

FLAME-RETARDANT RESIN COMPOSITION AND FLAME-RETARDANT CABLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 [0001] The present invention relates to a flame-retardant resin composition that can be used as a material forming a semiconducting layer of a power cable, and a flame-retardant cable that includes a semiconducting layer including the flame-retardant resin composition.

2. Description of the Related Art

[0002] In general, a power cable used for, for example, power transmission or power
10 distribution has a basic structure including a conductor, an insulating layer disposed on the conductor, and a sheath layer (including an anticorrosion layer, and hereinafter referred to as "sheath layer") that covers the insulating layer or the like. In many cases, such a power cable includes semiconducting layers such as an inner semiconducting layer disposed
15 between a conductor and an insulating layer, and an outer semiconducting layer disposed between an insulating layer and a sheath layer. Such power cables often require, for example, high flame retardancy, high mechanical strength, in particular, good tensile properties such as modulus of elasticity in tension and tensile elongation, and a property of resistance to external scratches (external scratch resistance) due to high hardness. Such power cables may also be desired to have a property of not easily deforming even in a
20 high-temperature environment (low heat deformation rate) so as to withstand use in an environment at a high temperature, and a low brittleness temperature (low-temperature performance) so as not to become brittle even when used at a low temperature. These properties are provided against influencing factors from the outside of a cable, such as the environment (for example, temperature and strain) during laying or after laying of the
25 cable. In general, these properties are ensured by a sheath layer located as the outermost layer of a power cable for the purpose of protecting a conductor, an insulating layer, and other layers of the cable.

[0003] In order to satisfy these requirements, power cables having various structures and various materials that can form power cables have been proposed. For example, Japanese
30 Unexamined Patent Application Publication No. 2014-191907 describes a high-tension cable for railway vehicles, the cable including a sheath layer that contains 80 to 200 parts by weight of a metal hydroxide serving as a flame retardant and 0.5 to 10 parts by weight

of a cross-linking agent relative to 100 parts by weight of an olefin-based polymer that includes an ethylene-vinyl acetate copolymer as a main component.

[0004] Japanese Patent No. 5690807 describes a non-crosslinked polyethylene resin composition for power cables, the resin composition being capable of being used for an insulating layer, a semiconducting layer, or a sheath layer of power cables. The polyethylene resin composition contains 0.1 to 10 parts by weight of at least one additive selected from a flame retardant, an oxidation stabilizer, an ultraviolet (UV) stabilizer, and a processing aid and 1 to 5 parts by weight of carbon black relative to 100 parts by weight of a polymer including a medium-density polyethylene resin and a high-density polyethylene resin that include, as a comonomer, an α -olefin having 4 or more carbon atoms and that have particular melt indices, differential scanning calorimetry enthalpies, and molecular-weight distributions. In the polyethylene resin composition, a metal hydroxide such as aluminum hydroxide is used as the flame retardant.

[0005] Recently, there has been an application of a semiconducting layer provided as an outermost layer of a power cable. Hitherto, in power cables, a semiconducting layer is provided as a layer disposed inside a sheath layer, and thus, for example, high flame retardancy, high mechanical strength, and external scratch resistance have not been required for such a semiconducting layer. However, when a semiconducting layer is disposed as an outermost layer of a power cable, the semiconducting layer is required to have, for example, high flame retardancy and high external scratch resistance, which have not hitherto been required, while having semiconductivity.

[0006] However, for example, a sheath layer of an existing typical power cable disclosed in Japanese Unexamined Patent Application Publication No. 2014-191907 does not have semiconductivity required for a semiconducting layer, and a semiconducting layer that can be provided as a layer inside a sheath layer does not have sufficient flame retardancy required for an outermost layer of a power cable. The polyethylene resin composition disclosed in Japanese Patent No. 5690807 is not a satisfactory material that can form a semiconducting layer disposed as an outermost layer of a power cable, in particular, from the viewpoint of, for example, conductivity, flame retardancy, and hardness (external scratch resistance).

[0007] With regard to this point, for example, when a sheath layer of a power cable disclosed in Japanese Unexamined Patent Application Publication No. 2014-191907 is

used as a semiconducting layer disposed as an outermost layer of a power cable, in order to provide semiconductivity, it is necessary to incorporate a relatively large amount of carbon black in a composition of the sheath layer disclosed in the patent literature. However, the sheath layer disclosed in the patent literature contains a large amount of a metal hydroxide as a flame retardant. When a large amount of carbon black is mixed with this sheath layer, tensile properties such as tensile elongation significantly decrease. Thus, it is difficult to provide mechanical properties required for power cables. Furthermore, the olefin-based polymer that forms the sheath layer and includes an ethylene-vinyl acetate copolymer as a main component is soft. Accordingly, when a layer disposed as an outermost layer of a power cable is formed with this composition, external scratches are more likely to occur, and it is difficult to use the composition in applications in which high hardness (external scratch resistance) is required.

[0008] When the polyethylene resin composition disclosed in Japanese Patent No. 5690807 is used as a material that forms a semiconducting layer disposed as an outermost layer of a power cable, it is necessary to increase the content of the flame retardant in order to provide sufficiently high flame retardancy and to incorporate a larger amount of carbon black in order to improve conductivity. In the polyethylene resin composition disclosed in the patent literature, a metal hydroxide is used as the flame retardant. When a large amount of carbon black is mixed with this resin composition, tensile properties such as tensile elongation significantly decrease. Thus, it is difficult to ensure mechanical properties required for power cables.

[0009] As described above, it is difficult to ensure semiconductivity and high flame retardancy and to achieve external scratch resistance and mechanical strength (in particular, tensile properties) required for a layer disposed as an outermost layer of a power cable at the same time using the structures of a sheath layer and a semiconducting layer of the existing typical power cables or the materials that form the layers. It is desirable to develop a flame-retardant resin composition that satisfies these requirements.

SUMMARY OF THE INVENTION

[0010] It is an object of the present invention to provide a flame-retardant resin composition that has semiconductivity and high flame retardancy and that satisfies high external scratch resistance and mechanical strength (tensile properties).

[0011] The above object is achieved by aspects of the present invention described below.

[0012] A first aspect of the present invention provides a flame-retardant resin composition containing a resin, carbon black, and a metal phosphinate. The resin includes at least one selected from the group consisting of an ethylene-vinyl acetate copolymer
5 having a melting point of 80°C or more, an ethylene-ethyl acrylate copolymer having a melting point of 80°C or more, and an ethylene-methyl acrylate copolymer having a melting point of 80°C or more. A content of the carbon black is 25 parts by mass or more and 60 parts by mass or less relative to 100 parts by mass of the resin.

[0013] A second aspect of the present invention provides a flame-retardant cable
10 including a semiconducting layer that includes the flame-retardant resin composition of the first aspect.

[0014] According to the aspects of the present invention, it is possible to provide a flame-retardant resin composition and a flame-retardant cable that have semiconductivity and high flame retardancy and that satisfy high external scratch resistance and high mechanical
15 strength (tensile properties).

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Embodiments of the present invention will be described in detail. The scope of the present invention is not limited to the embodiments described below, and various
20 modifications may be made within a range that does not impair the gist of the present invention.

[0016] The present invention covers preferred embodiments described below.

[1] A flame-retardant resin composition contains a resin, carbon black, and a metal phosphinate. The resin includes at least one selected from the group consisting of an
25 ethylene-vinyl acetate copolymer having a melting point of 80°C or more, an ethylene-ethyl acrylate copolymer having a melting point of 80°C or more, and an ethylene-methyl acrylate copolymer having a melting point of 80°C or more. A content of the carbon black is 25 parts by mass or more and 60 parts by mass or less relative to 100 parts by mass of the resin.

[2] In the flame-retardant resin composition described in [1], a content of the metal phosphinate is preferably 10 parts by mass or more and 45 parts by mass or less relative to
30 100 parts by mass of the resin.

[3] In the flame-retardant resin composition described in [1] or [2], the resin preferably further includes a polyethylene resin, and a content of the polyethylene resin is preferably 45 parts by mass or less relative to 100 parts by mass of the resin.

[4] In the flame-retardant resin composition described in [3], the polyethylene resin preferably has a density of 0.90 g/mL or more and less than 0.93 g/mL.

[5] In the flame-retardant resin composition described in any one of [1] to [4], the carbon black is preferably at least one selected from the group consisting of furnace black, Ketjenblack, and acetylene black.

[6] A flame-retardant cable includes a semiconducting layer including the flame-retardant resin composition described in any one of [1] to [5].

[0017] A flame-retardant resin composition according to a first aspect of the present invention contains a resin, a metal phosphinate, and carbon black.

(1) Resin

[0018] In the first aspect of the present invention, the resin includes at least one resin (hereinafter may be referred to as "resin (A1)") selected from the group consisting of an ethylene-vinyl acetate copolymer having a melting point of 80°C or more, an ethylene-ethyl acrylate copolymer having a melting point of 80°C or more, and an ethylene-methyl acrylate copolymer having a melting point of 80°C or more, and optionally includes a polyethylene resin (hereinafter may be referred to as "polyethylene resin (A2)").

(I) Resin (A1)

[0019] The ethylene-vinyl acetate copolymer, the ethylene-ethyl acrylate copolymer, and the ethylene-methyl acrylate copolymer are respectively copolymers including, as structural units, ethylene and vinyl acetate, ethylene and ethyl acrylate, and ethylene and methyl acrylate. The structures of the copolymers are not limited and may be, for example, a block copolymer structure, a random copolymer structure, or a graft copolymer structure. The ethylene-vinyl acetate copolymer, the ethylene-ethyl acrylate copolymer, and the ethylene-methyl acrylate copolymer are resins having high oxygen indices and good flame retardancy. Thus, high flame retardancy can be provided to the flame-retardant resin composition by incorporating any of these copolymers. In particular, the resin (A1) is preferably an ethylene-ethyl acrylate copolymer or preferably includes an ethylene-ethyl acrylate copolymer from the viewpoint of exhibiting the effect of the metal phosphinate, which is one of essential components of the flame-retardant resin composition according to

the present invention.

[0020] The resin (A1) has a melting point of 80°C or more. When the melting point of the resin (A1) is less than 80°C, heat resistance of the flame-retardant resin composition tends to decrease, for example, the flame-retardant resin composition is easily deformed by stress at a temperature equal to or higher than the melting point. Accordingly, the melting point of the resin (A1) is preferably 90°C or more.

[0021] When the resin (A1) includes an ethylene-vinyl acetate copolymer, the content of vinyl acetate in the ethylene-vinyl acetate copolymer is preferably 20% by mass or less, and more preferably 17% by mass or less. When the content of vinyl acetate in the ethylene-vinyl acetate copolymer is equal to or less than the above values, the flame-retardant resin composition can be provided with good flame retardancy and good heat resistance. The content of vinyl acetate in the ethylene-vinyl acetate copolymer is usually 10% by mass or more.

[0022] When the resin (A1) includes an ethylene-ethyl acrylate copolymer, the content of ethyl acrylate in the ethylene-ethyl acrylate copolymer is preferably 30% by mass or less, and more preferably 25% by mass or less. When the content of ethyl acrylate in the ethylene-ethyl acrylate copolymer is equal to or less than the above values, the flame-retardant resin composition can be provided with good flame retardancy and good heat resistance. The content of ethyl acrylate in the ethylene-ethyl acrylate copolymer is usually 8% by mass or more.

[0023] When the resin (A1) includes an ethylene-methyl acrylate copolymer, the content of methyl acrylate in the ethylene-methyl acrylate copolymer is preferably 25% by mass or less, and more preferably 20% by mass or less. When the content of methyl acrylate in the ethylene-methyl acrylate copolymer is equal to or less than the above values, the flame-retardant resin composition can be provided with good flame retardancy and good heat resistance. The content of methyl acrylate in the ethylene-methyl acrylate copolymer is usually 8% by mass or more.

[0024] The resin (A1) preferably has a melt flow rate (MFR) of 0.01 to 100 g/10 min, and more preferably 0.1 to 30 g/10 min. The MFR is a value measured at a temperature of 190°C under a load of 21.6 kg. When the MFR of the resin (A1) is within the above ranges, a high extrusion pressure is not necessary during molding of the resulting flame-retardant resin composition, and thus appearance defects and burned marks can be

suppressed.

[0025] The flame-retardant resin composition according to the first aspect of the present invention contains the resin (A1) preferably in an amount of 55 to 100 parts by mass, more preferably in an amount of 60 to 100 parts by mass, and still more preferably in an amount of 65 to 100 parts by mass relative to 100 parts by mass of the resin in total. When the resin (A1) is contained in an amount of 55 parts by mass or more, the flame-retardant resin composition can be provided with good tensile properties and low-temperature performance, in particular, have improved aging properties while sufficiently ensuring flame retardancy. In particular, a flame-retardant resin composition having good tensile elongation is obtained by increasing the content of the resin (A1) within the above ranges. Consequently, a molded body (for example, a semiconducting layer) including the flame-retardant resin composition is good in terms of flame retardancy, mechanical strength, low-temperature performance, and aging properties.

(II) Polyethylene resin (A2)

[0026] The flame-retardant resin composition according to the first aspect of the present invention may contain a polyethylene resin (A2). Incorporation of the polyethylene resin (A2) increases the hardness of the flame-retardant resin composition of the first aspect of the present invention and provides good external scratch resistance to a molded body (for example, a semiconducting layer) including the flame-retardant resin composition.

[0027] Examples of the polyethylene resin (A2) that may be incorporated in the flame-retardant resin composition of the first aspect of the present invention include very low-density polyethylene (VLDPE) resins having a density of less than 0.90 g/mL, low-density polyethylene (LDPE) resins having a density of 0.90 g/mL or more and less than 0.93 g/mL, medium-density polyethylene (MDPE) resins having a density of 0.93 g/mL or more and less than 0.94 g/mL, and high-density polyethylene (HDPE) resins having a density of 0.94 g/mL or more. In the first aspect of the present invention, as the polyethylene resin (A2), these resins may be used alone or in combination of a plurality of resins. Among these, the polyethylene resin (A2) is preferably a low-density polyethylene resin having a density of 0.90 g/mL or more and less than 0.93 g/mL because a flame-retardant resin composition having good tensile properties, such as tensile elongation, while having high external scratch resistance is obtained. In the present invention, the low-density polyethylene resin may be a linear low-density polyethylene (LLDPE). In this case, a

flame-retardant resin composition having high external scratch resistance and good tensile properties is obtained as in the case where the polyethylene resin (A2) is a low-density polyethylene resin. In the present invention, a linear low-density polyethylene may be used in combination with other polyethylene resins such as a low-density polyethylene resin.

[0028] The polyethylene resin (A2) may be, for example, a polyethylene resin modified with a compound such as an acid (maleic anhydride-modified polyethylene resin). In this case, a flame-retardant resin composition having high external scratch resistance and good tensile properties is obtained as in the cases where the polyethylene resin (A2) is a low-density polyethylene resin or a linear low-density polyethylene resin. In the present invention, the term "maleic anhydride-modified" means that a polyethylene resin is modified by grafting with maleic anhydride, or copolymerization is performed while maleic anhydride is coexisted from the polymerization stage. It is easy to modify a resin by grafting. For example, a maleic anhydride-modified resin can be produced by a method in which a resin and maleic anhydride are melt-kneaded in the presence of a radical generator such as an organic peroxide.

[0029] The MFR of the polyethylene resin (A2) is preferably 0.01 to 100 g/10 min, and more preferably 0.1 to 30 g/10 min. When the MFR of the polyethylene resin (A2) is within the above ranges, a high extrusion pressure is not necessary during molding of the resulting flame-retardant resin composition, and thus appearance defects and burned marks can be suppressed. Furthermore, miscibility of the polyethylene resin (A2) with the resin (A1) becomes good, and thus good tensile properties and good low-temperature performance are obtained.

[0030] The polyethylene resin (A2) preferably has a melting point of 80°C or more, more preferably 90°C or more, and still more preferably 100°C or more. When the polyethylene resin (A2) has a melting point in the above ranges, the hardness can be improved, and the heat deformation rate can be suppressed to be low.

[0031] In the flame-retardant resin composition according to the first aspect of the present invention, the content of the polyethylene resin (A2) is preferably 45 parts by mass or less relative to 100 parts by mass of the resin in total, the resin being contained in the flame-retardant resin composition of the present invention. When the content of the polyethylene resin (A2) is 45 parts by mass or less, it is possible to obtain a flame-retardant

resin composition having high hardness, good tensile properties and low-temperature performance, and further having good aging properties and the like while ensuring high flame retardancy. Dispersion failures of the carbon black can also be suppressed. In the first aspect of the present invention, incorporation of the polyethylene resin (A2) is not essential. However, from the viewpoint of achieving high external scratch resistance and further improving heat resistance, the flame-retardant resin composition preferably contains the polyethylene resin (A2). The flame-retardant resin composition according to the first aspect of the present invention contains the polyethylene resin (A2) preferably in an amount of 40 parts by mass or less and more preferably in an amount of 35 parts by mass or less relative to 100 parts by mass of the resin in total, the resin being contained in the flame-retardant resin composition. The lower limit of the content of the polyethylene resin (A2) is not particularly limited and may be, for example, 5 parts by mass or more.

[0032] The flame-retardant resin composition of the first aspect of the present invention may contain another resin besides the resin (A1) and the polyethylene resin (A2).

Examples of the other resin include ethylene-propylene copolymer rubbers and polyethylene elastomers from the viewpoint of, for example, improving low-temperature performance and further improving elongation. When the flame-retardant resin composition contains another resin, the content of the other resin is preferably smaller than the content of the resin (A1) and the content of the polyethylene resin (A2).

(2) Carbon black

[0033] The flame-retardant resin composition of the first aspect of the present invention contains carbon black. The incorporation of carbon black can ensure suitable semiconductivity required for a material that can form a semiconducting layer. The incorporation of carbon black can increase hardness of the flame-retardant resin composition.

In the first aspect of the present invention, for example, tensile properties and hardness can be controlled by incorporating the carbon black and the resins (specifically, the resin (A1) and the polyethylene resin (A2)) in amounts in particular ranges. In particular, in the first aspect of the present invention, hardness of the resulting flame-retardant resin composition can be controlled in a suitable range by using the resin (A1) and the carbon black in combination. Accordingly, even when, for example, the resin includes the resin (A1) alone or the content of the polyethylene resin (A2) is very small, the flame-retardant resin composition can be provided with required hardness. Thus, it is

possible to obtain a flame-retardant resin composition that is suitable for use in applications (for example, a semiconducting layer disposed as an outermost layer of a power cable) in which high external scratch resistance is required.

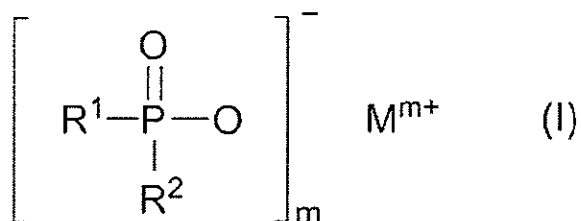
[0034] The content of the carbon black in the flame-retardant resin composition of the first aspect of the present invention is 25 parts by mass or more and 60 parts by mass or less relative to 100 parts by mass of the resin. When the content of the carbon black is less than 25 parts by mass, the flame-retardant resin composition is not provided with sufficient conductivity. In addition, it becomes difficult to ensure sufficient hardness, and external scratch resistance of the flame-retardant resin composition tends to decrease. On the other hand, when the content of the carbon black exceeds 60 parts by mass, tensile elongation and low-temperature performance of the flame-retardant resin composition tend to decrease. Accordingly, the flame-retardant resin composition of the first aspect of the present invention preferably contains 30 to 55 parts by mass, and more preferably 35 to 45 parts by mass of carbon black relative to 100 parts by mass of the resin.

[0035] In the first aspect of the present invention, the carbon black is preferably at least one selected from the group consisting of furnace black, Ketjenblack, and acetylene black. These may be used alone or in combination of a plurality thereof. Among these, furnace black is widely used as carbon black and is available at a relatively low cost. Therefore, for example, in the production in an industrial scale, furnace black is more preferably used in terms of the cost.

(3) Metal phosphinate

[0036] The flame-retardant resin composition of the first aspect of the present invention contains a metal phosphinate. Incorporation of a metal phosphinate can provide high flame retardancy.

[0037] In the first aspect of the present invention, the metal phosphinate is a compound represented by formula (I). In formula (I), R^1 and R^2 are each independently hydrogen, an alkyl group having 1 to 8 carbon atoms, or an aryl group having 12 or less carbon atoms, and M is an alkali metal, an alkaline earth metal, a trivalent metal, a monovalent to trivalent transition metal, or ammonium, such as calcium, aluminum, zinc, magnesium, potassium, sodium, lithium, ammonium, barium, or strontium. From the viewpoint of good dispersibility with the resin (A1) and the ease of an increase in flame retardancy, M is preferably calcium, aluminum, or zinc, and more preferably aluminum.



[0038] The phosphorus content of the metal phosphinate is preferably 15% by mass or more, more preferably 18% by mass or more, and still more preferably 20% by mass or more from the viewpoint of exhibiting flame retardancy. Commercially available metal phosphinates may be used. Specific examples thereof include aluminum salts of organic phosphinic acids.

[0039] The content of the metal phosphinate in the flame-retardant resin composition of the first aspect of the present invention is preferably 10 parts by mass or more and 45 parts by mass or less relative to 100 parts by mass of the resin. When the content of the metal phosphinate is 10 parts by mass or more relative to 100 parts by mass of the resin, the flame-retardant resin composition can be provided with sufficiently high flame retardancy. On the other hand, when the content of the metal phosphinate is excessively high, tensile properties, such as tensile strength and tensile elongation, and low-temperature performance tend to decrease. Accordingly, the flame-retardant resin composition of the first aspect of the present invention preferably contains 15 parts by mass or more and 40 parts by mass or less, and more preferably 18 parts by mass or more and 35 parts by mass or less of the metal phosphinate relative to 100 parts by mass of the resin. When the content of the metal phosphinate is in the above ranges, sufficiently high flame retardancy is obtained, and good tensile properties and good low-temperature performance are also obtained.

[0040] The content of the metal phosphinate in the flame-retardant resin composition of the first aspect of the present invention is preferably 6% to 25% by mass, more preferably 8% to 20% by mass, and still more preferably 10% to 18% by mass relative to the total amount of the flame-retardant resin composition. When the content of the metal phosphinate is in the above ranges relative to the total amount of the flame-retardant resin composition, a flame-retardant resin composition having good tensile properties and good low-temperature performance while ensuring sufficiently high flame retardancy can be obtained.

[0041] When a semiconducting layer is disposed as an outermost layer of a power cable,

in addition to semiconductivity and high flame retardancy, for example, high external scratch resistance for withstanding shock from the outside is required for the semiconducting layer. Incorporating a large amount of carbon black is effective to provide semiconductivity and suitable hardness. However, when a large amount of a metal hydroxide is incorporated as a flame retardant as in existing resin compositions (for example, Japanese Unexamined Patent Application Publication No. 2014-191907 and Japanese Patent No. 5690807), an increase in the content of carbon black for the purpose of ensuring sufficient semiconductivity required for a semiconducting layer extremely decreases tensile properties and low-temperature performance of the resulting composition. Thus, it is difficult to satisfy external scratch resistance and mechanical strength required for a power cable. Furthermore, in a composition in which a metal hydroxide is used as a flame retardant, semiconductivity and flame retardancy that can be provided as a result of addition of a large amount of carbon black are limited. Such a composition is not a fully satisfactory material for forming a semiconducting layer disposed as an outermost layer. In contrast, the flame-retardant resin composition of the first aspect of the present invention contains particular amounts of carbon black and a metal phosphinate, and flame retardancy of the flame-retardant resin composition is further improved by the interaction between the carbon black and the metal phosphinate. Thus, high flame retardancy can be effectively ensured by adding a relatively small amount of the metal phosphinate without decreasing conductivity and suitable hardness that are provided by the incorporation of the carbon black.

(4) Other components

[0042] In the first aspect of the present invention, the flame-retardant resin composition may contain other components in addition to the resin, carbon black, and metal phosphinate within a range that does not impair the gist of the present invention. Examples of the other components include inorganic fillers such as calcium carbonate, calcined clay, and talc; an antioxidant; a lubricant; and a modified silicone. The flame-retardant resin composition may contain a pigment, a dye, and the like for coloring.

[0043] An inorganic filler may be incorporated in a small amount, as required, in order to improve, for example, tensile properties and hardness. Specifically, the content of the inorganic filler in the flame-retardant resin composition of the first aspect is preferably 20 parts by mass or less relative to 100 parts by mass of the resin. The incorporation of an

inorganic filler improves tensile properties, modulus of elasticity, and hardness but may cause problems of a significant decrease in elongation and a decrease in low-temperature performance. Therefore, the flame-retardant resin composition of the first aspect of the present invention preferably contains no inorganic filler.

5 [0044] Flame retardancy can be further improved by incorporating a modified silicone in the flame-retardant resin composition of the first aspect. In order to exhibit the effect of improving flame retardancy, the content of the modified silicone is preferably 0.5% by mass or more relative to the total amount of the resin. The flame-retardant resin composition of the first aspect contains an inorganic filler in a small amount or contains no
10 inorganic filler. Therefore, addition of a large amount of a modified silicone to the flame-retardant resin composition may cause a problem of, for example, bleeding-out of the modified silicone on a surface of the resulting product. Accordingly, the upper limit of the content of the modified silicone is preferably 5% by mass or less.

(5) Properties of flame-retardant resin composition

15 [0045] The flame-retardant resin composition of the first aspect of the present invention may have an oxygen index of, for example, 29 or more determined in accordance with JIS K7201. In particular, regarding a flame-retardant resin composition used for forming a semiconducting layer which is disposed as an outermost layer of a power cable and for which high flame retardancy is required, the oxygen index is preferably 30 or more, more
20 preferably 32 or more, and particularly preferably 33 or more. The oxygen index can be measured by the method described Experimental Examples below.

[0046] The flame-retardant resin composition of the first aspect of the present invention is a resin composition having good external scratch resistance. Therefore, for example, the D-hardness determined in accordance with Type D in JIS K7215 is preferably 45 or more,
25 and more preferably 46 or more. The D-hardness can be measured by the method described in Experimental Examples below.

[0047] The flame-retardant resin composition of the first aspect of the present invention is a resin composition having semiconductivity. Therefore, for example, the volume resistance is preferably less than 10,000 $\Omega \cdot \text{cm}$, more preferably less than 6,000 $\Omega \cdot \text{cm}$, and
30 still more preferably less than 3,000 $\Omega \cdot \text{cm}$. The volume resistance can be measured by the method described in Experimental Examples below.

[0048] The flame-retardant resin composition of the first aspect of the present invention

is a resin composition having good mechanical strength. Therefore, the tensile strength determined in accordance with JIS K6251 is preferably 9.0 MPa or more, more preferably 9.3 MPa or more, and still more preferably 9.5 MPa or more. The tensile elongation is preferably 200% or more, more preferably 250% or more, and still more preferably 300% or more. The tensile strength and the tensile elongation can be measured by the method described in Experimental Examples below.

[0049] The flame-retardant resin composition of the first aspect of the present invention is a resin composition having good low-temperature performance. Therefore, for example, the brittleness temperature determined in accordance with JIS K7216 is preferably less than -25°C. The brittleness temperature can be measured by the method described in Experimental Examples below.

[0050] The flame-retardant resin composition of the first aspect of the present invention is a resin composition having good aging properties. Therefore, for example, a tensile strength retention after standing at 100°C for 168 hours is preferably 90% or more, more preferably 93% or more, and particularly preferably 95% or more. A tensile elongation retention after standing at 100°C for 168 hours is preferably 90% or more, more preferably 93% or more, and particularly preferably 95% or more. The tensile strength retention and the tensile elongation retention can be measured by the method described in Experimental Examples below.

[0051] The flame-retardant resin composition of the first aspect of the present invention is a resin composition having good heat resistance. Therefore, for example, the heat deformation rate determined in accordance with JIS C3005 is preferably 25% or less, more preferably 20% or less, and still more preferably 15% or less. The heat deformation rate can be measured by the method described in Experimental Examples below.

[0052] The flame-retardant resin composition of the first aspect of the present invention can be produced by mixing the resin, the carbon black, the metal phosphinate, and as required, other components using a known melt-kneading method with, for example, a twin-screw extruder, a roll mill, or a Banbury mixer in accordance with known conditions. An example of the method is a method in which the components are mixed at room temperature, and the resulting mixture is then melt-kneaded using a twin-screw kneading extruder.

[0053] The flame-retardant resin composition of the first aspect of the present invention

can be suitably used in the formation of a semiconducting layer as a material for forming a semiconducting layer of a power cable. However, the applications of the flame-retardant resin composition are not limited thereto. Since the flame-retardant resin composition of the first aspect of the present invention has both semiconductivity and high flame

5 retardancy, in particular, the flame-retardant resin composition can be suitably used as a material for forming a semiconducting layer disposed as an outermost layer of a power cable.

[0054] With the flame-retardant resin composition of the first aspect of the present invention, it is possible to form a semiconducting layer of a flame-retardant cable of the
10 second aspect, the semiconducting layer having semiconductivity and high flame retardancy, having high external scratch resistance and high mechanical strength (tensile properties), and further having good low-temperature performance (low brittleness temperature), good aging properties (small change in mechanical strength), and good heat resistance (low heat deformation rate). In a flame-retardant cable, the semiconducting
15 layer may be present as an inner semiconducting layer or an outer semiconducting layer. Since the semiconducting layer is good in terms of flame retardancy, external scratch resistance, mechanical strength (tensile properties), low-temperature performance, aging properties, and heat resistance while having semiconductivity, in particular, the semiconducting layer can be suitably disposed as an outermost layer of a power cable.

20 [0055] According to an embodiment of the present invention, it is possible to provide a flame-retardant cable of the second aspect, the flame-retardant cable including a semiconducting layer containing the flame-retardant resin composition of the first aspect. The flame-retardant cable of the second aspect has high external scratch resistance and high mechanical strength (tensile properties), and further has good low-temperature
25 performance (low brittleness temperature), good aging properties (small change in mechanical strength), and good heat resistance (low heat deformation rate) while having semiconductivity and high flame retardancy.

[0056] The present invention will be described more specifically using Examples. The scope of the present invention is not limited to the contents of Examples below.

30

EXAMPLES

(Materials)

[0057] Materials used in Experimental Examples (Examples and Comparative Examples) below will be described.

[Ethylene-vinyl acetate copolymer]

·EVA 1: vinyl acetate content 14% by mass, melting point 92°C, MFR 1.3 g/10 min (The MFR was measured at 190°C and under a load of 21.6 kg. Hereinafter the same.)

·EVA 2: vinyl acetate content 25% by mass, melting point 77°C, MFR 2.0 g/10 min

[Ethylene-ethyl acrylate copolymer]

·EEA: ethyl acrylate content 15% by mass, melting point 100°C, MFR 0.8 g/10 min

[Ethylene-methyl acrylate copolymer]

·EMA: methyl acrylate content 14% by mass, melting point 87°C, MFR 6.0 g/10 min

[Polyethylene resin]

·LDPE (low-density polyethylene): density 0.92 g/mL, melting point 110°C, MFR 1.4 g/10 min

·LLDPE (linear low-density polyethylene): density 0.92 g/mL, melting point 126°C, MFR 0.6 g/10 min

·MAH-LLDPE (maleic anhydride-modified linear low-density polyethylene): density 0.928 g/mL, melting point 122°C, MFR 1.5 g/10 min, maleic acid content 0.8% by mass

·MDPE (medium-density polyethylene): density 0.936 g/mL, melting point 126°C, MFR 0.5 g/10 min

[Metal phosphinate]

·Metal phosphinate: Aluminum diethyl phosphinate, density 1.35 g/mL, phosphorus content 23% to 24% by mass, mean particle size 20 to 40 μm

[Carbon black]

·Furnace black, arithmetic mean particle size 38 nm, nitrogen adsorption specific surface area 49 m^2/g

·Ketjenblack, arithmetic mean particle size 39.5 nm, nitrogen adsorption specific surface area 800 m^2/g

[Aluminum hydroxide]

·Aluminum hydroxide: mean particle size 1.0 μm , surface-untreated product

(Preparation of sheet for test piece preparation)

[0058] The materials listed above were kneaded in a pressure kneader at 180°C in the compositions (mass ratios) shown in Tables 1 to 3. The resulting mixture was then press-

formed at 160°C to prepare sheets having thicknesses of 1 mm, 2 mm, and 3 mm.

(Measuring method)

[0059] Methods for measuring physical properties, the methods being used in Experimental Examples (Examples and Comparative Examples) below, will be described.

5 ·Oxygen index

[0060] Test pieces were prepared from the sheets obtained by press forming at 160°C and having a thickness of 3 mm. The oxygen index was measured in accordance with JIS K7201. The oxygen index was measured up to 40.

·D-hardness

10 [0061] The D-hardness was measured in accordance with Type D in JIS K7215 using the sheets having a thickness of 3 mm with a Shore D durometer (manufactured by Kobunshi Keiki Co., Ltd.).

·Volume resistance

15 [0062] Initial volume resistance of the sheet having a thickness of 1 mm was measured at room temperature at a voltage of 500 V.

(Measurement of sample having volume resistance of $1.0\text{E}+10\ \Omega\cdot\text{cm}$ or more)

[0063] In the measurement of the volume resistance, the thickness of a central portion of the measurement of the sheet was measured, and a current was measured with a 4339B High Resistance meter manufactured by Agilent Technologies. The volume resistance was
20 calculated from the measured value.

(Measurement of sample having volume resistance of less than $1.0\text{E}+10\ \Omega\cdot\text{cm}$)

[0064] In the measurement of the volume resistance, the thickness of a central portion of the measurement of the sheet was measured, and a current was measured with, for example, an RM3545 resistance meter manufactured by Hioki E. E. Corporation. The volume
25 resistance was calculated from the measured value.

·Tensile strength and tensile elongation

[0065] Tensile test pieces were punched from the sheets obtained by press forming at 160°C and having a thickness of 1 mm. A tensile test was performed in accordance with JIS K6251 using an Autograph manufactured by Shimadzu Corporation at a test speed of
30 200 mm/min.

·Brittleness temperature

[0066] Tensile test pieces were punched from the sheets obtained by press forming at

160°C and having a thickness of 2 mm. The brittleness temperature was measured in accordance with JIS K7216 using a measuring apparatus manufactured by Toyo Seiki Seisaku-sho Ltd. The measurement was performed up to a temperature of -25°C.

·Tensile strength retention after heating and tensile elongation retention after heating

- 5 [0067] Tensile test pieces were punched from the sheets obtained by press forming at 160°C and having a thickness of 1 mm. The tensile test pieces were hung in a Geer oven set at 100°C and heated for 168 hours. The tensile test pieces were then taken out into an atmosphere at room temperature. After it was confirmed that the temperature of the tensile test pieces decreased, a tensile test was performed in accordance with JIS K6251 using an
- 10 Autograph manufactured by Shimadzu Corporation at a test speed of 200 mm/min. The tensile strength retention after heating and the tensile elongation retention after heating were calculated by the following formulae.

Tensile strength retention after heating (%) = tensile strength after heating/initial tensile strength × 100

15 Tensile elongation retention after heating (%) = tensile elongation after heating/initial tensile elongation × 100

[0068] The term "Not performed" in the table means that this test was not performed because the tensile strength and tensile elongation of the tensile test piece before heating were low.

20 ·Heat deformation rate

[0069] The heat deformation rate was measured in accordance with JIS C3005 using a measuring apparatus manufactured by Yasuda Seiki seisakusho Ltd. The measurement was performed at 75°C and under a load of 4 kg by pressing with an iron rod having a diameter of 10 mm.

25 Table 1

		Experi- mental Example 1	Experi- mental Example 2	Experi- mental Example 3	Experi- mental Example 4	Experi- mental Example 5	Experi- mental Example 6	Experi- mental Example 7	Experi- mental Example 8
Compo- sition [parts by mass]	EVA1	100			70	55			70
	EVA2								
	EEA		100				70	55	
	EMA			100					
	LLDPE				30	45	30	45	
	LDPE								30
	MAH-LLDPE								
	MDPE								
	Metal phosphinate	20	20	20	20	20	20	20	20
	Aluminum hydroxide								
	Carbon black 1	40	40	40	40	40	40	40	40
	Carbon black 2								
Ratio [mass %]	Ratio of metal phosphinate	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
	Ratio of carbon black	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Physical proper- ties	Oxygen index	34	36	35	34	33	36	35	33
	D-hardness	46	46	46	48	50	48	50	48
	Volume resistance [$\Omega \cdot \text{cm}$]	150	200	150	150	200	250	300	150
	Tensile strength [Mpa]	9.8	10.5	9.7	10.8	11.3	10.9	11.6	10.1
	Tensile elongation [%]	480	440	410	430	390	410	360	370
	Brittleness temperature [$^{\circ}\text{C}$]	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$
	Tensile strength retention after heating (100 $^{\circ}\text{C}$ 168h) [%]	95	98	99	97	98	98	99	96
	Tensile elongation retention after heating (100 $^{\circ}\text{C}$ 168h) [%]	95	103	105	93	91	100	98	94
	Heat deformation rate [%]	22	11	18	6	0	3	0	8

Table 2

		Experi- mental Example 9	Experi- mental Example 10	Experi- mental Example 11	Experi- mental Example 12	Experi- mental Example 13	Experi- mental Example 14	Experi- mental Example 15
Compo- sition [parts by mass]	EVA1	70	70					
	EVA2							
	EEA			70	70	70	70	70
	EMA							
	LLDPE			30	30	30	30	30
	LDPE							
	MAH-LLDPE	30						
	MDPE		30					
	Metal phosphinate	20	20	10	45	20	20	20
	Aluminum hydroxide							
	Carbon black 1	40	40	40	40	25	60	
	Carbon black 2							40
Ratio [mass %]	Ratio of metal phosphinate	12.5	12.5	6.7	24.3	13.8	11.1	12.5
	Ratio of carbon black	25.0	25.0	26.7	21.6	17.2	33.3	25.0
Physical proper- ties	Oxygen index	34	33	31	>40	32	38	35
	D-hardness	48	49	48	48	46	51	48
	Volume resistance [$\Omega \cdot \text{cm}$]	150	200	100	500	5000	50	50
	Tensile strength [Mpa]	10.7	11.2	11.1	9.9	10.7	12.3	11.9
	Tensile elongation [%]	390	310	440	280	420	250	380
	Brittleness temperature [$^{\circ}\text{C}$]	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$
	Tensile strength retention after heating (100 $^{\circ}\text{C}$ 168h) [%]	95	98	97	99	95	96	97
	Tensile elongation retention after heating (100 $^{\circ}\text{C}$ 168h) [%]	93	91	103	98	101	100	100
	Heat deformation rate [%]	5	0	1	5	4	0	0

Table 3

		Experi- mental Example 16	Experi- mental Example 17	Experi- mental Example 18	Experi- mental Example 19	Experi- mental Example 20	Experi- mental Example 21	Experi- mental Example 22
Compo- sition [parts by mass]	EVA1		50					100
	EVA2	100						
	EEA				70	70	70	
	EMA							
	LLDPE		50	100	30	30	30	
	LDPE							
	MAH-LLDPE							
	MDPE							
	Metal phosphinate	20	20	20	8	20	20	
	Aluminum hydroxide							100
	Carbon black 1	40	40	40	40	20	65	60
	Carbon black 2							
Ratio [mass %]	Ratio of metal phosphinate	12.5	12.5	12.5	5.4	14.3	10.8	0.0
	Ratio of carbon black	25.0	25.0	25.0	27.0	14.3	35.1	23.1
Physical proper- ties	Oxygen index	34	33	31	29	34	>40	28
	D-hardness	46	50	53	48	44	51	52
	Volume resistance [$\Omega \cdot \text{cm}$]	150	200	300	100	1.0E+13	50	1.0E+11
	Tensile strength [Mpa]	9.3	11.4	10.5	11.3	10.3	6.5	9.4
	Tensile elongation [%]	520	330	280	450	430	15	3
	Brittleness temperature [$^{\circ}\text{C}$]	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	-10 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	<-25 $^{\circ}\text{C}$	-15 $^{\circ}\text{C}$	-10 $^{\circ}\text{C}$
	Tensile strength retention after heating (100 $^{\circ}\text{C}$ 168h) [%]	98	85	75	98	97	Not per- formed	Not per- formed
	Tensile elongation retention after heating (100 $^{\circ}\text{C}$ 168h) [%]	103	68	45	102	98	Not per- formed	Not per- formed
	Heat deformation rate [%]	35	0	0	0	6	0	0

[0070] Referring to the results shown in Tables 1 to 3, in Experimental Examples 1 to 15, 17, and 19, which correspond to the first aspect of the present invention, an oxygen index of 29 or more, a D-hardness of 45 or more, a volume resistance of less than 10,000 $\Omega \cdot \text{cm}$, a tensile strength of 9.0 MPa or more, and a tensile elongation of 200% or more are obtained. Thus, it is clear that the resin compositions have semiconductivity and flame retardancy, and have high external scratch resistance and high mechanical properties (tensile properties). In particular, in Experimental Examples 1 to 15, a brittleness temperature of -25 $^{\circ}\text{C}$ or less, a tensile strength retention after heating of 90% or more, a tensile elongation

retention after heating of 90% or more, and a heat deformation rate of 25% or less are obtained. Thus, it is clear that the resin compositions satisfy all the requirements of low-temperature performance, aging properties, and heat resistance in addition to the above properties. In the cases where the resin includes both the resin (A1) and the polyethylene resin (A2) (Experimental Examples 4 to 10), the D-hardness is higher and the heat deformation rate is lower than those in the cases where the resin includes the resin (A1) alone (Experimental Examples 1 to 3). These results show that external scratch resistance and heat resistance are further improved when the resin includes the polyethylene resin (A2) in an amount in a specific range in addition to the resin (A1). Furthermore, referring to the results of Experimental Examples 4, 8, and 10, in the cases where the polyethylene resin (A2) is a linear low-density polyethylene resin or a low-density polyethylene resin, higher tensile elongation is obtained compared with the case where a medium-density polyethylene resin is used.

[0071] In contrast, Experimental Example 16, in which the ethylene-vinyl acetate copolymer serving as one component of the resin has a melting point of less than 80°C, shows a high heat deformation rate. Experimental Example 18, in which the resin (A1) is not contained, shows a low tensile strength retention after heating and a low tensile elongation retention after heating. Regarding Experimental Example 20, in which the content of the carbon black is less than the lower limit in the first aspect of the present invention, the conductivity is low and the hardness is also low. On the other hand, regarding Experimental Example 21, in which the content of the carbon black exceeds the upper limit in the first aspect of the present invention, the tensile strength and tensile elongation are low, and the brittleness temperature is high, showing poor low-temperature performance. Regarding Experimental Example 22, in which aluminum hydroxide is used as a flame retardant instead of the metal phosphinate, although the hardness is high, the tensile strength and tensile elongation are significantly low, and the oxygen index is low, showing poor flame retardancy. In addition, the conductivity is also low, though a considerable amount of carbon black is incorporated.

WHAT IS CLAIMED IS:

1. A flame-retardant resin composition comprising:
a resin;
carbon black; and
a metal phosphinate,
wherein the resin includes at least one selected from the group consisting of an ethylene-vinyl acetate copolymer having a melting point of 80°C or more, an ethylene-ethyl acrylate copolymer having a melting point of 80°C or more, and an ethylene-methyl acrylate copolymer having a melting point of 80°C or more, and
a content of the carbon black is 25 parts by mass or more and 60 parts by mass or less relative to 100 parts by mass of the resin.
2. The flame-retardant resin composition according to Claim 1, wherein a content of the metal phosphinate is 10 parts by mass or more and 45 parts by mass or less relative to 100 parts by mass of the resin.
3. The flame-retardant resin composition according to Claim 1 or 2,
wherein the resin further includes a polyethylene resin, and
a content of the polyethylene resin is 45 parts by mass or less relative to 100 parts by mass of the resin.
4. The flame-retardant resin composition according to any one of Claims 1 to 3,
wherein the carbon black is at least one selected from the group consisting of furnace black, and acetylene black.
5. A flame-retardant cable comprising a semiconducting layer including the flame-retardant resin composition according to any one of Claims 1 to 4.