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(54) Title: FLAME-RETARDANT INSULATING MATERIALS COMPRISING POLYPROPYLENE WITH IMPROVED DISPERSION AND MECHANICAL PROPERTIES

(57) Abstract: Disclosed are a polypropylene-based flame-retardant insulating resin composition and an insulating cable equipped with an insulation layer formed using the same. The insulating resin composition comprises a polypropylene resin, and 50 to 200 parts by weight of an inorganic flame-retardant based on 100 parts by weight of the polypropylene resin. The insulating resin composition has the controlled polarity and hydrophilicity of the flame-retardant or the optimized particle distribution of the flame-retardant, and consequently uniform dispersion of the flame-retardant and maximum compatibility with the resin. Thus, the composition has the improved properties as an insulating material of an electric cable.



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Description

Title of Invention: FLAME-RETARDANT INSULATING MATERIALS COMPRISING POLYPROPYLENE WITH IMPROVED DISPERSION AND MECHANICAL PROPERTIES

Technical Field

- [1] The present invention relates to a polypropylene-based flame-retardant insulating resin composition and an insulating cable equipped with an insulation layer formed using the same. In particular, the present invention relates to a polypropylene-based insulating resin composition comprising a polypropylene resin and an inorganic flame-retardant that satisfies the predetermined electrical and mechanical properties, and an insulating cable using the same.

Background Art

- [2] Polypropylene (PP) has advantages of low cost, excellent processability, good mechanical strength and so on, and thus is widely used. Unfavorably, polypropylene is subject to stress whitening due to its low flexibility. Furthermore, polypropylene has poor flame retardancy. For this reason, polypropylene found limited application to coating layers for insulating cables that require flame retardancy. However, as environmental regulations on constituent materials of an electric cable become more restrict, polypropylene attracts attention as an insulating material of a cable. As mentioned above, polypropylene is an all-purpose material of low cost and good mechanical strength, and besides is capable of recycling, differently from polyethylenes. And, polypropylene is free of a halogen component.
- [3] To make up for poor flame retardancy of polypropylene, a halogen-free flame-retardant is added. As the halogen-free flame-retardant, a polypropylene-based resin, a metal hydroxide flame-retardant such as magnesium hydroxide or aluminium hydroxide is generally used. A conventional flame-retardant thermoplastic resin is disclosed in Korean Patent Publication No. 2001-0001126 related to a low-smoke and low-toxicity flame-retardant resin composition, in which magnesium hydroxide coated with saturated fat acid or fatty acid ester is added to a base resin free of a halogen component. Meanwhile, Korean Patent Publication No. 2005-0043136 discloses a high-temperature resistant coating material composition of an insulating cable, in which an aluminium hydroxide flame-retardant is added to a water-crosslinked polyolefin.
- [4] The conventional flame-retardant resin compositions use a large amount of metal hydroxide flame-retardant of a single component such as uncoated magnesium hydroxide or aluminium hydroxide, or magnesium hydroxide or aluminium hydroxide

surface-coated with saturated fatty acid or the like, so as to improve flame retardancy. However, a large amount of metal hydroxide flame-retardant deteriorates the mechanical properties of the polypropylene-based insulating resin composition, such as elongation, flexibility and so on. Consequently, as the processability and tensile strength of an electric cable reduces, bend distortion may cause stress whitening. On the contrary, a small amount of metal hydroxide flame-retardant results in unsatisfactory flame retardancy.

- [5] To ensure harmony of the mechanical properties of the whole polypropylene-based insulating resin composition with a sufficient amount of a metal hydroxide flame-retardant for flame retardancy, it is important to uniformly disperse the metal hydroxide flame-retardant in the polypropylene resin. If the metal hydroxide particles are not uniformly dispersed in the polypropylene resinous network, but agglomerate with each other, the polypropylene-based insulating resin composition suffers from deterioration in mechanical properties since parts are burdened with excess and insufficient flame-retardants. However, because the metal hydroxide is an ionic salt and has a low compatibility and the non-polar polypropylene resin, there are limitations in uniformly dispersing the metal hydroxide in the polypropylene resin.
- [6] Accordingly, the related industry has steadily attempted to solve the problems of the conventional polypropylene-based insulating resin composition and insulating cable using the same, and this invention was devised under this technical background.

Disclosure of Invention

Technical Problem

- [7] Therefore, it is an object of the present invention to solve the problems, i.e., deterioration in mechanical properties that may occur when a large amount of a halogen-free inorganic flame-retardant is used, and unsatisfactory flame retardancy that may occur when a small amount of a halogen-free inorganic flame-retardant is used, and to obtain an insulating resin composition with properties pursued by the present invention by uniformly dispersing a proper amount of an inorganic flame-retardant in a polypropylene resin.

Solution to Problem

- [8] To achieve the object, the present invention provides a polypropylene-based insulating resin composition comprising a polypropylene resin, and 50 to 200 parts by weight of an inorganic flame-retardant based on 100 parts by weight of the polypropylene resin, and an insulating cable equipped with an insulation layer or sheath layer formed using the polypropylene-based insulating resin composition.
- [9] According to an aspect of the present invention, the inorganic flame-retardant may include at least two types of inorganic flame-retardants. At this time, at least two types

of inorganic flame-retardants form a composite flame-retardant containing at least one pair of inorganic flame-retardants, of which the difference in surface electrical conductivity is 100 $\mu\text{S}/\text{cm}$ or more. Alternatively, the inorganic flame-retardant may be a single component flame-retardant having an electrical conductivity of 100 to 400 $\mu\text{S}/\text{cm}$. The polypropylene-based insulating resin composition comprising the composite flame-retardant or the single component flame-retardant has a contact angle with water of 50 to 150°, and an insulation resistance of 1×10^{-14} to $1 \times 10^{-17} \Omega \cdot \text{cm}$.

[10] According to another aspect of the present invention, the inorganic flame-retardant has an average particle diameter of 0.5 to 5 μm . At this time, the insulating resin composition has an abrasion resistance of 0.001 to 0.2 mm according to a scrape test. Here, the scrape test is performed using a specimen made from the insulating resin composition, said scrape test comprising moving back and forth in the surface plane of said specimen a needle having a diameter of 0.45 ± 0.01 mm with a load of 1,500 g applied vertically against said surface, and determining the abraded depth of the surface of the specimen as abrasion resistance.

[11] The inorganic flame-retardant usable in the polypropylene-based insulating resin composition is, for example, magnesium oxide, magnesium hydroxide, aluminium hydroxide, calcium hydroxide and/or hydromagnesite ($\text{Mg}_5(\text{CO}_3)_4(\text{OH})_2$). And, the inorganic flame-retardant is uncoated or surface-coated with a hydrophobic material. The hydrophobic material includes, for example, stearic acid, oleic acid, fatty acid, amino silane and vinyl silane.

[12] According to an aspect of the present invention, the polypropylene-based insulating resin composition may further comprise 1 to 80 parts by weight of an adjuvant resin. The adjuvant resin is, for example, a rubber and/or a polar modified resin. The rubber may include various elastomers such as an ethylene-alpha olefin copolymer, a propylene-alpha olefin copolymer and so on. The polar modified resin is polypropylene or thermoplastic polyolefin elastomer, grafted with at least one polar material selected from the group consisting of maleic anhydride, fatty acid, amino silane and vinyl silane.

Advantageous Effects of Invention

[13] The polypropylene-based insulating resin composition of the present invention and the insulating cable using the same exhibit sufficient flame retardancy, and have excellent workability and storage stability due to harmony of the mechanical properties such as abrasion resistance, flexibility, elongation and so on.

Best Mode for Carrying out the Invention

[14] Hereinafter, the present invention will be described in detail. The present invention provides a polypropylene-based flame-retardant insulating resin composition, in which

a flame-retardant is uniformly dispersed in a polypropylene resin without agglomeration, to ensure harmony of the mechanical properties. The present invention also provides an insulating cable equipped with an insulation layer or sheath layer formed using the composition.

- [15] The polypropylene-based insulating resin composition of the present invention comprises a polypropylene resin, and 50 to 200 parts by weight of an inorganic flame-retardant based on 100 parts by weight of the polypropylene resin. To achieve the object of the present invention, the insulating resin composition has uniform dispersion of the inorganic flame-retardant in the polypropylene resin by properly controlling hydrophilicity and electrical conductivity of the inorganic flame-retardant and insulation resistance of the whole composition or by restricting particle properties of the inorganic flame-retardant and abrasion resistance of the composition to a specific level.
- [16] In the present invention, the "polypropylene resin" is a homopolymer of propylene or a random or block copolymer of propylene and an olefin monomer such ethylene or the like. For example, the copolymer may be created by polymerizing 70 weight% or more of a propylene monomer and other monomer, however the present invention is not limited to a specific ratio. The polypropylene resin may include various types of polypropylene-based resins, but to reduce or eliminate stress whitening, a polypropylene random copolymer is preferred. And, the "polypropylene resin" of the present invention may be mixtures of the exemplary polymers.
- [17] A suitable polypropylene resin for the insulating resin composition of the present invention is not limited to a specific type, if it satisfies its definition and the industrial specifications applied to the end use of an insulating cable. Generally, a polypropylene resin satisfying such conditions has a melt flow index of about 0.2 to 10 g/10 minutes, a density of about 0.85 to 0.95 g/cm³, and a weight average molecular mass of about 150,000 to 600,000. A polypropylene resin having such numerical values is suitable as a base resin of the composition according to the present invention.
- [18] According to an aspect of the present invention, for the purpose of controlling the dispersion of the inorganic flame-retardant based on metal hydroxide, metal oxide and so on, a plurality of inorganic flame-retardants (hereinafter referred to as a "composite flame-retardant" including a high polarity flame-retardant and a low polarity flame-retardant is employed. Alternatively, a single component of flame retardant (hereinafter referred to as the "single component flame-retardant" may be used, in which the single component flame-retardant has its hydrophilicity adjusted to match that of the polypropylene resin by coating its surface with a proper hydrophobic material. Here, the flame-retardant may be uncoated or surface-coated with a hydrophobic material. The polarity and hydrophilicity of the inorganic flame-retardant may be evaluated by measuring the electrical conductivity of the surface of the

inorganic flame-retardant.

- [19] The composite flame-retardant, wherein two components having a large difference in surface electrical conductivity are used, enables strong interactions between the low polarity flame-retardant component and the non-polar polypropylene resin as well as between the highly polar flame-retardant component and the polar modified resin. This leads to an increased compatibility between the flame-retardant and the resinous network, resulting in an efficient dispersion of the flame-retardant. Thus, a smaller amount of flame-retardant can be used and dispersed more uniformly, compared with the conventional insulating resin composition using a polar metal hydroxide flame-retardant only. Moreover, even with a large quantity of flame-retardants, the inventive composition suffers less from deterioration in physical properties since no part is burdened with excess or insufficient flame-retardants. When compared based on an identical amount of flame-retardant, the composition of the present invention has more uniform dispersion of the flame-retardant, and consequently better flame retardancy than the conventional composition. The same principle applies to a single component flame-retardant, in which a difference in polarity between the polypropylene resin and the flame-retardant is reduced by surface-coating the flame-retardant with a hydrophobic material.
- [20] The polypropylene-based insulating resin composition comprising the composite flame-retardant uses at least two types of inorganic flame-retardants, with the provision that at least one pair of inorganic flame-retardants, of which the difference in surface electrical conductivity is 100 $\mu\text{S}/\text{cm}$ or more. For example, uncoated magnesium hydroxide or aluminium hydroxide, widely used as a metal hydroxide flame-retardant, has an electrical conductivity of 350 $\mu\text{S}/\text{cm}$ or less. However, if magnesium hydroxide or aluminium hydroxide is surface-coated with a hydrophobic polymer, its electrical conductivity is generally 150 to 450 $\mu\text{S}/\text{cm}$, though variable depending on the coating polymer used. If surface-coated magnesium hydroxide or the like is combined with uncoated magnesium hydroxide or the like, a mixed metal hydroxide flame-retardant, of which difference in surface electrical conductivity is 100 $\mu\text{S}/\text{cm}$ or more, can be obtained. Other metal hydroxides may be used in a similar fashion to obtain the composite flame-retardant.
- [21] If the difference in surface electrical conductivity of the composite flame-retardant is less than 100 $\mu\text{S}/\text{cm}$, secondary bonding is reduced between the composite flame-retardant and the resinous network including the polypropylene resin and the modified resin, thereby deteriorating the mechanical properties of the composition. Because the uncoated metal hydroxide is basically polar, there is no need to set a maximum limit of the difference in surface electrical conductivity to practice the present invention. Any combination of two or more inorganic flame-retardants with the difference in electrical

conductivity of 100 $\mu\text{S}/\text{cm}$ or more may be employed. Meanwhile, in consideration of economical efficiency, availability of practical materials and so on, the maximum limit of the difference in surface electrical conductivity is practically about 300 $\mu\text{S}/\text{cm}$.

- [22] According to an aspect of the present invention, the composite flame-retardant includes 1 to 40 weight% of uncoated magnesium hydroxide having an electrical conductivity of 350 $\mu\text{S}/\text{cm}$, and 60 to 99 weight% of surface-coated magnesium hydroxide having an electrical conductivity of 100 to 500 $\mu\text{S}/\text{cm}$. The 100 to 500 $\mu\text{S}/\text{cm}$ electrical conductivity of the surface-coated magnesium hydroxide may be attained by physically and chemically surface-coating magnesium hydroxide with vinyl silane, amino silane, stearic acid or other polymers capable of surface-coating.
- [23] The single component flame-retardant, of which electrical conductivity is close to that of the polypropylene resin through surface-coating with a hydrophobic material, achieves an electrical conductivity of 100 to 400 $\mu\text{S}/\text{cm}$. When the electrical conductivity of the single component flame-retardant is in this range, the flame-retardant has an increase in thermodynamic affinity with the polypropylene resin of the base resin and consequently an increase in compatibility with the polypropylene resin, so that the flame-retardant is uniformly dispersed in the resin. This improves the mechanical properties of end-use products and consequently makes it advantageous to manufacture high-performance products. If the electrical conductivity of the single component flame-retardant is less than 100 $\mu\text{S}/\text{cm}$, the attractive forces between materials coated on the surface of the flame-retardant cause agglomeration of the flame-retardant, which makes uniform dispersion of the flame-retardant in the resin difficult. If the electrical conductivity of the single component flame-retardant is more than 400 $\mu\text{S}/\text{cm}$, a large difference in polarity between the flame-retardant and the polypropylene resin makes uniform dispersion of the flame-retardant in the resin difficult.
- [24] And, the insulating resin composition comprising the composite flame-retardant or single component flame-retardant has an insulation resistance of 1×10^{-14} to 1×10^{-17} $\Omega \cdot \text{cm}$ and a contact angle with water of 50 to 150°. The inventors found that the above-mentioned ranges of insulation resistance and contact angle with water of a polypropylene-based insulating resin composition guarantee a proper dispersion of a flame-retardant and manufacture of an insulating cable with excellent mechanical properties. In other words, the insulation resistance and contact angle of the insulating resin composition are proxies for indicating uniform dispersion of a flame-retardant without the need of measuring the mechanical properties of the whole composition.
- [25] The insulation resistance of the polypropylene-based insulating resin composition is greatly affected by the surface electrical conductivity of the flame-retardant. The insulation resistance of 1×10^{-14} to 1×10^{-17} $\Omega \cdot \text{cm}$ implies uniform dispersion of the flame-

retardant and consequently excellent mechanical properties. The insulation resistance larger than $1 \times 10^{-14} \Omega \cdot \text{cm}$ implies agglomeration of the flame-retardant and uneven dispersion. The insulation resistance smaller than $1 \times 10^{-17} \Omega \cdot \text{cm}$ implies that the insulating resin composition lacks insulating properties required as an insulation layer of an electric cable.

- [26] The contact angle with water of the propylene-based insulating resin composition is evaluated in such a way that a specimen of $100 \text{ mm} \times 100 \text{ mm} \times 1 \text{ mm}$ is formed by compression molding, a drop of water is free-fallen onto the specimen from the vertical height of 20 mm above the specimen, and an angle between the specimen and a waterdrop formed on the surface of the specimen is measured. This experiment is repeated at least five times, and an average of the measured angles is used as a contact angle. The contact angle between the surface of the insulating resin composition and water is an index of hydrophobicity and polarity of the surface of the specimen, and relies on how uniformly the flame-retardant is dispersed in the resin. The contact angle less than 50° indicates a high hydrophobicity, which means a hydrophilic flame-retardant hardly exists on the surface of the composition. The contact angle more than 150° indicates that an excessive amount of a flame-retardant exists at a corresponding location.
- [27] According to another aspect, the present invention provides an insulating resin composition comprising 50 to 200 parts by weight of an inorganic flame-retardant based on 100 parts by weight of the polypropylene resin, wherein the inorganic flame-retardant has an average particle diameter of 0.5 to 5 μm , and the whole insulating resin composition has an abrasion resistance of 0.001 to 0.2 mm.
- [28] The average particle diameter of the inorganic flame-retardant is an important control factor to uniformly disperse the flame-retardant in the polypropylene resin. If the average particle diameter is less than 0.5 μm , the flame-retardant particles agglomerate with each other and are not uniformly dispersed in the resin. As a result, an area of contact interface between the flame-retardant and the resin decreases and flame retardancy and mechanical properties of the composition deteriorate. If the average particle diameter is more than 5 μm , an area of contact interface between the flame-retardant and the resin decreases and flame retardancy and mechanical properties of the composition deteriorate. According to an aspect of the present invention, the insulating resin composition comprises a composite flame-retardant, as an inorganic flame-retardant, including 1 to 40 weight% of uncoated magnesium hydroxide having a particle size of 1 to 3 μm and 60 to 99 weight% of an inorganic flame-retardant coated with a hydrophobic material, having a particle size of 2 to 3 μm , to ensure harmony of polarity and particle size.
- [29] The abrasion resistance of the insulating resin composition may be determined by a

scrape test. The scrape test is performed using a specimen made from the insulating resin composition, said scrape test comprising moving back and forth in the surface plane of said specimen a needle having a diameter of 0.45 ± 0.01 mm over a distance of 10 mm with a load of 900 g applied vertically against said surface, and determining as the abraded depth of the surface of the specimen as abrasion resistance. If the abrasion resistance of the whole resin composition is 0.001 to 0.2 mm, the composition has a high molecular mass and consequently excellent basic properties, and a high melt strength and consequently excellent processability with the flame-retardant. If the abrasion resistance of the composition is more than 0.2 mm (i.e., the abraded depth is greater than 0.2 mm), flowability increases and compatibility of the composition deteriorates when melting. And, if the abrasion resistance of the composition is less than 0.001 mm (i.e., the abraded depth is smaller than 0.001 mm), the composition becomes brittle and less flexible, and thus is not suitable as a material for a cable.

[30] According to an aspect of the present invention, the insulating resin composition may further comprise an adjuvant resin to improve flexibility of the composition and prevent stress whitening, thereby improving the mechanical properties of the composition. The adjuvant resin may be included at an amount of 1 to 80 parts by weight based on 100 parts by weight of the polypropylene resin. If the adjuvant resin is included more than 80 parts by weight, further improvement in performance is not expected. If the adjuvant resin is included less than 1 part by weight, improvement in mechanical properties is trivial.

[31] In the present invention, the adjuvant resin may be a rubber, a polar modified resin or mixtures thereof. The rubber follows the most broad definition given generally in the art, and is not limited to a specific type if it is an elastomer. For example, the rubber usable in the present invention includes low density polyethylene (LDPE), linear low density polyethylene (LLDPE), ethylene-alpha olefin copolymer, propylene-alpha olefin copolymer, ethylene-vinyl acetate (EVA) copolymer, ethylene-methyl acrylate (EMA) copolymer, ethylene-ethylacrylate (EEA), styrene-butadiene-styrene (SBS) rubber, styrene-ethylene-butadiene-styrene (SEBS) copolymer, ethylene-propylene-diene monomer (EPDM) rubber, ethylene glycol dimethacrylate (EGDM) rubber, ethylene-butylacrylate (EBA) copolymer, polyolefin elastomer (POE) and so on, however the present invention is not limited in this regard. The ethylene-alpha olefin or propylene-alpha olefin copolymer includes ethylene-butene, ethylene-octene, ethylene-propylene, propylene-butene copolymers and so on. The propylene-alpha olefin copolymer is preferred due to good compatibility with the polypropylene resin component.

[32] Meanwhile, the polar modified resin is a polymer grafted with a polar material such as maleic anhydride, anhydrous maleic acid, silane, stearic acid, oleic acid, fatty acid

and so on, to introduce a polar functional group to polypropylene and/or thermoplastic polyolefin elastomer. Among the exemplary polar materials, maleic anhydride is preferred. The graft modification of a polymer resin with maleic anhydride is well known in the art, and its detailed description is herein omitted. It is preferable to use 0.3 to 2.0 weight% of maleic anhydride based on weight of a polymer to be modified. It is of help to use, as polyolefin to be grafted with a polar molecule, the same polypropylene-based elastomer of the base resin in consideration of compatibility with the base resin component so as to ensure excellent mechanical properties.

- [33] In the insulating resin composition of the present invention, preferably the inorganic flame-retardant may be selected from the group consisting of magnesium oxide, magnesium hydroxide, aluminium hydroxide, calcium hydroxide and hydromagnesite ($\text{Mg}_5(\text{CO}_3)_4(\text{OH})_2$). The metal hydroxide flame-retardant may be uncoated or surface-coated with a hydrophobic material to control hydrophilicity, polarity and compatibility with the polypropylene resin. For example, the hydrophobic material used to surface coat the inorganic flame-retardant may include stearic acid, oleic acid, fatty acid, amino silane and vinyl silane. For surface coating, the inorganic flame-retardant may be treated with a surfactant or induced to bond with a hydrophobic material by physical bondability. The metal hydroxide flame-retardant surface-coated with the hydrophobic material may be, for example, MagnifinTM magnesium hydroxide flame-retardant from Albemarle in Germany.
- [34] In the present invention, preferably the inorganic flame-retardant is included at an amount of 50 to 200 parts by weight based on 100 parts by weight of the polypropylene resin. When the content of the inorganic flame-retardant is within the range, sufficient flame retardancy exhibits and the mechanical properties are not deteriorated. If the content of the inorganic flame-retardant is less than 50 parts by weight, it is difficult to exhibit flame retardancy of a proper level for the industrial specifications. If the content of the inorganic flame-retardant is more than 200 parts by weight, flame-retardant particles agglomerate and processability reduces.
- [35] Meanwhile, the insulating resin composition of the present invention may further comprise a secondary flame-retardant to improve flame retardancy, if necessary. The secondary flame-retardant may include talc, melamine cyanurate (MC), red phosphorus, magnesium oxide (MgO), zinc borate, antimony trioxide and so on. At this time, preferably 1 to 20 parts by weight of the secondary flame-retardant is included based on 100 parts by weight of the polypropylene resin. If the content of the secondary flame-retardant is more than 20 parts by weight, the mechanical properties deteriorate and cost increases.
- [36] And, the polypropylene-based insulating resin composition of the present invention may further comprise an additive such as a lubricant, an antioxidant, a processing aid,

and so on.

- [37] According to another aspect, the present invention provides an insulating cable comprising a conductor, and an insulation layer or sheath layer surrounding the conductor and formed from the polypropylene-based insulating resin composition of the present invention. The conductor of the insulating cable may include copper, silver and so on. The thickness of the conductor may be properly controlled according to necessity. The insulation layer or sheath layer is made from the polypropylene-based insulating resin composition of the present invention. The insulation layer or sheath layer is formed on the surface of the conductor by mix-milling the polypropylene-based insulating resin composition into pellets and extruding the pellets using an extruder. Preferably, the insulation layer or sheath layer surrounds the conductor with a thickness of 0.1 to 0.5 mm.

Mode for the Invention

- [38] Hereinafter, the present invention will be described in detail through examples and exemplary production method. Prior to the description, it should be understood that the terms used in the specification and appended claims should not be construed as limited to general and dictionary meanings, but interpreted based on the meanings and concepts corresponding to technical aspects of the present invention on the basis of the principle that the inventor is allowed to define terms appropriately for the best explanation.
- [39] Polypropylene-based insulating resin compositions according to examples of the present invention and conventional compositions according to comparative examples were prepared. Their performances were compared as mentioned below. Methods for preparing a composition and manufacturing an insulating cable equipped with an insulation layer formed using the composition are well known in the art, and its description is herein omitted. The elements and contents of the compositions according to examples are shown in Table 1, and the elements and contents of the compositions according to comparative examples are shown in Table 2. In Tables 1 and 2, the unit of numerical values is parts by weight.
- [40] Table 1

[Table 1]

[Table]

Classification	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8
Base resin	100	60	60	60	60	60	60	60
Adjuvant resin	-	40	40	40	40	40	40	40
Flame-retardant a	-	20	30	40	-	-	-	-
Flame-retardant b	-	-	-	-	-	-	-	20
Flame-retardant c	-	80	-	-	60	-	20	-
Flame-retardant d	-	-	70	-	-	-	-	-
Flame-retardant e	100	-	-	60	-	80	80	80
Flame-retardant f	-	-	-	-	40	20	-	-
Additive	5	5	5	5	5	5	5	5

[41] [Note] Elements of composition

[42] - Base resin: Polypropylene resin, R274J (Melt flow index: 1.9 g/10 minutes, Density: 0.900 g/cm³) propylene-ethylene random copolymer (Propylene monomer:Ethylene monomer=94 mol%:6 mol%) from GS Caltex in South Korea

[43] - Adjuvant resin: Ethylene-octene copolymer (octane monomer: 39 weight%), Engage 8150 (Melt flow index: 0.5 g/10 minutes) from Elastomer in U.S.A.

[44] - Flame-retardant a: Uncoated magnesium hydroxide (Electrical conductivity: 350

- $\mu\text{S/cm}$, Particle diameter: 1 μm)
- [45] - Flame-retardant b: Magnesium hydroxide surface-coated with vinyl silane
(Electrical conductivity: 350 $\mu\text{S/cm}$, Particle diameter: 4.5 μm)
- [46] - Flame-retardant c: Magnesium hydroxide surface-coated with stearic acid
(Electrical conductivity: 250 $\mu\text{S/cm}$, Particle diameter: 1.4 μm)
- [47] - Flame-retardant d: Magnesium hydroxide surface-coated with oleic acid (Electrical conductivity: 200 $\mu\text{S/cm}$, Particle diameter: 3 μm)
- [48] - Flame-retardant e: Magnesium hydroxide surface-coated with H5MV from Al-bermarle in Germany (Electrical conductivity: 150 $\mu\text{S/cm}$, Particle diameter: 2 μm)
- [49] - Flame-retardant f: Magnesium hydroxide surface-coated with amino silane
(Electrical conductivity: 400 $\mu\text{S/cm}$, Particle diameter: 3 μm)
- [50] - Additive: Irganox 1010 phenol-based antioxidant from Ciba in Switzerland,
Dispersant and Lubricant
- [51] Table 2

[Table 2]

[Table]

Classification	Comparative example 1	Comparative example 2	Comparative example 3	Comparative example 4	Comparative example 5	Comparative example 6	Comparative example 7	Comparative example 8
Base resin	100	60	60	60	60	60	60	60
Adjuvant resin		40	40	40	40	40	40	40
Flame-retardant a	-	-	-	-	-	-	-	60
Flame-retardant b	-	-	-	-	60	-	-	-
Flame-retardant c	-	-	-	-	-	-	30	-
Flame-retardant d	-	-	-	-	-	30	70	-
Flame-retardant e	-	-	-	80		70	-	-
Flame-retardant f	-	-	-	-	40		-	40
Flame-retardant g	100	100						
Flame-retardant h			100	20				
Additive	5	5	5	5	5	5	5	5

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- [52] [Note] Elements of composition
- [53] - Flame-retardants a to f are equal to those of Table 1
- [54] - Additional element, Flame-retardant g: Magnesium hydroxide surface-coated with amino silane (Electrical conductivity: 550 $\mu\text{S}/\text{cm}$, Particle diameter: 3 μm)
- [55] - Additional element, Flame-retardant h: Magnesium hydroxide surface-coated with polymer (Electrical conductivity: 80 $\mu\text{S}/\text{cm}$, Particle diameter: 4 μm)
- [56] Meanwhile, the compositions according examples and comparative examples were evaluated in aspects of contact angle with water, insulation resistance and abrasion resistance. The preferable insulation resistance is 1×10^{-14} to $1 \times 10^{-17} \Omega \cdot \text{cm}$, the preferable contact angle 50° to 150° , preferable abrasion resistance 0.001 to 0.2 mm, and preferable average diameter of flame-retardant particles 0.5 to 5 μm . However, the insulating resin composition of the present invention does not necessarily need to satisfy all of these conditions. And, cable specimens were manufactured using the compositions of examples and comparative examples, and evaluated in aspects of tensile strength, elongation, stress whitening and abrasion resistance.
- [57] The tensile strength was determined as the strength at break when a specimen was pulled by a universal testing machine (UTM) at a regular rate of 50 mm/min. The elongation was determined as how much a specimen was lengthened when the specimen was pulled under said conditions. Stress whitening was observed by naked eyes when a specimen was bent at an angle of 180° , and evaluated as none, slight whitening, or severe whitening, according to discoloration and cracks. The abrasion resistance was determined as the abraded depth of surface of a specimen made from the composition when moving back and forth in the surface plane of said specimen a needle having a diameter of 0.45 ± 0.01 mm over a distance of 10 mm with a load of 1,500 g applied vertically against said surface.
- [58] The ensile strength of 10 MPa or more, elongation of 150% or more, and no whitening or slight whitening are suitable as properties of the cable.
- [59] The measurement results are shown in Table 3.
- [60] Table 3

[Table 3]

[Table]

Classification	Tensile strength (MPa)	Elongation (%)	Insulation resistance ($\Omega \cdot \text{cm}$)	Contact angle	Stress whitening	Abrasion resistance (mm)
Example 1	14	250	8×10^{-16}	125°	Slight whitening	0.037
Example 2	22	450	3×10^{-16}	111°	None	0.011
Example 3	21	470	2×10^{-16}	107°	None	0.012
Example 4	11	170	3×10^{-15}	96°	Slight whitening	0.048
Example 5	17	360	2×10^{-15}	142°	Slight whitening	0.021
Example 6	28	680	7×10^{-16}	64°	None	0.001
Example 7	23	470	4×10^{-15}	72°	None	0.009
Example 8	26	640	5×10^{-15}	83°	None	0.025
Comparative example 1	5.8	102	6×10^{-13}	172°	Severe whitening	0.107
Comparative example 2	6.2	108	9×10^{-13}	158°	Severe whitening	0.104
Comparative example 3	6.8	115	3×10^{-17}	32°	Severe whitening	0.100
Comparative example 4	8	140	9×10^{-16}	53°	Severe whitening	0.088
Comparative example 5	7.5	125	9×10^{-14}	64°	Severe whitening	0.092
Comparative example 6	4.2	97	6×10^{-15}	72°	Severe whitening	0.213
Comparative example 7	9	155	2×10^{-15}	66°	Slight whitening	0.050
Comparative example 8	4.6	98	4×10^{-14}	82°	Slight whitening	0.180

[61] As shown in Table 3, the examples of the present invention all fall in the preferred

ranges of contact angle, insulation resistance, particle diameter and abrasion resistance. The examples 1 to 8 comprising a polypropylene resin and a composite flame-retardant, of which the difference in surface electrical conductivity is less than 100 $\mu\text{S}/\text{cm}$, have tensile strength of 10 MPa or more, elongation of 150% or more and no whitening or slight whitening, and thus exhibit excellent mechanical properties above the standards. However, the comparative examples 1 to 8 comprising a single component flame-retardant out of the preferred surface electrical conductivity or comprising at least two types of flame-retardants, of which the difference in surface electrical conductivity is less than 100 $\mu\text{S}/\text{cm}$, have tensile strength, elongation and whitening below the standards in addition to low abrasion resistance.

[62] As such, the preferred embodiments of the present invention were described hereinabove. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

Claims

- [Claim 1] A polypropylene-based insulating resin composition, comprising:
a polypropylene resin; and
50 to 200 parts by weight of an inorganic flame-retardant based on 100 parts by weight of the polypropylene resin,
wherein the inorganic flame-retardant is either a composite flame-retardant that includes at least two types of flame-retardants and contains at least one pair of inorganic flame-retardants, of which the difference in surface electrical conductivity is 100 $\mu\text{S}/\text{cm}$ or more, or a single component flame-retardant having an electrical conductivity of 100 to 400 $\mu\text{S}/\text{cm}$,
said inorganic flame-retardant being uncoated or surface-coated with a hydrophobic material,
wherein the insulating resin composition has a contact angle with water of 50 to 150°, and
wherein the insulating resin composition has an insulation resistance of 1×10^{-14} to $1 \times 10^{-17} \Omega \cdot \text{cm}$.
- [Claim 2] The polypropylene-based insulating resin composition according to claim 1,
wherein the polypropylene resin is at least one selected from the group consisting of a homopolymer, a block copolymer and a random copolymer of propylene.
- [Claim 3] The polypropylene-based insulating resin composition according to claim 1, further comprising:
1 to 80 parts by weight of an adjuvant resin,
wherein the adjuvant resin includes a rubber and/or a polar modified resin,
wherein the rubber of the adjuvant resin is at least one selected from the group consisting of low density polyethylene (LDPE), linear low density polyethylene (LLDPE), ethylene-alpha olefin copolymer, propylene-alpha olefin copolymer, ethylene-vinyl acetate (EVA) copolymer, ethylene-methyl acrylate (EMA) copolymer, ethylene-ethyl acrylate (EEA), styrene-butadiene-styrene (SBS) rubber, styrene-ethylene-butadiene-styrene (SEBS) copolymer, ethylene-propylene-diene monomer (EPDM) rubber, ethylene glycol dimethacrylate (EGDM) rubber, ethylene-butyl acrylate (EBA) copolymer and polyolefin elastomer (POE), and

wherein the polar modified resin is polypropylene or thermoplastic polyolefin elastomer grafted with at least one selected from maleic anhydride, fatty acid, amino silane and vinyl silane.

[Claim 4] The polypropylene-based insulating resin composition according to claim 3,
wherein the ethylene-alpha olefin or propylene-alpha olefin copolymer is at least one selected from the group consisting of ethylene-butene copolymer, ethylene-octene copolymer, ethylene-propylene copolymer and propylene-butene copolymer.

[Claim 5] The polypropylene-based insulating resin composition according to claim 1,
wherein the inorganic flame-retardant is at least one selected from the group consisting of magnesium oxide, magnesium hydroxide, aluminium hydroxide, calcium hydroxide and hydromagnesite ($\text{Mg}_5(\text{CO}_3)_4(\text{OH})_2$).

[Claim 6] The polypropylene-based insulating resin composition according to claim 1,
wherein the hydrophobic material is selected from the group consisting of stearic acid, oleic acid, fatty acid, amino silane and vinyl silane.

[Claim 7] The polypropylene-based insulating resin composition according to claim 1, further comprising:
1 to 20 parts by weight of a secondary flame-retardant being at least one selected from the group consisting of talc, melamine cyanurate, red phosphorus, magnesium oxide, zinc borate and antimony trioxide.

[Claim 8] The polypropylene-based insulating resin composition according to claim 1,
wherein the inorganic flame-retardant includes 1 to 40 weight% of uncoated magnesium hydroxide having a surface electrical conductivity of 350 $\mu\text{S}/\text{cm}$ and 60 to 99 weight% of an inorganic flame-retardant surface-coated with a hydrophobic material to achieve a surface electrical conductivity of 100 to 400 $\mu\text{S}/\text{cm}$.

[Claim 9] A polypropylene-based insulating resin composition, comprising:
a polypropylene resin; and
50 to 200 parts by weight of an inorganic flame-retardant based on 100 parts by weight of the polypropylene resin,
wherein the inorganic flame-retardant is uncoated or surface-coated with a hydrophobic material,
said inorganic flame-retardant having an average particle diameter of

0.5 to 5 μm , and

wherein the inorganic flame-retardant has an abrasion resistance of 0.001 to 0.2 mm according to a scrape test conducted on a specimen made from the insulating resin composition, said scrape test comprising moving back and forth in the surface plane of said specimen a needle having a diameter of 0.45 ± 0.01 mm with a load of 1,500 g applied vertically against said surface, and determining the abraded depth of the surface of the specimen as abrasion resistance.

[Claim 10] The polypropylene-based insulating resin composition according to claim 9,

wherein the polypropylene resin is at least one selected from the group consisting of a homopolymer, a block copolymer and a random copolymer of propylene.

[Claim 11] The polypropylene-based insulating resin composition according to claim 9, further comprising:

1 to 80 parts by weight of an adjuvant resin,

wherein the adjuvant resin includes a rubber and/or a polar modified resin,

wherein the rubber of the adjuvant resin is at least one selected from the group consisting of low density polyethylene (LDPE), linear low density polyethylene (LLDPE), ethylene-alpha olefin copolymer, propylene-alpha olefin copolymer, ethylene-vinyl acetate (EVA) copolymer, ethylene-methyl acrylate (EMA) copolymer, ethylene-ethyl acrylate (EEA), styrene-butadiene-styrene (SBS) rubber, styrene-ethylene-butadiene-styrene (SEBS) copolymer, ethylene-propylene-diene monomer (EPDM) rubber, ethylene glycol dimethacrylate (EGDM) rubber, ethylene-butyl acrylate (EBA) copolymer and polyolefin elastomer (POE), and

wherein the polar modified resin is polypropylene or thermoplastic polyolefin elastomer grafted with at least one selected from the group consisting of maleic anhydride, fatty acid, amino silane and vinyl silane.

[Claim 12] The polypropylene insulating resin composition according to claim 11, wherein the ethylene-alpha olefin or propylene-alpha olefin copolymer is at least one selected from ethylene-butene copolymer, ethylene-octene copolymer, ethylene-propylene copolymer and propylene-butene copolymer.

[Claim 13] The polypropylene-based insulating resin composition according to

- claim 9,
wherein the inorganic flame-retardant is at least two selected from the group consisting of magnesium oxide, magnesium hydroxide, aluminium hydroxide, calcium hydroxide and hydromagnesite.
- [Claim 14] The polypropylene-based insulating resin composition according to claim 9,
wherein the hydrophobic material is selected from the group consisting of stearic acid, oleic acid, fatty acid, amino silane and vinyl silane.
- [Claim 15] The polypropylene-based insulating resin composition according to claim 9, further comprising:
1 to 20 parts by weight of a secondary flame-retardant being at least one selected from the group consisting of talc, melamine cyanurate, red phosphorus, magnesium oxide, zinc borate and antimony trioxide.
- [Claim 16] The polypropylene-based insulating resin composition according to claim 9,
wherein the inorganic flame-retardant includes 1 to 40 weight% of uncoated magnesium hydroxide having a particle size of 1 to 3 μm and 60 to 99 weight% of an inorganic flame-retardant surface-coated with a hydrophobic material, having a particle size of 2 to 3 μm .
- [Claim 17] An insulating cable, comprising:
a metal conductor bundle; and
an insulation layer or sheath layer surrounding the metal conductor bundle,
wherein the insulation layer or sheath layer is formed using the polypropylene-based insulating resin composition defined in any one of claims 1 to 8.
- [Claim 18] An insulating cable, comprising:
a metal conductor bundle; and
an insulation layer or sheath layer surrounding the metal conductor bundle,
wherein the insulation layer or sheath layer is formed using the polypropylene-based insulating resin composition defined in any one of claims 9 to 16.