxial cable according to any one of claims 1 to 3, wherein
the insulating layer has a moisture permeability of no greater than 0.55 $g/m^2 \cdot day \cdot atm$.

5. A coaxial cable according to any one of claims 1 to 4, wherein
the insulating layer has a relative permittivity of no greater than 1.20 in a frequency domain of from 1 GHz to 10 GHz.

6. The coaxial cable according to any one of claims 1 to 5, wherein
the cyclic olefin-based resin is a copolymer of cyclic olefin and $\alpha$-olefin, or a hydrogenated product thereof.

7. The coaxial cable according to any one of claims 1 to 6, wherein
the cyclic olefin-based resin has a relative permittivity of no greater than 2.3 in a frequency domain of from 1 GHz to 10 GHz, a dielectric dissipation factor of no greater than $4 \times 10^{-4}$, and a flexural modulus at room temperature of no less than 2.0 GPa.

FIG. 1

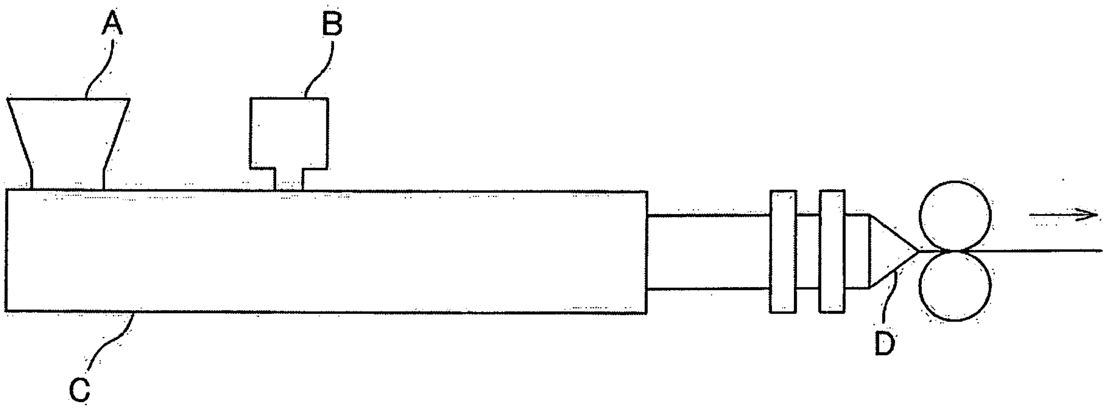
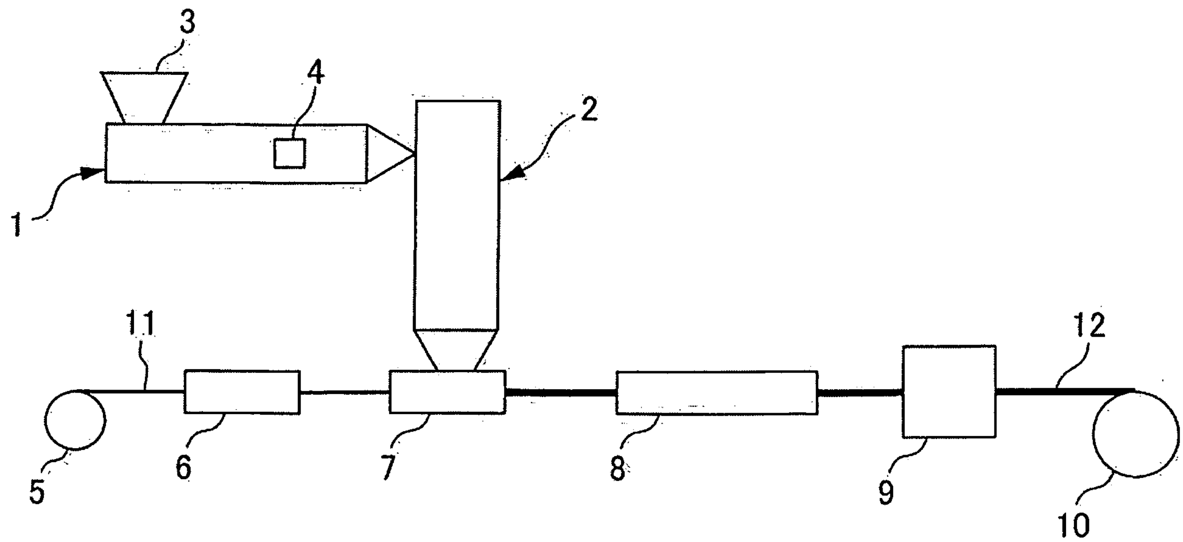



FIG. 2



**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2008/059569

A. CLASSIFICATION OF SUBJECT MATTER
*H01B11/18*(2006.01)i, *H01B3/44*(2006.01)i, *H01B7/02*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01B11/18, H01B3/44, H01B7/02

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

| | | | |
|---|---|---|---|
| Jitsuyo Shinan Koho | 1922-1996 | Jitsuyo Shinan Toroku Koho | 1996-2008 |
| Kokai Jitsuyo Shinan Koho | 1971-2008 | Toroku Jitsuyo Shinan Koho | 1994-2008 |

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. |
|---|---|---|
| Y | JP 2000-311519 A (Sumitomo Electric Industries, Ltd.), 07 November, 2000 (07.11.00), Claims; Par. Nos. [0001], [0002], [0007] to [0010]; table 1 (Family: none) | 1-7 |
| Y | JP 11-189743 A (Nippon Zeon Co., Ltd.), 13 July, 1999 (13.07.99), Claims; Par. Nos. [0037], [0038], [0050], [0051] & WO 99/020676 A1 & EP 1026189 A1 & US 6511756 B1 | 1-7 |

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 22 July, 2008 (22.07.08) | 05 August, 2008 (05.08.08) |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| Japanese Patent Office | |
| Facsimile No. | Telephone No. |

Form PCT/ISA/210 (second sheet) (April 2007)

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2008/059569

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | JP 8-36920 A (Showa Electric Wire & Cable Co., Ltd.), 06 February, 1996 (06.02.96), Claims; Par. Nos. [0001], [0017] to [0019] (Family: none) | 1-7 |
| Y | JP 2000-297172 A (Mitsubishi Cable Industries, Ltd.), 24 October, 2000 (24.10.00), Claims; Par. No. [0010] (Family: none) | 1-7 |
| A | JP 2007-237645 A (Fujikura Ltd.), 20 September, 2007 (20.09.07), Claims; table 3 (Family: none) | 1-7 |
| A | JP 2001-200085 A (Mitsubishi Cable Industries, Ltd.), 24 July, 2001 (24.07.01), Claims; table 1 (Family: none) | 1-7 |
| A | JP 2001-135145 A (Nippon Unicar Co., Ltd.), 18 May, 2001 (18.05.01), Claims; Par. Nos. [0023], [0026] (Family: none) | 1-7 |
| A | JP 5-234430 A (Showa Electric Wire & Cable Co., Ltd.), 10 September, 1993 (10.09.93), Claims; Par. Nos. [0011] to [0014] (Family: none) | 1-7 |
| A | JP 2005-343916 A (Fujikura Ltd.), 15 December, 2005 (15.12.05), Claims; Par. No. [0011]; table 1 (Family: none) | 1-7 |
| A | JP 8-157652 A (Japan Synthetic Rubber Co., Ltd.), 18 June, 1996 (18.06.96), Claims; Par. Nos. [0001], [0019] (Family: none) | 1-7 |

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

## REFERENCES CITED IN THE DESCRIPTION

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

### Patent documents cited in the description


- JP 2000297172 A **[0005]**
- JP 2000311519 A **[0005]**
- JP S58127728 B **[0057]**
- JP S58129013 B **[0057]**