

DESCRIPTION

ETHYLENE/ALPHA-OLEFIN COPOLYMER WITH EXCELLENT ELECTRICAL INSULATION

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TECHNICAL FIELD

Cross-reference to Related Applications

[0001] This application claims the benefit of Korean Patent Application No. 2020-0046027, filed on April 16, 2020, in the
10 Korean Intellectual Property Office, the contents of which are incorporated herein by reference.

Technical Field

[0002] The present invention relates to an ethylene/alpha-
15 olefin copolymer having high volume resistance and light transmittance, and a method for preparing the same.

BACKGROUND ART

[0003] As global environmental problems, energy problems,
20 etc. get worse and worse, solar cells receive attention as an energy generating means without fear of environmental contamination and exhaustion. If solar cells are used outside such as the roof of a building, generally, a module type of the solar cells is used. In order to obtain a
25 crystalline solar cell module when manufacturing a solar cell

module, protection sheet for solar cell module (surface side protection member)/solar cell encapsulant/crystalline solar cell device/solar cell encapsulant/protection sheet for solar cell module (back side protection member) are stacked in order. In addition, when manufacturing a thin film-based solar cell module, thin film-type solar cell device/solar cell encapsulant/protection sheet for solar cell module (back side protection member) are stacked in order. As the encapsulant of the solar cell, generally, an ethylene/vinyl acetate copolymer or ethylene/alpha-olefin copolymer having excellent transparency, flexibility, adhesiveness, etc. is used.

[0004] Meanwhile, the solar cell module is generally used outside for a long time, and defects including performance degradation due to various external stimuli are consistently observed. Particularly, the resolution of potential induced degradation (PID) phenomenon found in high-powered power plant types is urgently needed.

[0005] In a large-capacity generating system for obtaining high voltage by connecting multiple solar cell modules, the volume resistance of an encapsulant decreases according to the increase of the temperature and humidity at an installed place, and a potential difference is generated between the cell of the solar cells and a frame. At last, toward the end of an array of multiple solar cell modules connected in

series, the potential difference between the cell of the solar cells and the frame increases. In the presence of such potential difference, leakage current may be generated, and generating efficiency may be rapidly reduced, and this is the PID phenomenon.

[0006] Based on such backgrounds, the development of an ethylene/alpha-olefin copolymer which may improve volume resistance without degrading light transmittance and may consistently prevent PID phenomenon is required.

[0007] [Prior Art Document]

[0008] [Patent Document]

[0009] (Patent Document 1) Japanese Laid-open Patent No. 2010-258439

DISCLOSURE OF THE INVENTION

TECHNICAL PROBLEM

[0010] An object of the present invention is to provide an ethylene/alpha-olefin copolymer having high volume resistance and may be usefully utilized as an insulating material, and a method for preparing the same.

TECHNICAL SOLUTION

[0011] To solve the above tasks, the present invention provides an ethylene/alpha-olefin copolymer satisfying the

following conditions (a) to (d):

[0012] (a) a density is 0.85 to 0.89 g/cc;

[0013] (b) a molecular weight distribution is 1.8 to 2.3;

[0014] (c) a melt index (MI, 190°C, 2.16 kg load conditions)

5 is 1 to 100 dg/min; and

[0015] (d) a full width at half maximum (FWHM) of a crystallization peak shown during measuring a crystallization temperature by cross-fractionation chromatography (CFC) is 15 or more.

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ADVANTAGEOUS EFFECTS

[0016] The ethylene/alpha-olefin copolymer of the present invention has high crystallinity distribution and a small free volume, and shows excellent volume resistance and
15 excellent electrical insulation, and accordingly, may be widely used for various uses in electric and electronic industrial fields.

BEST MODE FOR CARRYING OUT THE INVENTION

20 **[0017]** Hereinafter, the present invention will be described in more detail to assist the understanding of the present invention.

[0018] It will be understood that words or terms used in the
25 present disclosure and claims shall not be interpreted as the

meaning defined in commonly used dictionaries. It will be further understood that the words or terms should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the technical
5 idea of the invention, based on the principle that an inventor may properly define the meaning of the words or terms to best explain the invention.

[0019] [Ethylene/alpha-olefin copolymer]

10 **[0020]** The ethylene/alpha-olefin copolymer of the present invention is characterized in satisfying the following conditions (a) to (d):

[0021] (a) a density is 0.85 to 0.89 g/cc;

[0022] (b) a molecular weight distribution is 1.8 to 2.3;

15 **[0023]** (c) a melt index (MI, 190°C, 2.16 kg load conditions) is 1 to 100 dg/min; and

[0024] (d) a full width at half maximum (FWHM) of a crystallization peak shown during measuring a crystallization temperature by cross-fractionation chromatography (CFC) is 15
20 or more.

[0025] The present invention relates to an ethylene/alpha-olefin copolymer having high volume resistance and showing excellent electrical insulation. Particularly, for preparing
25 the ethylene/alpha-olefin copolymer of the present invention,

transition metal compounds represented by Formula 1 and Formula 2 are mixed and used as a catalyst. The introduction of an alpha-olefin-based monomer into the transition metal compound represented by Formula 1 is difficult due to the structural characteristics of the catalyst, and a copolymer of a high-density region tends to be prepared, and a large amount of alpha-olefin may be introduced into the transition metal compound represented by Formula 2, a polymer (elastomer) in a very low-density region may be prepared. Accordingly, if each of the two transition metal compounds is used solely, copolymerization properties of mixing and introducing an alpha-olefin-based monomer are different.

[0026] The ethylene/alpha-olefin copolymer of the present invention, prepared by using the mixture composition as a catalyst is a copolymer in which both a low-density region in which a large amount of an alpha-olefin-based monomer is mixed and introduced and a high-density region in which a small amount of an alpha-olefin-based monomer is mixed and introduced, are present, and have wide crystallinity distribution and a small free volume, and accordingly, charge mobility is low, and electrical insulation is excellent.

[0027] The ethylene/alpha-olefin copolymer of the present invention is a polymer having a low density in a range of 0.85 to 0.89 g/cc, and in this case, the density may mean a

density measured according to ASTM F-792. More particularly, the density may be 0.850 g/cc or more, 0.860 g/cc or more, or 0.870 g/cc or more, or 0.874 g/cc or more, and may be 0.890 g/cc or less, or 0.880 g/cc or less, 0.878 g/cc or less.

5 **[0028]** If the density deviates from the range, problems of degrading the volume resistance or light transmittance of the ethylene/alpha-olefin copolymer may arise.

[0029] Generally, the density of the ethylene/alpha-olefin copolymer is influenced by the type and amount of a monomer
10 used for polymerization, a polymerization degree, etc., and is largely influenced by the amount of a comonomer in case of a copolymer. In this case, if the amount of the comonomer increases, an ethylene/alpha-olefin copolymer of a low density may be prepared, and the amount of the comonomer
15 introduced into the copolymer may be dependent on the intrinsic copolymerization properties of a catalyst.

[0030] The copolymer of the present invention is a copolymer prepared using the compounds represented by Formula 1 and Formula 2 as catalysts, and has a low density as described
20 above, and as a result, excellent processability may be shown.

[0031] The ethylene/alpha-olefin copolymer of the present invention has narrow molecular weight distribution (MWD) in a range of 1.8 to 2.3. More particularly, the molecular weight
25 distribution may be 1.80 or more, 1.90 or more, and 2.30 or

less, 2.20 or less, 2.10 or less, 2.05 or less.

[0032] Generally, if two or more types of monomers are polymerized, molecular weight distribution increases, and as a result, impact strength and mechanical properties are reduced, and there is possibility of generating blocking phenomenon. Particularly, since the polymerization properties of a monomer are different according to the catalyst, the molecular weight of a polymer finally prepared may be influenced by the type of the catalyst. If two or more types of catalysts are mixed and used in polymerization reaction, and if the difference of the polymerization properties of the catalysts is large, there are problems of increasing the molecular weight distribution of a polymer.

[0033] In order to reduce the molecular weight distribution to prevent the degradation of the crosslinking properties, impact strength, mechanical properties, etc. of a copolymer, a suitable amount of hydrogen may be injected during polymerization reaction to prevent the generation of optional β -hydride elimination reaction in a polymer chain and induce uniform termination reaction, and in this case, the weight average molecular weight and melt index of the copolymer tend to decrease according to the injection of hydrogen. Accordingly, appropriate catalyst type and hydrogen injection amount are determined in ranges for achieving both the intrinsic properties of a catalyst structure influencing the

weight average molecular weight and the melt index and the reducing effects of molecular weight distribution according to the injection of hydrogen.

[0034] Considering the above-described points, in the present invention, since a transition metal compound represented by Formula 1 and a transition metal compound represented by Formula 2 are mixed and used as a catalyst, and an optimum amount of hydrogen is injected during preparation, the above-described range of narrow molecular weight distribution may be obtained, the degradation of crosslinking properties, impact strength, mechanical properties, etc. may be prevented, and high volume resistance and electrical insulation may be achieved.

[0035] The weight average molecular weight (M_w) and the number average molecular weight (M_n) are polystyrene conversion molecular weights analyzed by gel permeation chromatography (GPC), and the molecular weight distribution may be calculated from the ratio of M_w/M_n .

[0036] In addition, the ethylene/alpha-olefin copolymer of the present invention may have a weight average molecular weight (M_w) of 40,000 to 150,000 g/mol. More particularly, the weight average molecular weight may be 45,000 g/mol or more, 50,000 g/mol or more, or 60,000 g/mol or more, and 130,000 g/mol or less, 100,000 g/mol or less, or 90,000 g/mol or less.

[0037] The ethylene/alpha-olefin copolymer of the present invention has a melt index (MI, 190°C, 2.16 kg load conditions) of 1 to 100 dg/min. Particularly, the melt index
5 may be 1 dg/min or more, 2 dg/min or more, 3 dg/min or more, or 4 dg/min or more, and 100 dg/min or less, 20 dg/min or less, or 15 dg/min or less.

[0038] If the melt index is less than 1 dg/min, a production rate may be reduced due to high load, and if the melt index
10 is greater than 100 dg/min, there are problems in that the volume resistance or light transmittance of the ethylene/alpha-olefin copolymer may be degraded, or film molding is difficult, and the use of an encapsulant composition for a solar cell is unsuitable.

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[0039] In addition, the ethylene/alpha-olefin copolymer may have a melt flow rate ratio (MFRR, $MI_{10}/MI_{2.16}$) which is a value of a melt index (MI_{10}) measured at 190°C and 10 kg load conditions with respect to the melt index ($MI_{2.16}$) measured at
20 190°C and 2.16 kg load conditions of 8.0 or less, particularly, 4.0 or more, 4.2 or more, 4.5 or more, and 8.0 or less, 7.0 or less, 6.8 or less. The melt flow rate ratio is an index of the degree of long chain branching of a copolymer, and the ethylene/alpha-olefin copolymer of the
25 present invention satisfies the melt flow rate ratio together

with the above-described physical properties and has excellent physical properties, and thus, may be suitably applied to an encapsulant composition for a solar cell with excellent physical properties.

5 **[0040]** Particularly, if the ethylene/alpha-olefin copolymer of the present invention has a low melt index of 1 to 100 dg/min as described above, the melt flow rate ratio may be low and 8.0 or less. Since the copolymer of the present invention has such a low melt index and melt flow rate ratio,
10 the copolymer is characterized in having a high molecular weight, the small long chain branch content, and an excellent crosslinking degree.

[0041] It is difficult for the conventional copolymer to have such a low melt index and melt flow rate ratio, and at
15 the same time, have a high full width at half maximum (FWHM) of a crystallization peak, which will be explained later, of 15 or more and have wide crystallinity distribution, but in the present invention, since a copolymer is prepared by using the compounds represented by Formula 1 and Formula 2 as
20 catalysts and an appropriate amount of hydrogen, and polymerization is terminated by the injection of hydrogen, the terminal of the copolymer is a saturated state, a long chain branch is not formed, and the characteristics of a low melt flow rate ratio are achieved. Also, a copolymer having
25 wide crystallinity distribution is prepared by using two

types of catalysts having different crystallization degree properties.

[0042] The ethylene/alpha-olefin copolymer of the present invention has the full width at half maximum (FWHM) of a crystallization peak shown during measuring a crystallization temperature by cross-fractionation chromatography (CFC) of 15 or more. Here, the full width at half maximum of the peak is a value derived from a crystallinity distribution graph drawn by dw/dT value in accordance with the temperature measured in bivariate distribution by cross-fractionation chromatography.

[0043] The cross-fractionation chromatography is a method combining temperature rising elution fractionation (TREF) with gel filtration chromatography (GPC) and is a type of method for getting the crystallinity distribution and molecular weight distribution of a copolymer at the same time.

[0044] Particularly, a specimen solution of high temperature in which an ethylene/alpha-olefin copolymer is completely dissolved in a solvent is injected into a column filled with an inert carrier, the temperature of the column is lowered to attach the specimen on the surface of the filler, and the temperature of the column is gradually elevated while flowing o-dichlorobenzene in the column. The concentration of a copolymer eluted at each temperature is detected, and at the same time, the component eluted at each temperature is sent

to GPC via online for each fraction to obtain a chromatogram, and after that, the molecular weight distribution of each component is calculated therefrom. In this case, since the elution temperature is elevated according to the increase of the crystallinity of the eluted component, the crystallinity distribution of the copolymer may be found by obtaining the relation of the elution temperature and the elution amount (wt%) of the ethylene/alpha-olefin copolymer.

[0045] The ethylene/alpha-olefin copolymer of the present invention has a high FWHM value of 15 or more, and this indicates that the crystallinity distribution of the copolymer is high. At last, the free volume in the copolymer is small, the charge mobility is low, volume resistance is high, and insulation properties are excellent.

[0046] As in the present invention, in order to prepare an ethylene/alpha-olefin copolymer having excellent volume resistance and light transmittance, it is important to increase the FWHM value and decrease the molecular weight distribution. The FWHM is related to the uniformity of crystallinity according to the copolymerization properties for mixing and introducing an alpha-olefin-based monomer, and the molecular weight distribution is related to the uniformity of a chain length according to the propagation rate of ethylene, etc. In a catalyst, if a part capable of reacting with a monomer is a single site, the chain

propagation may be uniform, and molecular weight distribution may be narrow, but by the same principle, copolymerization properties may be uniform, crystallinity distribution may be narrow, and the FWHM value may become small. Accordingly, the preparation of a copolymer having narrow molecular weight distribution and a high FWHM of 15 or more by using one catalyst is difficult.

[0047] On the contrary, by using two types of catalysts having similar propagation rate of ethylene but different copolymerization properties, an ethylene/alpha-olefin copolymer having a high FWHM value of 15 or more and showing narrow molecular weight distribution of 1.8 to 2.3 is prepared.

[0048] Particularly, the FWHM value may be 15 or more, 16 or more, 16.5 or more, 16.8 or more, and 50 or less, 40 or less, 30 or less, 25 or less, 21 or less.

[0049] In addition, the ethylene/alpha-olefin copolymer of the present invention may have a melting temperature (T_m) of 70°C or less. More particularly, the melting temperature may be 50°C or more, 55°C or more, 58°C or more, and 70°C or less, 68°C or less, 67°C or less. By having the melting temperature in such a temperature range, excellent thermal stability may be shown.

[0050] In addition, the ethylene/alpha-olefin copolymer of

the present invention may have a crystallization temperature (T_c) of 70°C or less, 60°C or less, 55°C or less, 51°C or less, and 30°C or more, 35°C or more, 40°C or more, 42°C or more. Such a low crystallization temperature is due to the non-uniform distribution of a comonomer in the ethylene/alpha-olefin copolymer and high crystallinity distribution, and by having the above-described temperature range, excellent volume resistance and electrical insulation may be shown.

[0051] The melting temperature and crystallization temperature may be measured using differential scanning calorimeter (DSC). Particularly, a copolymer is heated to 150°C and maintained for 5 minutes, and the temperature is reduced to 20°C again and elevated again. In this case, the elevating rate and decreasing rate of the temperature is controlled to 10°C/min. Measured results in the second temperature elevating section is the melting temperature, and the measured results in a range shown while reducing the temperature is the crystallization temperature.

[0052] The ethylene/alpha-olefin copolymer of the present invention is prepared by copolymerizing ethylene and an alpha-olefin-based monomer, and in this case, the alpha-olefin which means a moiety derived from an alpha-olefin-based monomer in the copolymer may be C₄ to C₂₀ alpha-olefin,

particularly, propylene, 1-butene, 1-pentene, 4-methyl-1-pentene, 1-hexene, 1-heptene, 1-octene, 1-decene, 1-undecene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-eicosene, etc., and any one among them or mixtures of two or more thereof may
5 be used.

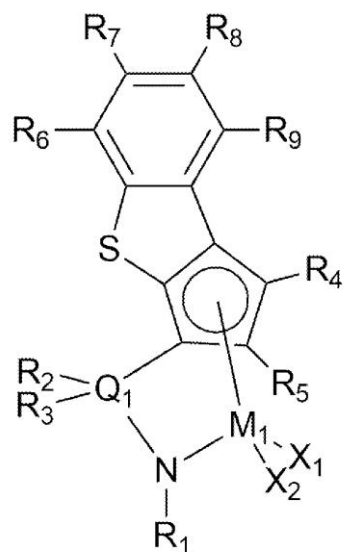
[0053] Among them, the alpha-olefin may be 1-butene, 1-hexene or 1-octene, preferably, 1-butene, 1-hexene, or a combination thereof.

[0054] In addition, in the ethylene/alpha-olefin copolymer,
10 the alpha-olefin content may be suitably selected in the range satisfying the physical conditions, particularly, greater than 0 to 99 mol%, or 10 to 50 mol%, without limitation.

15 **[0055] [Method for preparing ethylene/alpha-olefin copolymer]**

[0056] The ethylene/alpha-olefin copolymer of the present invention may be prepared by a preparation method characterized in including a step of polymerizing ethylene
20 and an alpha-olefin-based monomer in the presence of a catalyst composition including transition metal compounds represented by Formula 1 and Formula 2 below.

[0057] [Formula 1]



[0058] In Formula 1,

[0059] R₁ is hydrogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; alkoxy of 1 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; arylalkoxy of 7 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; or arylalkyl of 7 to 20 carbon atoms,

[0060] R₂ and R₃ are each independently hydrogen; halogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; arylalkyl of 7 to 20 carbon atoms; alkylamido of 1 to 20 carbon atoms; or arylamido of 6 to 20 carbon atoms,

[0061] R₄ and R₅ are each independently hydrogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; or alkenyl of 2 to 20 carbon atoms,

[0062] R₆ to R₉ are each independently hydrogen; alkyl of 1

to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; or alkenyl of 2 to 20 carbon atoms,

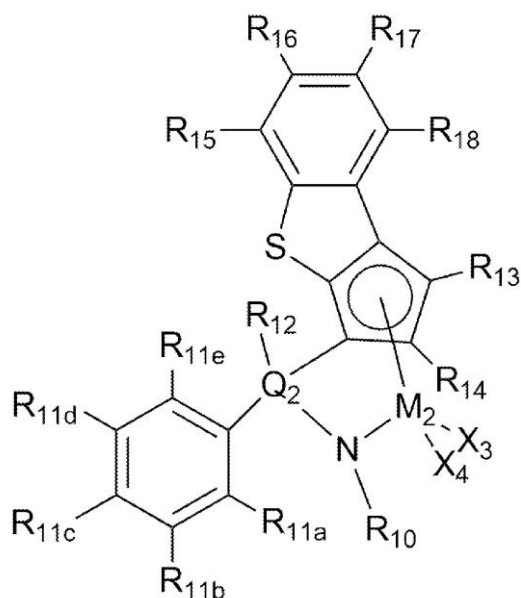
[0063] two or more adjacent groups among R₆ to R₉ may be connected with each other to form a ring,

5 **[0064]** Q₁ is Si, C, N, P or S,

[0065] M₁ is Ti, Hf or Zr, and

[0066] X₁ and X₂ are each independently hydrogen; halogen; alkyl of 1 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; arylalkyl of 7 to 20 carbon atoms; alkylamino of 1 to 20 carbon atoms; or arylamino of 6 to 20 carbon atoms.

[0067] [Formula 2]



[0068] In Formula 2,

15 **[0069]** R₁₀ is hydrogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20 carbon

atoms; alkoxy of 1 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; arylalkoxy of 7 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; or arylalkyl of 7 to 20 carbon atoms,

[0070] R_{11a} to R_{11e} are each independently hydrogen; halogen;
5 alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; alkoxy of 1 to 20 carbon atoms; or aryl of 6 to 20 carbon atoms,

[0071] R₁₂ is hydrogen; halogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20
10 carbon atoms; aryl of 6 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; arylalkyl of 7 to 20 carbon atoms; alkylamido of 1 to 20 carbon atoms; or arylamido of 6 to 20 carbon atoms,

[0072] R₁₃ and R₁₄ are each independently hydrogen; alkyl of
15 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; or alkenyl of 2 to 20 carbon atoms,

[0073] R₁₅ to R₁₈ are each independently hydrogen; alkyl of 1
20 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; or alkenyl of 2 to 20 carbon atoms,

[0074] two or more adjacent groups among R₁₅ to R₁₈ may be connected with each other to form a ring,

[0075] Q₂ is Si, C, N, P or S,

[0076] M₂ is Ti, Hf or Zr, and

25 **[0077]** X₃ and X₄ are each independently hydrogen; halogen;

alkyl of 1 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; arylalkyl of 7 to 20 carbon atoms; alkylamino of 1 to 20 carbon atoms; or arylamino of 6 to 20 carbon atoms.

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[0078] Particularly, in Formula 1, R_1 is hydrogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; alkoxy of 1 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; arylalkoxy of 7 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; or arylalkyl of 7 to 20 carbon atoms, and more particularly, R_1 may be methyl, ethyl, propyl, butyl, isobutyl, tert-butyl, isopropyl, cyclohexyl, benzyl, phenyl, methoxyphenyl, ethoxyphenyl, fluorophenyl, bromophenyl, chlorophenyl, dimethylphenyl or diethylphenyl.

[0079] Particularly, in Formula 1, R_2 and R_3 are each independently hydrogen; halogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; arylalkyl of 7 to 20 carbon atoms; alkylamido of 1 to 20 carbon atoms; or arylamido of 6 to 20 carbon atoms, and more particularly, R_2 and R_3 may be each independently hydrogen; alkyl of 1 to 20 carbon atoms; or arylalkyl of 7 to 20 carbon atoms.

[0080] Particularly, in Formula 1, R_4 and R_5 may be the same or different, and may be each independently hydrogen; alkyl

of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; or alkenyl of 2 to 20 carbon atoms, more particularly, alkyl of 1 to 6 carbon atoms. More particularly, R₄ and R₅ may be methyl, ethyl or propyl.

5 **[0081]** Particularly, in Formula 1, R₆ to R₉ may be the same or different and may be each independently hydrogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; or alkenyl of 2 to 20 carbon atoms. More particularly, R₆ to R₉ may be the same or
10 different and may be each independently hydrogen or methyl.

[0082] Two or more adjacent groups among R₆ to R₉ may be connected with each other to form an aliphatic ring of 5 to 20 carbon atoms or an aromatic ring of 6 to 20 carbon atoms, and the aliphatic ring or aromatic ring may be substituted
15 with halogen, alkyl of 1 to 20 carbon atoms, alkenyl of 2 to 20 carbon atoms or aryl of 6 to 20 carbon atoms.

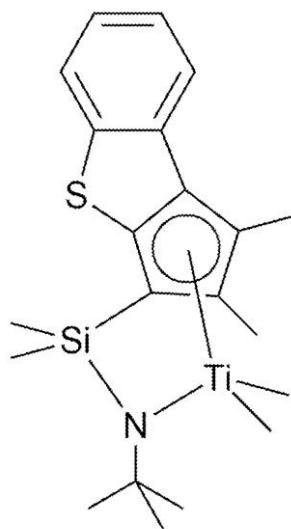
[0083] Particularly, in Formula 1, Q₁ is Si, C, N, P or S, and more particularly, Q₁ may be Si.

[0084] Particularly, in Formula 1, M₁ may be Ti, Hf or Zr.

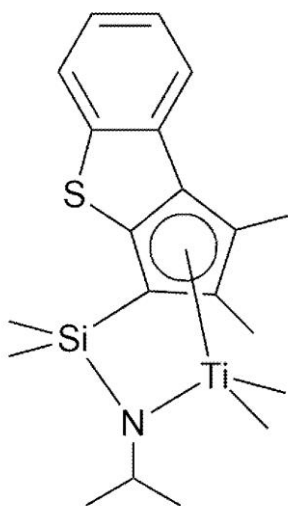
20 **[0085]** Particularly, in Formula 1, X₁ and X₂ may be the same or different and may be each independently hydrogen; halogen; alkyl of 1 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; arylalkyl of 7 to 20 carbon atoms; alkylamino
25 of 1 to 20 carbon atoms; or arylamino of 6 to 20 carbon atoms.

[0086] In addition, the compound represented by Formula 1 may be a compound represented by any one among the compounds below.

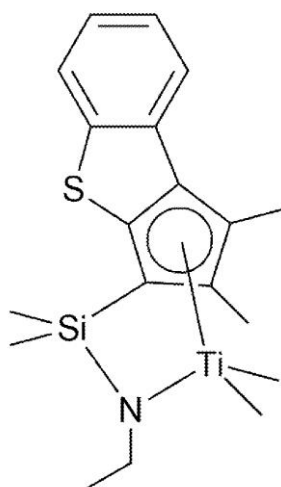
5 **[0087]** [Formula 1-1]



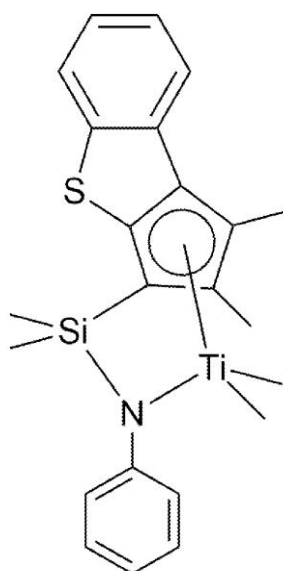
[0088] [Formula 1-2]



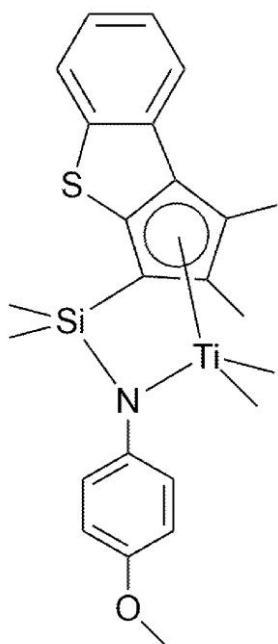
[0089] [Formula 1-3]



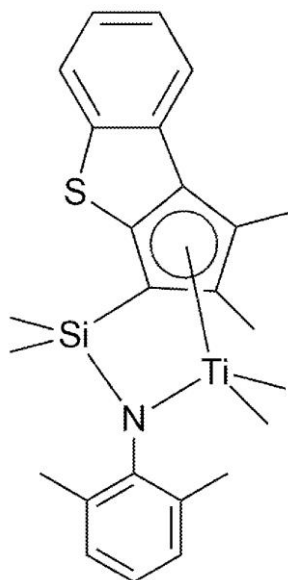
[0090] [Formula 1-4]



[0091] [Formula 1-5]



[0092] [Formula 1-6]



[0093] Besides, the compounds may have various structures
 5 within the range defined in Formula 1.

[0094] In addition, in Formula 2, R_{10} is hydrogen; alkyl of

1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; alkoxy of 1 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; arylalkoxy of 7 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; or arylalkyl of 7 to 20 carbon atoms, and more particularly, R₁₀ may be hydrogen; alkyl of 1 to 20 carbon atoms or 1 to 12 carbon atoms; alkoxy of 1 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; arylalkoxy of 7 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; or arylalkyl of 7 to 20 carbon atoms.

[0095] Particularly, in Formula 2, R_{11a} to R_{11e} are each independently hydrogen; halogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; alkoxy of 1 to 20 carbon atoms; or aryl of 6 to 20 carbon atoms, more particularly, hydrogen; halogen; alkyl of 1 to 12 carbon atoms; cycloalkyl of 3 to 12 carbon atoms; alkenyl of 2 to 12 carbon atoms; alkoxy of 1 to 12 carbon atoms; or phenyl.

[0096] Particularly, in Formula 2, R₁₂ is hydrogen; halogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; alkenyl of 2 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; arylalkyl of 7 to 20 carbon atoms; alkylamido of 1 to 20 carbon atoms; or arylamido of 6 to 20 carbon atoms, more particularly, hydrogen; halogen; alkyl of 1 to 12 carbon atoms; cycloalkyl of 3 to 12 carbon atoms; alkenyl of 2 to 12 carbon atoms; or

phenyl.

[0097] Particularly, in Formula 2, R_{13} and R_{14} are each independently hydrogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; aryl of 6 to 20 carbon
5 atoms; or alkenyl of 2 to 20 carbon atoms, more particularly, hydrogen; or alkyl of 1 to 12 carbon atoms.

[0098] Particularly, in Formula 2, R_{15} to R_{18} are each independently hydrogen; alkyl of 1 to 20 carbon atoms; cycloalkyl of 3 to 20 carbon atoms; aryl of 6 to 20 carbon
10 atoms; or alkenyl of 2 to 20 carbon atoms, more particularly, hydrogen; alkyl of 1 to 12 carbon atoms; or cycloalkyl of 3 to 12 carbon atoms, or hydrogen; or methyl.

[0099] Particularly, in Formula 2, two or more adjacent groups among R_{15} to R_{18} may be connected with each other to
15 form a ring.

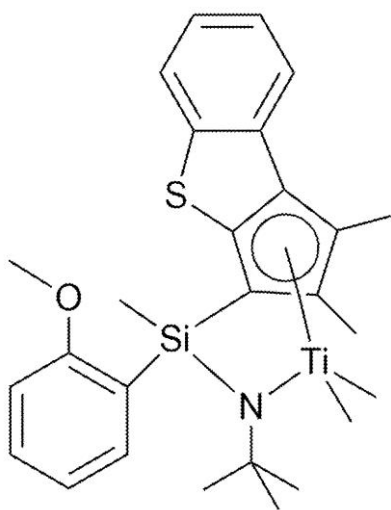
[00100] Particularly, in Formula 2, Q_2 is Si, C, N, P or S, more particularly, Q may be Si.

[00101] Particularly, in Formula 2, X_3 and X_4 are each independently hydrogen; halogen; alkyl of 1 to 20 carbon
20 atoms; alkenyl of 2 to 20 carbon atoms; aryl of 6 to 20 carbon atoms; alkylaryl of 7 to 20 carbon atoms; arylalkyl of 7 to 20 carbon atoms; alkylamino of 1 to 20 carbon atoms; or arylamino of 6 to 20 carbon atoms, particularly, hydrogen; halogen; alkyl of 1 to 12 carbon atoms; cycloalkyl of 3 to 12
25 carbon atoms; or alkenyl of 2 to 12 carbon atoms, more

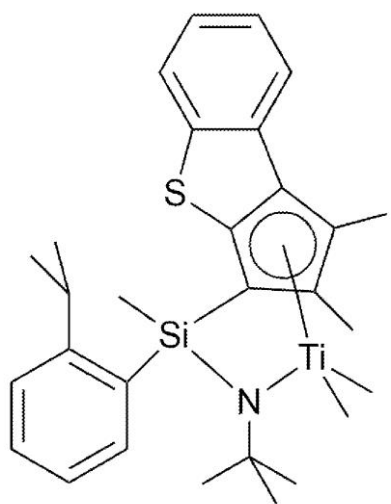
particularly, hydrogen; or alkyl of 1 to 12 carbon atoms.

[00102] In addition, the compound represented by Formula 2 may be any one among the compounds represented by Formula 2-1 to Formula 2-10 below.

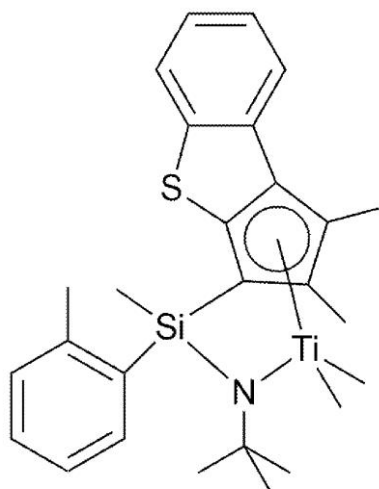
[00103] [Formula 2-1]



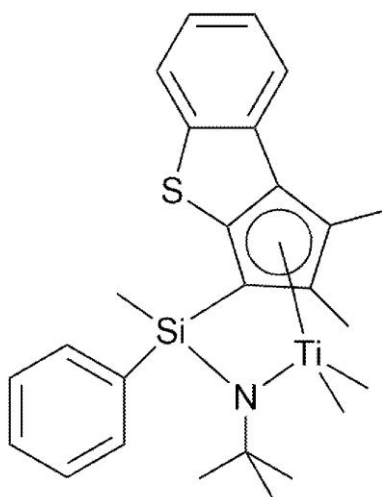
[00104] [Formula 2-2]



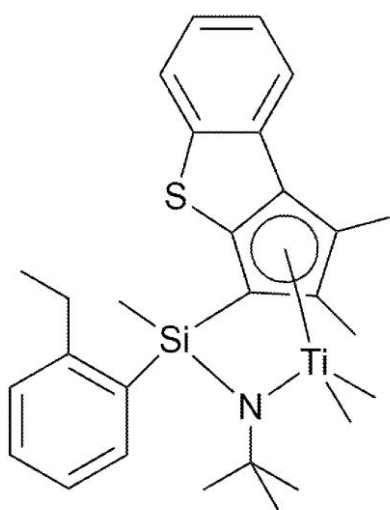
10 **[00105]** [Formula 2-3]



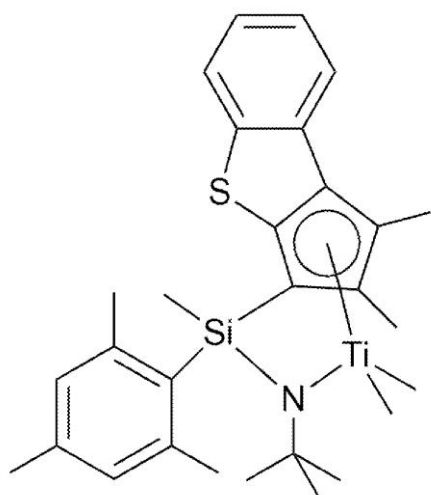
[00106] [Formula 2-4]



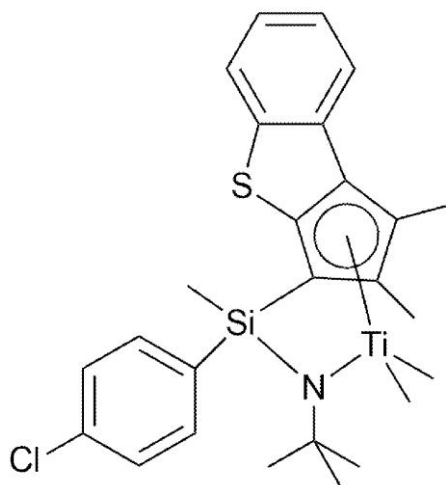
[00107] [Formula 2-5]



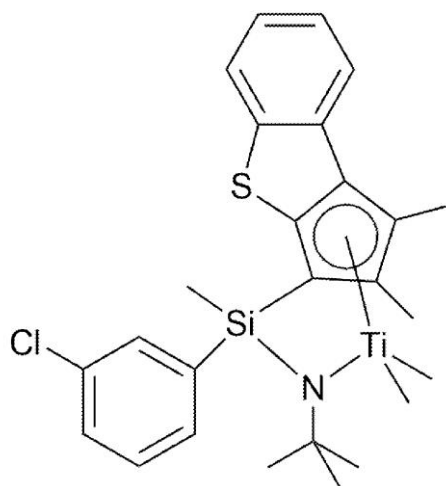
[00108] [Formula 2-6]



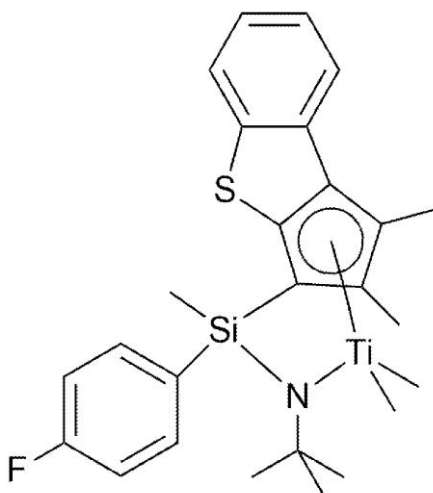
[00109] [Formula 2-7]



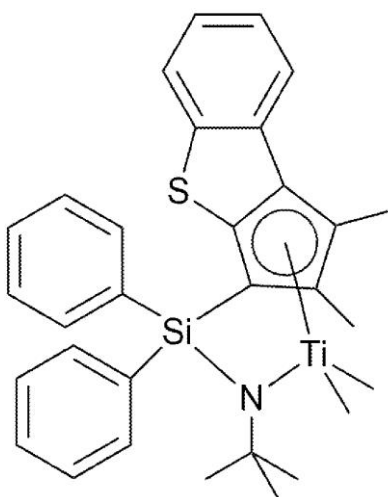
[00110] [Formula 2-8]



[00111] [Formula 2-9]



[00112] [Formula 2-10]



[00113] In the present invention, the molar ratio of the transition metal compounds represented by Formula 1 and Formula 2 may be 1:0.8 to 1:10, or 1:1 to 1:9, without limitation.

[00114] As described above, the transition metal compounds represented by Formula 1 and Formula 2 used in the present invention have different mixing and introducing capacity of a

comonomer, and by mixing and using them, a copolymer having both a low-density region and a high-density region and high crystallinity distribution may be prepared, and the copolymer of the present invention thus prepared may show high
5 crystallinity distribution, a small free volume, and excellent electrical insulation.

[00115] In the present invention, the polymerization reaction may be performed by continuously polymerizing ethylene and an
10 alpha-olefin-based monomer by continuously injecting hydrogen in the presence of the catalyst composition, particularly, may be performed by injecting hydrogen in 5 to 100 cc/min.

[00116] The hydrogen gas plays the role of restraining vigorous reaction of the transition metal compounds at the
15 initiation point of polymerization and terminating polymerization reaction. Accordingly, by the use of the hydrogen gas and the control of the amount used, an ethylene/alpha-olefin copolymer having narrow molecular weight distribution may be effectively prepared.

20 **[00117]** For example, the hydrogen may be injected in 5 cc/min or more, 7 cc/min or more, or 10 cc/min or more, or 15 cc/min or more, or 19 cc/min or more, and 100 cc/min or less, or 50 cc/min or less, or 45 cc/min or less, or 35 cc/min or less, or 29 cc/min or less. If injected in the above-described
25 conditions, the ethylene/alpha-olefin copolymer thus prepared

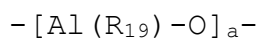
may achieve the physical properties of the present invention.

[00118] If the hydrogen gas is injected in less than 5 cc/min, the termination of polymerization reaction is not uniformly carried out, and the preparation of an ethylene/alpha-olefin copolymer having desired physical properties may become difficult, and if injected in greater than 100 cc/min, termination reaction may occur too fast, and it is apprehended that an ethylene/alpha-olefin copolymer having a very low molecular weight may be prepared.

[00119] In addition, the polymerization reaction may be performed at 100 to 200°C, and by controlling the polymerization temperature together with the injection amount of hydrogen, the crystallinity distribution and the molecular weight distribution in the ethylene/alpha-olefin copolymer may be controlled more advantageously. Particularly, the polymerization reaction may be performed at 100 to 200°C, 120 to 180°C, 130 to 170°C, or 130 to 150°C, without limitation.

[00120] In the present invention, a co-catalyst may be additionally used in the catalyst composition for activating the transition metal compounds represented by Formula 1 and/or Formula 2. The co-catalyst is an organometallic compound including a metal in group 13, and may particularly include one or more selected from Formula 3 to Formula 5 below.

[00121] [Formula 3]



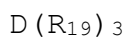
[00122] In Formula 3,

[00123] each R_{19} is independently halogen radical;

5 hydrocarbyl radical of 1 to 20 carbon atoms; or halogen-substituted hydrocarbyl radical of 1 to 20 carbon atoms, and

[00124] a is an integer of 2 or more.

[00125] [Formula 4]



10 **[00126]** In Formula 4,

[00127] D is aluminum or boron, and

[00128] each R_{19} is independently halogen radical;

hydrocarbyl radical of 1 to 20 carbon atoms; or halogen-substituted hydrocarbyl radical of 1 to 20 carbon atoms.

15 **[00129]** [Formula 5]



[00130] In Formula 5,

[00131] H is a hydrogen atom,

[00132] Z is an element in group 13,

20 **[00133]** each A is independently aryl of 6 to 20 carbon atoms, in which one or more hydrogen atoms may be substituted as substituents; or alkyl of 1 to 20 carbon atoms,

[00134] the substituent is halogen; hydrocarbyl of 1 to 20 carbon atoms; alkoxy of 1 to 20 carbon atoms; or aryloxy of 6
25 to 20 carbon atoms,

[00135] $[L-H]^+$ is trimethylammonium; triethylammonium; tripropylammonium; tributylammonium; diethylammonium; trimethylphosphonium; or triphenylphosphonium, and

[00136] $[L]^+$ is N,N-diethylanilinium; or triphenylcarbonium.

5

[00137] More particularly, the compound of Formula 3 may be an alkylaluminumoxane-based compound in which repeating units are combined in a linear, circular or network shape, and particular example may include methylaluminumoxane (MAO),
10 ethylaluminumoxane, isobutylaluminumoxane or tert-butylaluminumoxane.

[00138] In addition, the compound of Formula 4 may include trimethylaluminum, triethylaluminum, triisobutylaluminum, tripropylaluminum, tributylaluminum, dimethylchloroaluminum,
15 triisopropylaluminum, tri-s-butylaluminum, tricyclopentylaluminum, tripentylaluminum, triisopentylaluminum, trihexylaluminum, trioctylaluminum, ethyldimethylaluminum, methyldiethylaluminum, triphenylaluminum, tri-p-tolylaluminum,
20 dimethylaluminummethoxide, dimethylaluminummethoxide, trimethylboron, triethylboron, triisobutylboron, tripropylboron, tributylboron, etc. particularly, trimethylaluminum, triethylaluminum or triisobutylaluminum, without limitation.

25 **[00139]** The compound of Formula 5 may include a borate-based

compound of a trisubstituted ammonium salt, a dialkyl
 ammonium salt or a trisubstituted phosphonium salt type.
 More particular examples include a borate-based compound of a
 trisubstituted ammonium salt type such as trimethylammonium
 5 tetraphenylborate, methyldioctadecylammonium
 tetraphenylborate, triethylammonium tetraphenylborate,
 tripropylammonium tetraphenylborate, tri(n-butyl)ammonium
 tetraphenylborate, methyltetradecylcyclooctadecylammonium
 tetraphenylborate, N,N-dimethylanilinium tetraphenylborate,
 10 N,N-diethylanilinium tetraphenylborate, N,N-dimethyl(2,4,6-
 trimethylanilinium)tetraphenylborate, trimethylammonium
 tetrakis(pentafluorophenyl)borate, methylditetradecylammonium
 tetrakis(pentaphenyl)borate, methyldioctadecylammonium
 tetrakis(pentafluorophenyl)borate, triethylammonium,
 15 tetrakis(pentafluorophenyl)borate,
 tripropylammoniumtetrakis(pentafluorophenyl)borate, tri(n-
 butyl)ammonium tetrakis(pentafluorophenyl)borate, tri(sec-
 butyl)ammoniumtetrakis(pentafluorophenyl)borate, N,N-
 dimethylanilinium tetrakis(pentafluorophenyl)borate, N,N-
 20 diethylaniliniumtetrakis(pentafluorophenyl)borate, N,N-
 dimethyl(2,4,6-
 trimethylanilinium)tetakis(pentafluorophenyl)borate,
 trimethylammoniumtetrakis(2,3,4,6-tetrafluorophenyl)borate,
 triethylammonium tetrakis(2,3,4,6-tetrafluorophenyl)borate,
 25 tripropylammonium tetrakis(2,3,4,6-tetrafluorophenyl)borate,

tri(n-butyl) ammonium tetrakis(2,3,4,6-
, tetrafluorophenyl) borate, dimethyl(t-butyl) ammonium
tetrakis(2,3,4,6-tetrafluorophenyl) borate, N,N-
dimethylanilinium tetrakis(2,3,4,6-tetrafluorophenyl) borate,
5 N,N-diethylanilinium tetrakis(2,3,4,6-
tetrafluorophenyl) borate and N,N-dimethyl-(2,4,6-
trimethylanilinium) tetrakis-(2,3,4,6-
tetrafluorophenyl) borate; a borate-based compound of a
dialkyl ammonium salt type such as dioctadecylammonium
10 tetrakis(pentafluorophenyl) borate, ditetradecylammonium
tetrakis(pentafluorophenyl) borate and dicyclohexylammonium
tetrakis(pentafluorophenyl) borate; or a borate-based compound
of a trisubstituted phosphonium salt type such as
triphenylphosphonium tetrakis(pentafluorophenyl) borate,
15 methyldioctadecylphosphonium
tetrakis(pentafluorophenyl) borate and tri(2,6-,
dimethylphenyl) phosphonium tetrakis(pentafluorophenyl) borate,
without limitation.

[00140] By using such a co-catalyst, the molecular weight
20 distribution of the ethylene/alpha-olefin copolymer finally
prepared may become more uniform, and polymerization activity
may be improved.

[00141] The co-catalyst may be used in a suitable amount so
that the activation of the transition metal compounds of
25 Formula 1 and/or Formula 2 may be sufficiently achieved.

[00142] In the present invention, the transition metal compounds of Formula 1 and/or Formula 2 may be used in a supported type on a support.

5 **[00143]** In case where the transition metal compounds of Formula 1 and/or Formula 2 are supported by the support, the weight ratio of the transition metals and the support may be 1:10 to 1:1,000, more particularly, 1:10 to 1:500. If the support and the transition metal compounds are included in a
10 weight ratio in the above range, optimized type may be shown. In addition, if the co-catalyst is supported together by the support, the weight ratio of the co-catalyst and the support may be 1:1 to 1:100, more particularly, 1:1 to 1:50. If the co-catalyst and the support are included in the weight ratio,
15 catalyst activity may be improved, and the microstructure of a polymer prepared may be optimized.

[00144] Meanwhile, silica, alumina, magnesia or mixtures thereof may be used as the support, or these materials may be used after drying at a high temperature to remove moisture at
20 the surface and in a state including a hydroxyl group or siloxane group which has high reactivity at the surface. Also, the dried support at a high temperature may further include an oxide, a carbonate, a sulfate or a nitrate component such as Na_2O , K_2CO_3 , BaSO_4 and $\text{Mg}(\text{NO}_3)_2$.

25 **[00145]** The drying temperature of the support is preferably,

from 200 to 800°C, more preferably, from 300 to 600°C, most preferably, from 300 to 400°C. If the drying temperature of the support is less than 200°C, humidity is too high and moisture at the surface may react with the co-catalyst, and
5 if the temperature is greater than 800°C, the pores at the surface of the support may be combined to decrease the surface area, and a large amount of the hydroxyl groups at the surface may be removed to remain only siloxane groups to decrease reaction sites with the co-catalyst, undesirably.

10 **[00146]** In addition, the amount of the hydroxyl group at the surface of the support may preferably be 0.1 to 10 mmol/g, more preferably, 0.5 to 5 mmol/g. The amount of the hydroxyl group at the surface of the support may be controlled by the preparation method and conditions of the support, or drying
15 conditions, for example, temperature, time, vacuum or spray drying.

[00147] In addition, an organoaluminum compound may be further injected for removing moisture in a reactor during
20 polymerization reaction, and the polymerization reaction may be performed in the presence thereof. Particular examples of such organoaluminum compound may include trialkylaluminum, dialkylaluminum halide, alkyl aluminum dihalide, aluminum dialkyl hydride or alkyl aluminum sesqui halide, and more
25 particular examples may include $\text{Al}(\text{C}_2\text{H}_5)_3$, $\text{Al}(\text{C}_2\text{H}_5)_2\text{H}$, $\text{Al}(\text{C}_3\text{H}_7)_3$,

$\text{Al}(\text{C}_3\text{H}_7)_2\text{H}$, $\text{Al}(\text{i-C}_4\text{H}_9)_2\text{H}$, $\text{Al}(\text{C}_8\text{H}_{17})_3$, $\text{Al}(\text{C}_{12}\text{H}_{25})_3$, $\text{Al}(\text{C}_2\text{H}_5)(\text{C}_{12}\text{H}_{25})_2$,
 $\text{Al}(\text{i-C}_4\text{H}_9)(\text{C}_{12}\text{H}_{25})_2$, $\text{Al}(\text{i-C}_4\text{H}_9)_2\text{H}$, $\text{Al}(\text{i-C}_4\text{H}_9)_3$, $(\text{C}_2\text{H}_5)_2\text{AlCl}$, $(\text{i-C}_3\text{H}_9)_2\text{AlCl}$, $(\text{C}_2\text{H}_5)_3\text{Al}_2\text{Cl}_3$, etc. Such organoaluminum compound
may be continuously injected into a reactor, or may be
5 injected in a ratio of about 0.1 to 10 mol per 1 kg of a
reaction medium injected into the reactor for suitable
removal of moisture.

[00148] In addition, a polymerization pressure may be about 1
to about 100 Kgf/cm², preferably, about 1 to about 50 Kgf/cm²,
10 more preferably, about 5 to about 30 Kgf/cm².

[00149] Also, if the transition metal compound is used in a
supported type by a support, the transition metal compound
may be injected after being dissolved or diluted in an
aliphatic hydrocarbon solvent of 5 to 12 carbon atoms, for
15 example, pentane, hexane, heptane, nonane, decane, and
isomers thereof, an aromatic hydrocarbon solvent such as
toluene and benzene, or a hydrocarbon solvent substituted
with a chlorine atom such as dichloromethane and
chlorobenzene. The solvent used is preferably used after
20 treating with a small amount of alkyl aluminum to remove a
small amount of water or air, which acts as a catalyst poison,
and may be used by using a co-catalyst further.

[00150] The volume resistance of the ethylene/alpha-olefin
25 copolymer of the present invention may be $1.0 \times 10^{16} \Omega \cdot \text{cm}$ or

more, particularly, $1.1 \times 10^{16} \Omega \cdot \text{cm}$ or more, or $1.2 \times 10^{16} \Omega \cdot \text{cm}$. The volume resistance may be measured by processing the ethylene/alpha-olefin copolymer into a specimen under voltage conditions of 1000 V.

5 **[00151]** The ethylene/alpha-olefin copolymer of the present invention may be processed into a resin composition by including a crosslinking agent, a crosslinking auxiliary agent, a silane coupling agent, a light stabilizer, a UV absorbent, a thermal stabilizer, etc., and various additives
10 known in this corresponding field may be suitably additionally included according to the use of a resin component applied in addition to the components.

[00152] In addition, the ethylene/alpha-olefin copolymer may be utilized in various molded articles by molding by
15 extrusion, etc. Particularly, the ethylene/alpha-olefin copolymer may be used in various optoelectronic devices, for example, as an encapsulant for the encapsulation of a device in a solar cell, for example, may be used as an industrial material applied in a lamination process with heating, etc.,
20 without limitation.

[00153] Examples

[00154] Hereinafter, the present invention will be explained in more detail referring to embodiments. However, the
25 embodiments are provided only for illustration, and the scope

of the present invention is not limited thereto.

[00155] [Preparation of transition metal compound]

[00156] Preparation Example 1

5 **[00157]** (1) Preparation of ligand compound

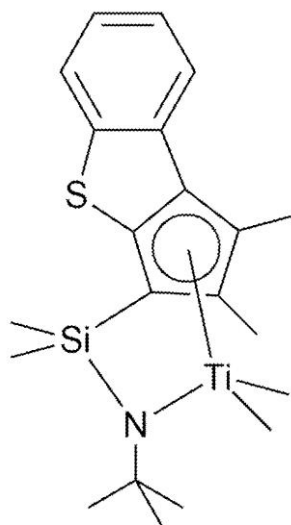
[00158] <Synthesis of N-tert-butyl-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophen-3-yl)-1,1-dimethylsilanamine>

[00159] To a 100 ml schlenk flask, 4.65 g (15.88 mmol) of chloro(1,2-dimethyl-6,7-dihydro-3H-benzo[b]cyclopenta[d]thiophene-3-yl)dimethylsilane was weighed and added, and 80 ml of THF was injected thereto. At room temperature, tBuNH₂ (4 eq, 6.68 ml) was injected thereto and reacted at room temperature for 3 days. After finishing the reaction, THF was removed, and the resultant reaction product was filtered with hexane. After drying solvents, 4.50 g (86%) of a yellow liquid was obtained.

[00160] ¹H-NMR (in CDCl₃, 500 MHz): 7.99 (d, 1H), 7.83 (d, 1H), 7.35 (dd, 1H), 7.24 (dd, 1H), 3.49 (s, 1H), 2.37 (s, 3H), 2.17 (s, 3H), 1.27 (s, 9H), 0.19 (s, 3H), -0.17 (s, 3H).

20 **[00161]** (2) Preparation of transition metal compound

[00162] [Formula 1-1]



[00163] To a 50 ml schlenk flask, the ligand compound (1.06 g, 3.22 mmol/1.0 eq) and 16.0 ml (0.2 M) of MTBE were put and stirred first. n-BuLi (2.64 ml, 6.60 mmol/2.05 eq, 2.5 M in THF) was added thereto at -40°C and reacted at room temperature overnight. After that, MeMgBr (2.68 ml, 8.05 mmol/2.5 eq, 3.0 M in diethyl ether) was slowly added thereto dropwisely at -40°C, and TiCl₄ (2.68 ml, 3.22 mmol/1.0 eq, 1.0 M in toluene) was put in order, followed by reacting at room temperature overnight. After that, the reaction mixture was passed through celite using hexane for filtration. After drying the solvents, 1.07 g (82%) of a brown solid was obtained.

[00164] ¹H-NMR (in CDCl₃, 500 MHz): 7.99 (d, 1H), 7.68 (d, 1H), 7.40 (dd, 1H), 7.30 (dd, 1H), 3.22 (s, 1H), 2.67 (s, 3H), 2.05 (s, 3H), 1.54 (s, 9H), 0.58 (s, 3H), 0.57 (s, 3H), 0.40 (s, 3H), -0.45 (s, 3H).

[00165] Preparation Example 2

[00166] (1) Preparation of ligand compound

[00167] <Synthesis of N-tert-butyl-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(2-ethylphenyl) (methyl)silaneamine>

[00168] (i) Preparation of chloro-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(2-ethylphenyl) (methyl)silane

[00169] To a 100 ml schlenk flask, 2 g (1 eq, 9.99 mmol) of 1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene and 50 ml of THF were put, and 4 ml (1 eq, 9.99 mmol, 2.5 M in hexane) of n-BuLi was added thereto dropwisely at -30°C, followed by stirring at room temperature overnight. A stirred Li-complex THF solution was cannulated into a schlenk flask containing 2.19 ml (1.0 eq, 9.99 mmol) of dichloro(2-ethylphenyl) (methyl)silane and 50 ml of THF at -78°C, followed by stirring at room temperature overnight. After stirring, drying in vacuum was carried out and extraction with 60 ml of hexane was carried out. After drying in vacuum again and washing with hexane, 3.83 g (99%, dr = 1:1) of an ivory solid was obtained.

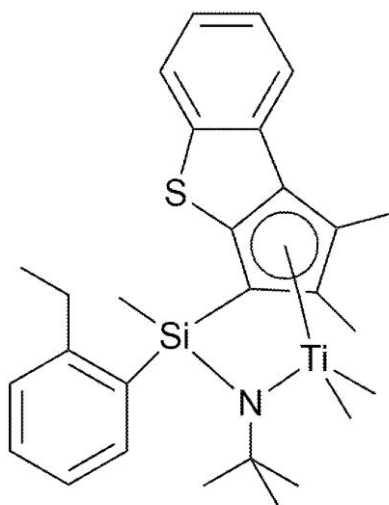
[00170] (ii) Preparation of N-tert-butyl-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(2-ethylphenyl) (methyl)silaneamine

[00171] To 100 ml round flask, 3.87 g (10.1 mmol) of chloro-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(2-ethylphenyl)(methyl)silane was weighed and added, and 40 ml of hexane was injected thereto. At room temperature, t-BuNH₂ (10 eq, 10.5 mL) was injected and reacted at room temperature for 2 days. After the reaction, hexane was removed, and filtering with hexane was carried out. After drying the solvents, 3.58 g (84.4%, dr = 1:0.8) of a yellow solid was obtained.

[00172] ¹H-NMR(CDCl₃, 500 MHz): δ 7.98(t, 2H), 7.71(d, 1H), 7.55(d, 1H), 7.52(d, 1H), 7.48(d, 1H), 7.30(t, 1H), 7.26-7.22(m, 3H), 7.19(dd, 2H), 7.12-7.06(m, 3H), 7.00(t, 1H), 3.08-2.84(m, 4H) 3.05-2.84(m, 2H), 2.28(s, 3H), 2.20(s, 3H), 2.08(s, 3H), 1.62(s, 3H), 1.26-1.22(m, 6H), 1.06(s, 9H), 0.99(s, 9H), 0.05(s, 3H), -0.02(s, 3H).

[00173] (2)Preparation of transition metal compound

[00174] [Formula 2-5]



[00175] To a 50 ml vial, the ligand compound (1.74 g, 4.14 mmol/1.0 eq) and 20.7 ml (0.2 M) of toluene were put and stirred. n-BuLi (3.48 ml, 8.7 mmol/2.1 eq, 2.5M in hexane) was added thereto at -40°C and stirred at room temperature

5 overnight. Then, MeMgBr (4.14 ml, 12.42 mmol/3.0 eq, 3.0 M in diethyl ether) was added thereto dropwisely at -40°C, and TiCl₄DME (1.1 g, 4.14 mmol/1.0 eq) was put in order, followed by stirring at room temperature overnight. After drying the solvents, the reaction mixture was filtered using hexane.

10 Then, DME (1.29 ml, 12.42 mmol/3.0 eq) was added to the filtrate and stirred at room temperature overnight. After drying the solvents, the resultant product was filtered using hexane to obtain 335 mg (16.3%, dr = 1:0.8) of a yellow solid.

[00176] ¹H NMR(CDCl₃, 500 MHz): δ 7.90(d, 1H), 7.85(d, 1H), 7.74(d, 1H), 7.71(d, 1H), 7.40(d, 1H), 7.37(d, 1H), 7.27(d, 1H), 7.23(t, 2H), 7.17(t, 2H), 7.13(t, 2H), 7.06(t, 1H), 7.01(t, 1H), 6.86(t, 1H), 2.97-2.91(m, 2H), 2.90-2.82(m, 2H), 2.33(s, 3H), 2.22(s, 3H), 1.96(s, 3H), 1.68(s, 9H), 1.66(s, 9H), 1.38(s, 3H), 1.32(t, 3H), 1.24(t, 3H), 1.07(s, 3H), 0.88(s, 3H), 0.85(s, 3H), 0.72(s, 3H), 0.19(s, 3H), 0.01(s, 3H).

[00177] Preparation Example 3

[00178] (1) Preparation of ligand compound

25 **[00179]** <Synthesis of N-tert-butyl-1-(1,2-dimethyl-3H-

benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(methyl) (2-methylphenyl)silaneamine>

[00180] (i) Preparation of chloro-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(methyl) (2-methylphenyl)silane

[00181] To a 250 ml schlenk flask, 2.0 g (1.0 eq, 9.985 mmol) of 1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene and 50 ml of THF were put, and 4.2 ml (1.05 eq, 10.484 mmol, 2.5 M in hexane) of n-BuLi was added thereto dropwisely at -30°C, followed by stirring at room temperature overnight. A stirred Li-complex THF solution was cannulated into a schlenk flask containing 2.46 g (1.2 eq, 11.982 mmol) of dichloro(o-tolylmethyl)silane and 30 ml of THF at -78°C, followed by stirring at room temperature overnight. After stirring, drying in vacuum was carried out, and extraction with 100 ml of hexane was carried out.

[00182] (ii) Preparation of N-tert-butyl-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(methyl) (2-methylphenyl)silaneamine

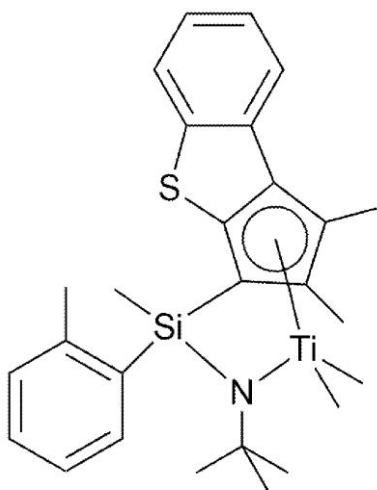
[00183] After stirring 4.0 g (1.0 eq, 10.0 mmol) of the extracted chloro-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(methyl) (2-methylphenyl)silane in 10 ml of hexane, 4.2 ml (4.0 eq, 40.0 mmol) of t-BuNH₂ was injected at room temperature, followed by stirring at room temperature overnight. After stirring,

drying in vacuum was carried out, and extraction with 150 ml of hexane was carried out. After drying the solvents, 4.26 g (99%, dr = 1:0.83) of a sticky liquid was obtained.

[00184] $^1\text{H-NMR}$ (CDCl_3 , 500 MHz): δ 7.95(t, 2H), 7.70(d, 1H), 7.52(d, 1H), 7.47-7.44(m, 2H), 7.24-7.02(m, 9H), 6.97(t, 1H), 3.59(s, 1H), 3.58(s, 1H), 2.50(s, 3H), 2.44(s, 3H), 2.25(s, 3H), 2.16(s, 3H), 2.06(s, 3H), 1.56(s, 3H), 1.02(s, 9H), 0.95(s, 9H), -0.03(s, 3H), -0.11(s, 3H).

[00185] (2) Preparation of transition metal compound

[00186] [Formula 2-3]



[00187] To a 250 ml round flask, the ligand compound (4.26 g, 10.501 mmol) was put in 53 ml (0.2 M) of MTBE and stirred. n-BuLi (8.6 ml, 21.52 mmol, 2.05 eq, 2.5M in hexane) was added thereto at -40°C and stirred at room temperature overnight.

[00188] Then, MeMgBr (8.8 ml, 26.25 mmol, 2.5 eq, 3.0 M in

diethyl ether) was slowly added thereto dropwisely at -40°C, and TiCl₄ (10.50 ml, 10.50 mmol) was put in order, followed by stirring at room temperature overnight. After that, the reaction mixture was filtered using hexane. DME (3.3 ml, 31.50 mmol) was added to the filtrate, and the resultant solution was filtered using hexane and concentrated to obtain 3.42 g (68%, dr = 1:0.68) of a yellow solid.

[00189] ¹H NMR(CDCl₃, 500 MHz): δ 7.83(d, 1H), 7.80(d, 1H), 7.74(d, 1H), 7.71(d, 1H), 7.68(d, 1H), 7.37(d, 1H), 7.31-6.90(m, 9H), 6.84(t, 1H), 2.54(s, 3H), 2.47(s, 3H), 2.31(s, 3H), 2.20(s, 3H), 1.65(s, 9H), 1.63(s, 9H), 1.34(s, 3H), 1.00(s, 3H), 0.98(s, 3H), 0.81(s, 3H), 0.79(s, 3H), 0.68(s, 3H), 0.14(s, 3H), -0.03(s, 3H).

[00190] Preparation Example 4

[00191] (1) Preparation of ligand compound

[00192] <Synthesis of N-tert-butyl-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(methyl)(phenyl)silaneamine>

[00193] (i) Preparation of chloro-1-(1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-(methyl)(phenyl)silane

[00194] To a 250 ml schlenk flask, 10 g (1.0 eq, 49.925 mmol) of 1,2-dimethyl-3H-benzo[b]cyclopenta[d]thiophene and 100 ml of THF were put, and 22 ml (1.1 eq, 54.918 mmol, 2.5 M in

hexane) of n-BuLi was added thereto dropwisely at -30°C, followed by stirring at room temperature for 3 hours. A stirred Li-complex THF solution was cannulated into a schlenk flask containing 8.1 ml (1.0 eq, 49.925 mmol) of
5 dichloro(methyl)(phenyl)silane and 70 ml of THF at -78°C, followed by stirring at room temperature overnight. After stirring, drying in vacuum was carried out, and extraction with 100 ml of hexane was carried out.

[00195] (ii) Preparation of N-tert-butyl-1-(1,2-dimethyl-3H-
10 benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-
(methyl)(phenyl)silaneamine

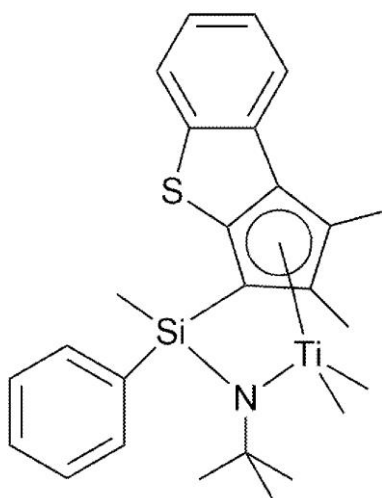
[00196] After injecting 42 ml (8 eq, 399.4 mmol) of t-BuNH₂ to 100 ml of the extracted chloro-1-(1,2-dimethyl-3H-
benzo[b]cyclopenta[d]thiophene-3-yl)-1,1-

15 (methyl)(phenyl)silane hexane solution, stirring was performed at room temperature overnight. After stirring, drying in vacuum was carried out, and extraction with 150 ml of hexane was carried out. After drying the solvents, 13.36 g (68%, dr = 1:1) of a yellow solid was obtained.

20 **[00197]** ¹H NMR(CDCl₃, 500 MHz): δ 7.93(t, 2H), 7.79(d, 1H), 7.71(d, 1H), 7.60(d, 2H), 7.48(d, 2H), 7.40~7.10(m, 10H, aromatic), 3.62(s, 1H), 3.60(s, 1H), 2.28(s, 6H), 2.09(s, 3H), 1.76(s, 3H), 1.12(s, 18H), 0.23(s, 3H), 0.13(s, 3H).

[00198] (2)Preparation of transition metal compound

25 **[00199]** [Formula 2-4]



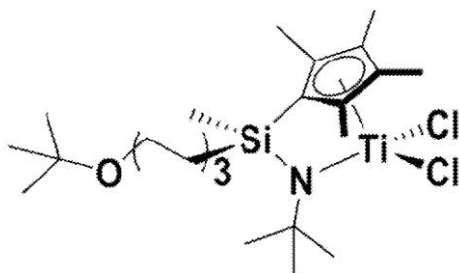
[00200] To a 100 ml schlenk flask, 4.93 g (12.575 mmol, 1.0 eq) of the ligand compound and 50 ml (0.2 M) of toluene were put, and 10.3 ml (22.779 mmol, 2.05 eq, 2.5M in hexane) of n-BuLi was added thereto dropwisely at -30°C, followed by stirring at room temperature overnight. After stirring, 12.6 ml (37.725 mmol, 3.0 eq, 3.0 M in diethyl ether) of MeMgBr was added thereto dropwisely, and 13.2 ml (13.204 mmol, 1.05 eq, 1.0 M in toluene) of TiCl₄ was put in order, followed by stirring at room temperature overnight. After stirring, the reaction product was dried in vacuum and extracted with 150 ml of hexane. The solvents were removed to 50 ml, and 4 ml (37.725 mmol, 3.0 eq) of DME was added dropwisely and stirred at room temperature overnight. After drying again in vacuum and extracting with 150 ml of hexane, 2.23 g (38%, dr = 1:0.5) of a brown solid was obtained.

[00201] ¹H NMR(CDCl₃, 500 MHz): δ 7.98(d, 1H), 7.94(d, 1H),

7.71 (t, 6H), 7.50~7.30 (10H), 2.66 (s, 3H), 2.61 (s, 3H), 2.15 (s, 3H), 1.62 (s, 9H), 1.56 (s, 9H), 1.53 (s, 3H), 0.93 (s, 3H), 0.31 (s, 3H), 0.58 (s, 3H), 0.51 (s, 3H), -0.26 (s, 3H), -0.39 (s, 3H).

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[00202] Comparative Preparation Example 1



[00203]

[00204] The compound above was synthesized according to a method described in PCT Publication WO 2016-186295 A1 and then, used.

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[00205] [Preparation of ethylene/alpha-olefin copolymer]

[00206] Example 1

[00207] While injecting a hexane solvent in 5.0 kg/h and 1-butene in 0.76 kg/h, a 1.5 L continuous process reactor was pre-heated to a temperature of 130°C. A triisobutylaluminum compound (0.045 mmol/min), a mixture (0.120 μmol/min) of the transition metal compounds obtained in Preparation Examples 1 and 2 in a molar ratio of 3:7, and a dimethylanilinium tetrakis(pentafluorophenyl)borate co-catalyst (0.144 μmol/min) were put in the reactor at the same time. Then,

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into the reactor, ethylene (0.87 kg/h) and a hydrogen gas (20 cc/min) were injected and copolymerization reaction was continuously carried out while maintaining a pressure of 89 bar and 130.1°C for 60 minutes or more to prepare a copolymer.

5 After drying for 12 hours or more in a vacuum oven, physical properties were measured.

[00208] Examples 2 to 10, and Comparative Examples 1 to 8

[00209] Ethylene/alpha-olefin copolymers were prepared by the same method as in Example 1 except for changing
10 polymerization conditions as shown in Table 1 below.

[00210] [Table 1]

	Catalyst type	Catalyst mixing ratio	Cat.	Co-cat.	Tibal	C2	1-C4	C6	Hydrogen	Temp.	Yield
			μmol/min		mmol/min	kg/h			cc/min	°C	g/min
Example 1	Preparation Example 1 + Preparation Example 2	3:7	0.120	0.144	0.045	0.87	0.76	5.0	20	130.1	10.8
Example 2	Preparation Example 1 + Preparation Example 3	3:7	0.120	0.144	0.058	0.87	0.92	5.0	22	130.9	10.8
Example 3	Preparation Example 1 + Preparation Example 3	3:7	0.150	0.180	0.030	0.87	1.00	5.0	15	141.6	10.3
Example 4	Preparation Example 1 + Preparation Example 3	3:7	0.170	0.204	0.030	0.87	1.05	5.0	13	145.0	11.9
Example 5	Preparation Example 1 + Preparation Example 4	5:5	0.110	0.220	0.045	0.87	0.80	5.0	8	139.0	13.3
Example 6	Preparation Example 1 + Preparation Example 4	4:6	0.135	0.162	0.045	0.87	0.94	5.0	18	136.0	10.0
Example 7	Preparation Example 1 + Preparation Example 4	3:7	0.110	0.220	0.045	0.87	0.85	5.0	12	136.1	12.2
Example 8	Preparation	3:7	0.151	0.144	0.035	0.87	0.82	5.0	34	131.7	11.1

	Example 1 + Preparation Example 4										
Example 9	Preparation Example 1 + Preparation Example 4	2:8	0.156	0.187	0.045	0.87	0.88	5.0	19	136.7	9.9
Example 10	Preparation Example 1 + Preparation Example 4	1:9	0.150	0.300	0.045	0.87	0.78	5.0	14	135.8	13.8
Comparative Example 1	Comparative Preparation Example 1	-	0.120	0.188	0.035	0.87	1.15	5.0	2	130.8	12.5
Comparative Example 2	Comparative Preparation Example 1 + Preparation Example 2	5:5	0.120	0.188	0.035	0.87	1.00	5.0	8	131.7	11.9
Comparative Example 3	Comparative Preparation Example 1 + Preparation Example 2	5:5	0.120	0.188	0.035	0.87	0.65	5.0	5	131.4	11.5
Comparative Example 4	Preparation Example 1	-	0.125	0.147	0.045	0.87	0.80	5.0	15	130.3	10.2
Comparative Example 5	Preparation Example 1	-	0.550	1.650	0.090	0.87	1.25	7.0	50	153.1	14.8
Comparative Example 6	Preparation Example 2	-	0.120	0.144	0.040	0.87	0.70	5.0	23	130.1	9.8
Comparative Example 7	Preparation Example 3	-	0.125	0.147	0.045	0.87	0.76	5.0	26	129.1	9.6
Comparative Example 8	Preparation Example 4	-	0.125	0.147	0.045	0.87	0.76	5.0	26	130.4	10.7

[00211] [Analysis of ethylene/alpha-olefin copolymer]

[00212] Experimental Example 1

[00213] With respect to the ethylene/alpha-olefin copolymers
5 prepared in the Examples and Comparative Examples, physical
properties were measured according to the methods below and
are shown in Table 2.

[00214] (1) Density (g/cm³)

[00215] Measurement was conducted according to ASTM D-792.

[00216] (2) Melt index ($MI_{2.16}$, dg/min)

[00217] Measurement was conducted according to ASTM D-1238 (condition E, 190°C, 2.16 kg load).

5 **[00218]** (3) Melt flow rate ratio ($MFRR$, $MI_{10}/MI_{2.16}$)

[00219] MI_{10} (condition E, 190°C, 10 kg load) and $MI_{2.16}$ (condition E, 190°C, 2.16 kg load) were measured according to ASTM D-1238 and $MI_{10}/MI_{2.16}$ was calculated.

10 **[00220]** (4) Melting temperature (T_m) and Crystallization temperature (T_c)

[00221] Melting temperature (T_m) and crystallization temperature (T_c) could be obtained using differential scanning calorimeter (DSC 6000), and particularly, under a nitrogen atmosphere using DSC, the temperature of a copolymer was elevated to 200°C, maintained for 5 minutes, decreased to 30°C, and elevated again, and a DSC curve was observed. In this case, the temperature elevating rate and decreasing rate were 10°C/min, respectively.

20 **[00222]** In the measured DSC curve, the melting temperature was the maximum point of an endothermic peak during the second temperature elevation, and the crystallization temperature was determined as the maximum point of an exothermal peak during decreasing the temperature.

25 **[00223]** (5) Weight average molecular weight (M_w) and molecular weight distribution (MWD)

[00224] A weight average molecular weight (Mw) and a number average molecular weight (Mn) of the copolymer prepared were measured under analysis conditions of gel permeation chromatography (GPC) below, and the molecular weight distribution (MWD) was calculated from the ratio of Mw/Mn.

[00225] - Column: Agilent Olexis

[00226] - Solvent: Trichlorobenzene

[00227] - Flow rate: 1.0 ml/min

[00228] - Specimen concentration: 1.0 mg/ml

10 **[00229]** - Injection amount: 200 μ l

[00230] - column temperature: 160°C

[00231] - Detector: Agilent High Temperature RI detector

[00232] - Standard: Polystyrene (calibrated by cubic function)

15 **[00233]** - Data processing: Cirrus

[00234] (6) Full width at half maximum (FWHM) of crystallization peak

[00235] CFC of PolymerChar Co. was used as a measurement apparatus. First, a copolymer solution was completely dissolved using o-dichlorobenzene as a solvent at 130°C for 60 minutes in an oven in a CFC analyzer, and then the solution was poured into a TREF column controlled to 130°C. Then, the column was cooled to 95°C and stabilized for 45 minutes. Then, the temperature of the TREF column was decreased to -20°C in a rate of 0.5°C/min and maintained at -

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20°C for 10 minutes. After that, an elution amount (mass%) was measured using an infrared spectrophotometer. Then, the temperature of the TREF column was elevated in a rate of 20°C/min to a preset temperature and at the reached

5 temperature, the temperature was maintained for a preset time (that is, about 27 minutes), and this work was repeated until the temperature of the TREF reached 130°C, and the amount (mass%) of an eluted fraction in each temperature range was measured. In addition, a molecular weight (Mw) was measured

10 by the same GPC measurement principle except for sending the eluted fraction at each temperature to a GPC column and using o-dichlorobenzene as a solvent. A FWHM value was calculated after fitting an elution amount graph according to temperature (dW/dT vs T) obtained through CFC on a program

15 (Origin) into a Gaussian curve shape.

[00236] [Table 2]

	Density	MI	MFRR	Tm	Tc	Mw	MWD	FWHM
	g/cm ³	dg/min	—	°C	°C	—	—	—
Example 1	0.878	5.8	6.2	64.1	47.0	80,000	1.98	18.7
Example 2	0.877	6.1	6.1	62.2	47.5	70,000	2.00	18.3
Example 3	0.875	6.2	6.3	60.6	45.7	68,000	2.00	17.9
Example 4	0.877	4.7	6.4	62.1	46.8	73,000	2.04	16.8
Example 5	0.877	5.2	6.7	62.0	45.1	76,000	2.03	18.6
Example 6	0.876	5.4	6.1	60.9	45.1	79,000	1.97	18.9
Example 7	0.877	4.8	6.5	62.4	45.1	80,000	1.97	20.2
Example 8	0.878	14.6	5.9	66.1	50.4	68,000	1.96	20.9
Example 9	0.878	4.7	6.1	64.5	46.8	83,000	1.98	19.8
Example 10	0.874	6.2	6.8	58.7	42.8	72,000	2.01	18.9
Comparative Example 1	0.878	5.0	7.3	62.8	47.7	83,000	2.23	13.7
Comparative Example 2	0.878	5.6	6.9	71.6	51.0	74,000	2.36	20.1
Comparative Example 3	0.902	5.1	7.2	105.0	80.1	75,000	2.27	19.0
Comparative Example 4	0.877	5.0	6.6	60.5	45.5	80,000	2.05	13.8

Comparative Example 5	0.878	500	-	74.9	59.1	23,000	2.11	22.1
Comparative Example 6	0.878	5.6	5.9	62.0	47.5	82,000	1.96	12.5
Comparative Example 7	0.878	5.0	5.8	61.2	46.3	83,000	1.94	13.1
Comparative Example 8	0.877	5.8	6.1	60.7	45.8	81,000	1.94	14.0

[00237] As summarized in Table 2, it could be confirmed that Examples 1 to 10 on the ethylene/alpha-olefin copolymers according to the present invention showed high FWHM values of 15 or more and narrow molecular weight distribution and satisfied the density and melt index in the ranges defined in the present invention. On the contrary, the ethylene/alpha-olefin copolymers of Comparative Examples 1, 4 and 6 to 8 showed small FWHM values of less than 15, and this indicates narrow crystallinity distribution and high free volume ratios of the copolymers.

[00238] In addition, Comparative Example 2 showed high molecular weight distribution, Comparative Example 3 showed a high density, and Comparative Example 5 showed a high melt index, and it was confirmed that all were deviated from the ranges defined in the present invention.

[00239] Experimental Example 2

[00240] 6 g of the ethylene/alpha-olefin copolymer was put in a 0.5 T square frame, the front and back sides were covered with 3T steel sheets, and this was injected into a high temperature press. After continuously treating at 190°C with 25 N/cm² (240 seconds), decompression/compression degassing

six times, and at 190°C with 151 N/cm² for 240 seconds, the temperature was decreased to 30°C by 15°C per minute. In this case, the pressure was kept to 151 N/cm². By keeping 30°C, 151 N/cm² for 300 seconds, the manufacture of a specimen was completed.

[00241] With respect to the specimen thus manufactured, a voltage of 1000 V was applied for 60 seconds using Agilent 4339B High-resistance meter (product of Agilent Technologies K.K.) under temperature conditions of 23±1°C and humidity conditions of 50%±3 to measure volume resistance, and the resultant values are summarized in Table 3 below.

[00242] [Table 3]

	Volume resistance ($\Omega \cdot \text{cm}$)	Light transmittance (%)
Example 1	1.4×10^{16}	91.6
Example 2	2.2×10^{16}	91.6
Example 3	1.8×10^{16}	91.3
Example 4	1.6×10^{16}	91.5
Example 5	2.3×10^{16}	91.3
Example 6	1.2×10^{16}	91.4
Example 7	2.1×10^{16}	91.5
Example 8	1.8×10^{16}	90.5
Example 9	2.3×10^{16}	91.3
Example 10	1.6×10^{16}	91.4
Comparative Example 1	5.0×10^{15}	90.1
Comparative Example 2	9.0×10^{15}	85.8
Comparative Example 3	9.5×10^{15}	84.1
Comparative Example 4	6.8×10^{15}	90.0
Comparative Example 5	6.8×10^{15}	87.6
Comparative Example 6	7.0×10^{15}	90.9
Comparative Example 7	7.3×10^{15}	91.5
Comparative Example 8	7.5×10^{15}	91.0

[00243] As summarized in Table 3, it was confirmed that, different from the ethylene/alpha-olefin copolymers of the Comparative Examples, the ethylene/alpha-olefin copolymers of the present invention achieved both high volume resistance

and high light transmittance.

[00244] Particularly, the ethylene/alpha-olefin copolymers of Comparative Examples 1, 4 and 6 to 8 showed the FWHM values of less than 15, and the volume resistance was largely degraded. Also, Comparative Examples 2, 3 and 5 of which molecular weight distribution, density and melt index were deviated from the ranges of the present invention, showed particularly low light transmittance.

[00245] As described above, the ethylene/alpha-olefin copolymers satisfying all of the density, molecular weight distribution, melt index and FWHM value defined in the present invention may achieve excellent degrees of volume resistance and light transmittance without using a separate additive.

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CLAIMS

1. An ethylene/alpha-olefin copolymer satisfying the following conditions (a) to (d):

5 (a) a density is 0.85 to 0.89 g/cc;

(b) a molecular weight distribution is 1.8 to 2.3;

(c) a melt index (MI, 190°C, 2.16 kg load conditions) is 1 to 100 dg/min; and

(d) a full width at half maximum (FWHM) of a
10 crystallization peak shown during measuring a crystallization temperature by cross-fractionation chromatography (CFC) is 15 or more.

2. The ethylene/alpha-olefin copolymer according to claim
15 1, wherein the melt index is 2 to 20 dg/min.

3. The ethylene/alpha-olefin copolymer according to claim 1, wherein the full width at half maximum of the crystallization peak is 16 to 50.

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4. The ethylene/alpha-olefin copolymer according to claim 1, wherein the copolymer has a melting temperature of 70°C or less.

25 5. The ethylene/alpha-olefin copolymer according to claim

1, wherein the copolymer has a weight average molecular weight (Mw) of 40,000 to 150,000 g/mol.

6. The ethylene/alpha-olefin copolymer according to claim 1, wherein the copolymer has a melt flow rate ratio (MFRR) of 8.0 or less, wherein MFRR is a ratio of a melt index (MI₁₀, 190°C, 10 kg load conditions) with respect to a melt index (MI_{2.16}, 190°C, 2.16 kg load conditions).

7. The ethylene/alpha-olefin copolymer according to claim 1, wherein the crystallization temperature is 70°C or less.

8. The ethylene/alpha-olefin copolymer according to claim 1, wherein an alpha-olefin of the copolymer comprises one or more selected from the group consisting of propylene, 1-butene, 1-pentene, 4-methyl-1-pentene, 1-hexene, 1-heptene, 1-octene, 1-decene, 1-undecene, 1-dodecene, 1-tetradecene, 1-hexadecene and 1-eicosene.

9. The ethylene/alpha-olefin copolymer according to claim 1, wherein an alpha-olefin of the copolymer is present in an amount of greater than 0 to 99 mol% with respect to the copolymer.