

## 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 an insulating layer or a semiconducting layer of a flame-retardant cable, and a flame-retardant cable that includes a layer formed of the flame-retardant resin composition.

## 2. Description of the Related Art

10 [0002] Insulated electric wires and cables used as, for example, internal wires of automobiles and railway vehicles (hereinafter referred to as "insulated electric wires/cables") and insulated electric wires/cables used in, for example, buildings and factories often require, for example, low smoke emission during combustion, high flame retardancy, high mechanical strength, in particular, good tensile properties such as tensile  
15 strength, modulus of elasticity in tension, and tensile elongation, and a property of resistance to external scratches (external scratch resistance) due to high hardness. Such insulated electric wires/cables are also often desired to have a property of not easily deforming even in a high-temperature environment (low heat deformation rate) so as to withstand use in an environment at a high temperature, and a low brittleness temperature  
20 (low-temperature performance) so as not to become brittle even when used at a low temperature.

[0003] In view of this, as a material for such insulated electric wires/cables, it is desirable to provide a flame-retardant resin composition which is free of halogens from the viewpoint of low smoke emission during combustion, which has high flame retardancy,  
25 high tensile properties, and high hardness, and which can provide a molded body that achieves a low heat deformation rate and a low brittleness temperature. Furthermore, the flame-retardant resin composition is also desired to have a low specific gravity because it is difficult to handle heavy insulated electric wires/cables during the laying operation, and such heavy insulated electric wires/cables increases the transport cost.

30 [0004] In order to form an insulating layer or a semiconducting layer of insulated electric wires/cables, various flame-retardant resin compositions have been proposed. For example, International Publication No. 2014/046165 discloses a flame-retardant resin composition

containing a thermoplastic resin, a metal hydroxide, and a modified silicone having, at an end thereof, a functional group having a carbon-carbon double bond. Examples of the thermoplastic resin in the flame-retardant resin composition include an ethylene-vinyl acetate copolymer and a polyethylene resin. Examples of the metal hydroxide include magnesium hydroxide and aluminum hydroxide.

[0005] Japanese Unexamined Patent Application Publication No. 2011-1506 discloses a flame-retardant resin composition containing a resin component, a functional group-containing olefin polymer component, and a flame retardant component, the resin component containing a propylene-ethylene-based copolymer component (A) produced in the presence of a single-site catalyst, an ethylene-based copolymer component (B) such as an ethylene-vinyl acetate copolymer, an ethylene-ethyl acrylate copolymer, or an ethylene- $\alpha$ -olefin copolymer having a density of 0.86 or more and less than 0.91 g/cm<sup>3</sup>, and a polyethylene-based resin component (C) having a density of 0.91 to 0.97 g/cm<sup>3</sup>. An example of the functional group-containing olefin polymer in the flame-retardant resin composition is maleic anhydride-grafted polyethylene. An example of the flame retardant component is a stearic acid surface-treated, synthesized magnesium hydroxide.

[0006] Japanese Patent No. 3953694 discloses an insulated electric wire/cable including, as an insulator and/or a sheath, an extrusion coating layer formed of a rubber/plastic, in which an outer layer of the coating layer is formed of a non-halogen flame-retardant composition containing, as a base polymer, a polyethylene having a weight-average molecular weight of 300,000 or more, and an inner layer of the coating layer is formed of a polyethylene, a polypropylene, or the like having a density of 0.925 or more.

[0007] Japanese Unexamined Patent Application Publication No. 2005-29605 discloses a flame-retardant resin material including a flame-retardant resin composition that contains 100 parts by mass of a resin component containing an ethylene copolymer (A) such as an ethylene- $\alpha,\beta$ -unsaturated carboxylic acid ester copolymer, a polyethylene resin (B) having a density of 0.91 to 0.96 g/cm<sup>3</sup>, and a functional group-containing olefin polymer (C), and 30 to 200 parts by mass of an inorganic flame retardant (D). The flame-retardant resin material may further include a scratch, whitening-preventing agent such as an organic silicone compound.

[0008] Japanese Patent No. 3908195 discloses a flame-retardant composition in which 5 to 300 parts by weight of an inorganic flame retardant (C) and 0.01 to 20 parts by weight of

an acrylic-modified polyorganosiloxane (D) are mixed relative to 100 parts by weight of a polymer component containing, as a main component, a polymer selected from an ethylene copolymer (A) and a thermoplastic elastomer (B).

[0009] Japanese Patent No. 5100284 discloses a flame-retardant resin composition

5 containing a high-density polyethylene having a density and a molecular-weight distribution in particular ranges, an ethylene-vinyl acetate copolymer, red phosphorus, and an inorganic flame retardant, in which a specific gravity is adjusted to 1.05 g/cm<sup>3</sup> or less.

[0010] However, in recent years, regarding the properties required for flame-retardant cables such as insulated electric wires/cables, higher standards have been often desired. It  
10 is difficult for flame-retardant cables formed from the existing flame-retardant resin compositions to satisfy all the requirements at the same time.

[0011] For example, in order to realize sufficient flame retardancy, an oxygen index of 30 or more is necessary. The use of a terminal vinyl-modified silicone described in International Publication No. 2014/046165 and the use of a functional group-containing  
15 olefin polymer component such as maleic anhydride-grafted polyethylene described in Japanese Unexamined Patent Application Publication Nos. 2011-1506 and 2005-29605 may improve flame retardancy and increase the oxygen index. However, heat resistance may be insufficient even when these compounds are simply used.

[0012] Flame retardancy corresponding to an oxygen index of 30 or more can be  
20 achieved by using a resin having a high content of an ethylene-vinyl acetate copolymer, which has a high oxygen index, or increasing a blending ratio of a flame retardant containing a metal hydroxide such as magnesium hydroxide or aluminum hydroxide. However, a resin having a high content of an ethylene-vinyl acetate copolymer is soft, and thus an external layer such as an insulating coating is susceptible to external scratches.  
25 Therefore, in order to pass an external scratch test in which a cable to which a load of 500 kg is applied per meter does not tear when the cable is dragged on a floor having a step of 8 mm, a D-hardness of 48 or more and a modulus of elasticity in tension of 180 MPa or more are desired. However, the above resins do not satisfy these requirements. In order to further improve external scratch resistance, it is desirable to improve the D-hardness and  
30 modulus of elasticity in tension so as to be equal to or higher than the above ranges.

[0013] An increase in the blending ratio of a flame retardant formed of a metal hydroxide decreases tensile properties such as tensile elongation and increases the brittleness

temperature, and thus good low-temperature performance is not obtained. Furthermore, there may be a problem in that torque during extrusion molding increases. For example, Japanese Patent No. 5100284 describes use of red phosphorus as a flame retardant.

Although the use of red phosphorus can reduce the amount of flame retardant, such as a metal hydroxide, red phosphorus is difficult to handle.

[0014] Furthermore, when a flame-retardant cable is immersed in hot water and volume resistance significantly changes, a stable insulating property or stable semiconductivity is not exhibited, which may result in a problem of stability during long-term use.

[0015] As described above, it is very difficult for flame-retardant cables formed from the existing flame-retardant resin compositions to satisfy all the requirements of a halogen-free property, flame retardancy, tensile properties (such as tensile strength, modulus of elasticity in tension, and tensile elongation), external scratch resistance, heat resistance (low heat deformation rate), and low-temperature performance (low brittleness temperature) while realizing a low specific gravity. Furthermore, achieving stabilization of the volume resistance (volume resistance stability) at the same time is not easily realized.

## SUMMARY OF THE INVENTION

[0016] An object of the present invention is to provide a flame-retardant resin composition that is free of halogens, that is good in terms of flame retardancy, tensile properties, external scratch resistance, heat resistance (low heat deformation rate), and low-temperature performance (low brittleness temperature), that has a low specific gravity, and that further has volume resistance stability. Another object of the present invention is to provide a flame-retardant cable, in particular, a flame-retardant insulated electric wire/cable including a layer, in particular, an insulating layer or a semiconducting layer, formed of the flame-retardant resin composition.

[0017] The above objects are achieved by aspects including structures described below.

[0018] A first aspect of the present invention provides a flame-retardant resin composition containing a resin, a metal phosphinate, and carbon black. The resin includes an ethylene-ethyl acrylate copolymer or an ethylene-vinyl acetate copolymer, and a polyethylene resin. The polyethylene resin includes a low-density polyethylene resin having a density of 0.9 g/mL or more and less than 0.93 g/mL and a medium- or high-density polyethylene resin having a density of 0.93 g/mL or more. A content of the metal

phosphinate is 10% by mass or more and 25% by mass or less relative to a total amount of the resin composition. A content of the carbon black is 1.5% by mass or more and 20% by mass or less relative to the total amount of the resin composition.

[0019] A second aspect of the present invention provides a flame-retardant cable

5 including a layer, in particular, an insulating layer or a semiconducting layer, formed of the flame-retardant resin composition of the first aspect. Examples of the flame-retardant cable include flame-retardant insulated electric wires/cables.

[0020] According to the aspects of the present invention, it is possible to provide a flame-retardant resin composition of the first aspect, which is good in terms of flame retardancy,

10 tensile properties, external scratch resistance, heat resistance, low-temperature performance, and volume resistance stability, and which has a low specific gravity. It is also possible to provide a flame-retardant cable, in particular, a flame-retardant insulated electric wire/cable, of the second aspect, the flame-retardant cable including a layer, such as an insulating layer or a semiconducting layer, formed of the flame-retardant resin

15 composition of the first aspect.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] Embodiments for carrying out the present invention will now be described. The scope of the present invention is not limited to the embodiments and Examples, and

20 various modifications may be made within a range that does not impair the gist of the present invention.

[0022] The present invention covers preferred embodiments described below.

[1] A flame-retardant resin composition contains a resin, a metal phosphinate, and carbon black. The resin includes an ethylene-ethyl acrylate copolymer or an ethylene-vinyl

25 acetate copolymer, and a polyethylene resin. The polyethylene resin includes a low-density polyethylene resin having a density of 0.9 g/mL or more and less than 0.93 g/mL and a medium- or high-density polyethylene resin having a density of 0.93 g/mL or more.

A content of the metal phosphinate is 10% by mass or more and 25% by mass or less relative to a total amount of the resin composition. A content of the carbon black is 1.5%  
30 by mass or more and 20% by mass or less relative to the total amount of the resin composition.

[2] In the flame-retardant resin composition described in [1], the resin preferably includes

10 parts by mass or more and 45 parts by mass or less of the ethylene-ethyl acrylate copolymer or the ethylene-vinyl acetate copolymer and 55 parts by mass or more and 90 parts by mass or less of the polyethylene resin relative to 100 parts by mass of the resin in total, and the polyethylene resin preferably includes 15 parts by mass or more and 80 parts  
 5 by mass or less of the low-density polyethylene resin and 10 parts by mass or more and 40 parts by mass or less of the medium- or high-density polyethylene resin relative to 100 parts by mass of the resin in total.

[3] In the flame-retardant resin composition described in [1] or [2], the medium- or high-density polyethylene resin preferably has a density of 0.942 g/mL or more.

10 [4] In the flame-retardant resin composition described in any one of [1] to [3], the polyethylene resin preferably includes 1 part by mass or more and 15 parts by mass or less of a maleic anhydride-modified polyethylene resin relative to 100 parts by mass of the resin in total.

[5] In the flame-retardant resin composition described in any one of [1] to [4], the carbon  
 15 black is preferably furnace black or acetylene black, and a content of the carbon black is preferably 1.5% by mass or more and 8% by mass or less relative to the total amount of the resin composition.

[6] In the flame-retardant resin composition described in any one of [1] to [4], the carbon black is preferably Ketjenblack, and a content of the carbon black is preferably 3% by  
 20 mass or more and 20% by mass or less relative to the total amount of the resin composition.

[7] A flame-retardant cable includes a layer formed of the flame-retardant resin composition described in any one of [1] to [4].

[8] A flame-retardant cable includes an insulating layer formed of the flame-retardant resin composition described in [5].

25 [9] A flame-retardant cable includes a semiconducting layer formed of the flame-retardant resin composition described in [6].

[0023] A flame-retardant resin composition of the first aspect contains (A) a resin, (B) a metal phosphinate, and (C) carbon black.

(A) Resin

30 [0024] In the first aspect, the resin (A) includes an ethylene-ethyl acrylate copolymer or ethylene-vinyl acetate copolymer (A1) and a polyethylene resin (A2).

(A1) Ethylene-ethyl acrylate copolymer or ethylene-vinyl acetate copolymer

[0025] The ethylene-ethyl acrylate copolymer and the ethylene-vinyl acetate copolymer are respectively copolymers including, as structural units, ethylene and ethyl acrylate, and ethylene and vinyl acetate. 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-ethyl acrylate copolymer and the ethylene-vinyl acetate copolymer are resins having high oxygen indices and good flame retardancy. The component (A1) is preferably an ethylene-ethyl acrylate copolymer from the viewpoint of enhancing a property of retaining a metal phosphinate, in particular, exhibiting the effect of the metal phosphinate.

[0026] When the component (A1) is an ethylene-ethyl acrylate copolymer, the content of ethyl acrylate in the ethylene-ethyl acrylate copolymer is preferably 8% by mass or more and 30% by mass or less (melting point: 85°C to 110°C), and more preferably 10% by mass or more and 25% by mass or less (melting point: 90°C to 105°C) from the viewpoint of improving dispersibility of the metal phosphinate and exhibiting flame retardancy.

[0027] When the component (A1) is an ethylene-vinyl acetate copolymer and the content of vinyl acetate in the ethylene-vinyl acetate copolymer increases, flame retardancy improves, but the melting point decreases and thus the copolymer is easily deformed by heating. Therefore, the content of vinyl acetate in the ethylene-vinyl acetate copolymer is preferably 30% by mass or less. From the viewpoint of achieving a lower heat deformation rate, the content of vinyl acetate in the ethylene-vinyl acetate copolymer is preferably 28% by mass or less (melting point: 71°C or more). The content of vinyl acetate in the ethylene-vinyl acetate copolymer is usually 10% by mass or more.

[0028] In the first aspect, the resin (A) preferably contains 10 parts by mass or more and 45 parts by mass or less, more preferably 10 parts by mass or more and 40 parts by mass or less, and still more preferably 15 parts by mass or more and 35 parts by mass or less of the ethylene-ethyl acrylate copolymer or ethylene-vinyl acetate copolymer (A1) relative to 100 parts by mass of the resin (A) in total. When the content of the ethylene-ethyl acrylate copolymer or ethylene-vinyl acetate copolymer (A1) in the resin (A) is equal to or more than the lower limit, dispersibility of the metal phosphinate can be improved and flame retardancy of the resulting flame-retardant resin composition can be enhanced. When the content of the ethylene-ethyl acrylate copolymer or ethylene-vinyl acetate copolymer (A1) in the resin (A) is equal to or less than the upper limit, flame retardancy can be enhanced,

and external scratch resistance can also be improved. When the content of the ethylene-ethyl acrylate copolymer or ethylene-vinyl acetate copolymer (A1) is excessively low, external scratches are less likely to occur, but flame retardancy may decrease. When the content of the ethylene-ethyl acrylate copolymer or ethylene-vinyl acetate copolymer (A1) is excessively high, flame retardancy can be enhanced, but external scratch resistance may decrease.

#### (A2) Polyethylene resin

[0029] In the first aspect, the polyethylene resin (A2) includes a low-density polyethylene resin and a medium- or high-density polyethylene resin.

[0030] In the first aspect, the low-density polyethylene resin usually has a density of 0.9 g/mL or more and less than 0.93 g/mL, preferably 0.905 g/mL or more and 0.925 g/mL or less, and more preferably 0.91 g/mL or more and 0.92 g/mL or less. When the density of the low-density polyethylene resin is in the above range, molded bodies (such as an insulating layer and a semiconducting layer) containing the flame-retardant resin

composition of the first aspect can be provided with good tensile properties in which both good tensile elongation and good modulus of elasticity in tension (contributing to external scratch resistance) are achieved, and low-temperature performance can be improved.

When the density of the low-density polyethylene resin is out of the above range, as a result of poor compatibility between the component (A1) and the component (A2), it

becomes difficult to exhibit properties such as good tensile properties. The low-density polyethylene resin may be a linear low-density polyethylene (LLDPE) resin.

[0031] In the first aspect, the medium- or high-density polyethylene resin usually has a density of 0.93 g/mL or more, and preferably has a density of 0.942 g/mL or more. When the density of the medium- or high-density polyethylene resin is in the above range, high rigidity can be provided to improve external scratch resistance. The upper limit of the density of the medium- or high-density polyethylene resin is usually 0.97 g/mL or less.

[0032] The polyethylene resin (A2) preferably has a melt flow rate (MFR) of 0.01 g/10 min or more and 100 g/10 min or less, and more preferably 0.1 g/10 min or more and 10 g/10 min or less. When the MFR of the polyethylene resin (A2) is equal to or more than the lower limit, during molding of molded bodies (such as an insulating layer and a semiconducting layer), the extrusion pressure does not become excessively high, and appearance defects and burned marks of the molded bodies can be suppressed. When the

MFR of the polyethylene resin (A2) is equal to or less than the upper limit, high crystallization can be suppressed, the tensile elongation becomes better, and the low-temperature performance can be further improved.

- [0033] The resin (A) preferably includes 55 parts by mass or more and 90 parts by mass or less, more preferably 60 parts by mass or more and 90 parts by mass or less, and still more preferably 65 parts by mass or more and 90 parts by mass or less of the polyethylene resin (A2) relative to 100 parts by mass of the resin (A) in total. When the content of the polyethylene resin (A2) is equal to or more than the lower limit, flame retardancy can be improved, and external scratch resistance can also be enhanced. When the content of the polyethylene resin (A2) is equal to or less than the upper limit, external scratch resistance can be enhanced, and flame retardancy can also be improved. When the content of the polyethylene resin (A2) is excessively low, flame retardancy improves but external scratches are more likely to occur. In addition, tensile properties such as modulus of elasticity in tension and tensile strength may also decrease. When the content of the polyethylene resin (A2) is excessively high, external scratches are less likely to occur, but flame retardancy, tensile elongation, and low-temperature performance may decrease.
- [0034] The polyethylene resin (A2) preferably includes 15 parts by mass or more and 80 parts by mass or less, more preferably 17 parts by mass or more and 75 parts by mass or less, and still more preferably 20 parts by mass or more and 70 parts by mass or less of the low-density polyethylene resin relative to 100 parts by mass of the resin (A) in total. When the content of the low-density polyethylene resin is equal to or more than the lower limit, tensile elongation and low-temperature performance can be enhanced, and external scratch resistance due to a high modulus of elasticity can also be enhanced. When the content of the low-density polyethylene resin is equal to or less than the upper limit, external scratch resistance due to a high modulus of elasticity can be enhanced, and tensile elongation and low-temperature performance can also be enhanced.
- [0035] The polyethylene resin (A2) preferably includes 10 parts by mass or more and 40 parts by mass or less, more preferably 15 parts by mass or more and 40 parts by mass or less, and still more preferably 20 parts by mass or more and 40 parts by mass or less of the medium- or high-density polyethylene resin relative to 100 parts by mass of the resin (A) in total. When the content of the medium- or high-density polyethylene resin is equal to or more than the lower limit, a good effect of improving hardness can be obtained, and an

improvement in modulus of elasticity and an increase in external scratch resistance can be realized. When the content of the medium- or high-density polyethylene resin is equal to or less than the upper limit, high crystallization can be suppressed, tensile elongation and low-temperature performance are further improved, and dispersion failures of a flame retardant can be suppressed.

[0036] The polyethylene resin (A2) may include other polyethylene resins besides the low-density polyethylene resin and the medium- or high-density polyethylene resin. For example, the polyethylene resin (A2) may include a polyethylene resin modified with a compound such as an acid (maleic anhydride-modified polyethylene resin). Maleic anhydride-modified polyethylene resins can enhance the interaction between a metal phosphinate and a resin, and can further improve the low-temperature performance and tensile properties such as tensile elongation and tensile strength. Accordingly, in the first aspect, the polyethylene resin (A2) preferably includes a maleic anhydride-modified polyethylene resin.

[0037] Herein, 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. By incorporating a polyethylene resin modified with maleic anhydride, the interaction between the resin and a flame retardant or the like can be enhanced, and the low-temperature performance and tensile properties such as tensile elongation can be improved. When the polyethylene resin has a high content of the low-density polyethylene resin, a maleic anhydride-modified ethylene-ethyl acrylate copolymer may be incorporated. The maleic anhydride-modified polyethylene resin or ethylene-ethyl acrylate copolymer may be a commercially available product. The content of maleic acid (anhydride) contained in the maleic anhydride-modified polyethylene resin is preferably 0.1 % by mass or more and 10% by mass or less, and more preferably 0.3% by mass or more and 2% mass or less from the viewpoint of low-temperature performance and tensile properties.

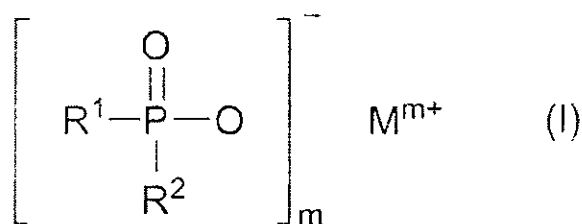
[0038] The content of the maleic anhydride-modified polyethylene resin in the polyethylene resin (A2) is preferably 1 part by mass or more and 15 parts by mass or less,

more preferably 3 parts by mass or more and 13 parts by mass or less, and still more preferably 5 parts by mass or more and 10 parts by mass or less relative to 100 parts by mass of the resin (A) in total. When the content of the maleic anhydride-modified polyethylene resin is equal to or more than the lower limit, the brittleness temperature of a layer, in particular, an insulating layer or a semiconducting layer, formed of the flame-retardant resin composition of the first aspect can be further lowered, and the tensile elongation and modulus of elasticity in tension of the layer can be further increased. When the content of the maleic anhydride-modified polyethylene resin is equal to or less than the upper limit, the above properties can be improved in proportion to the content of the maleic anhydride-modified polyethylene resin, and an excessive amount of the maleic anhydride-modified polyethylene resin is not used and thus this is industrially advantageous.

[0039] The resin (A) may contain another resin besides the ethylene-ethyl acrylate copolymer or ethylene-vinyl acetate copolymer (A1) and the polyethylene resin (A2). In view of, for example, dispersibility of flame retardants and adjustment of the modulus of elasticity, examples of the other resin include ethylene-propylene copolymer rubbers, very low-density polyethylene resins, and polyethylene elastomers. The content of the other resin is preferably smaller than the content of the ethylene-ethyl acrylate copolymer or ethylene-vinyl acetate copolymer (A1) and the content of the polyethylene resin (A2).

(B) Metal phosphinate

[0040] The flame-retardant resin composition of the first aspect contains a metal phosphinate (B). In the first aspect, 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 preferably hydrogen, an alkyl group having 1 to 4 carbon atoms, or an aryl group having 6 or less carbon atoms. In formula (I), 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.



[0041] 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.

[0042] The content of the metal phosphinate (B) in the flame-retardant resin composition of the first aspect is 10% by mass or more and 25% by mass or less, preferably 12% by mass or more and 20% by mass or less, and more preferably 13% by mass or more and 18% by mass or less relative to the total amount of the resin composition. When the content of the metal phosphinate (B) is equal to or more than the lower limit, high flame retardancy can be obtained. When the content of the metal phosphinate (B) is equal to or less than the upper limit, good low-temperature performance can be obtained, and good tensile elongation is also obtained.

(C) Carbon black

[0043] The flame-retardant resin composition of the first aspect contains carbon black (C). From the viewpoint of further improving weather resistance and flame retardancy of molded bodies (such as an insulating layer and a semiconducting layer), the flame-retardant resin composition of the first aspect contains 1.5% by mass or more, preferably 2% by mass or more, more preferably 3% by mass or more, and still more preferably 4% by mass or more, and 20% by mass or less, preferably 15% by mass or less, more preferably 8% by mass or less, and still more preferably 6% by mass or less of the carbon black (C) relative to the total amount of the resin composition.

[0044] Examples of the carbon black (C) include furnace black, acetylene black, and Ketjenblack.

[0045] When the carbon black (C) is furnace black or acetylene black, it is possible to obtain a flame-retardant resin composition that is good in terms of flame retardancy, tensile properties, external scratch resistance, heat resistance (low heat deformation rate), and low-temperature performance (low brittleness temperature), that has volume resistance stability,

and that has good insulating properties (high volume resistance). When the carbon black (C) is furnace black or acetylene black, a layer formed of the flame-retardant resin composition usually exhibits insulating properties, and an insulating layer is formed.

[0046] When the carbon black (C) is furnace black or acetylene black, the content of the carbon black (C) in the flame-retardant resin composition of the first aspect is preferably 1.5% by mass or more and 8% by mass or less, more preferably 2% by mass or more and 7% by mass or less, and still more preferably 3% by mass or more and 6% by mass or less relative to the total amount of the resin composition. When the content of the carbon black (C) is equal to or more than the lower limit, high insulating properties and high flame retardancy can be obtained. When the content of the carbon black (C) is equal to or less than the upper limit, it is possible to obtain a flame-retardant resin composition that provides a molded body (such as an insulating layer) which is a layer formed of the flame-retardant resin composition and which has a high volume resistance, the flame-retardant resin composition having sufficient insulating properties and good tensile properties.

[0047] When the carbon black (C) is Ketjenblack, a flame-retardant resin composition having not only flame retardancy, tensile properties, external scratch resistance, heat resistance (low heat deformation rate), low-temperature performance (low brittleness temperature), low specific gravity, and volume resistance stability, but also semiconductivity can be obtained. When the carbon black (C) is Ketjenblack, a layer formed of the flame-retardant resin composition usually exhibits semiconductivity, and a semiconducting layer is formed. In this case, the content of the carbon black (C) in the flame-retardant resin composition of the first aspect is preferably 3% by mass or more and 20% by mass or less, and more preferably 4% by mass or more and 15% by mass or less relative to the total amount of the resin composition. When the content of the carbon black (C) is equal to or more than the lower limit, a semiconducting layer having high flame retardancy and high semiconductivity can be obtained. When the content of the carbon black (C) is equal to or less than the upper limit, a flame-retardant resin composition having good tensile properties can be obtained.

(D) Other components

[0048] In the first aspect, the flame-retardant resin composition may contain other components in addition to the components (A) to (C) within a range that does not impair the gist of the present invention. Examples of the other components include an antioxidant,

a lubricant, and a modified silicone. The flame-retardant resin composition may contain a pigment, a dye, and the like for coloring.

[0049] The flame-retardant resin composition may contain an inorganic filler, as required, for the purpose of improving tensile properties, hardness (external scratch resistance), and volume resistance (insulating properties). The content of the inorganic filler in the flame-retardant resin composition of the first aspect is preferably 30% by mass or less relative to the total amount of the resin (A) from the viewpoint of flame retardancy and tensile properties. The incorporation of an inorganic filler improves tensile properties and hardness. On the other hand, the following problems may occur. Specifically, the incorporation of an inorganic filler decreases volume resistance during immersion in hot water (decrease in volume resistance stability). The incorporation of an inorganic filler increases the specific gravity, and thus it becomes difficult to handle the resulting insulated electric wire/cables during the laying operation, and the insulated electric wire/cables increase the transport cost. Therefore, in an embodiment, the flame-retardant resin composition of the first aspect preferably contains no inorganic filler.

[0050] 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 (A). In contrast, addition of a large amount of a modified silicone to the flame-retardant resin composition of the first aspect 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.

[0051] The flame-retardant resin composition of the first aspect is a resin composition having good flame retardancy. Therefore, regarding, for example, the oxygen index determined in accordance with JIS K7201, although a typical level that satisfies a flame-retardant test is 30 or more, the oxygen index is preferably 33 or more, more preferably 34 or more, and still more preferably 35 or more. The oxygen index can be measured by the method described in Experimental Examples below.

[0052] The flame-retardant resin composition of the first aspect 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 50 or more. The flame-

retardant resin composition of the first aspect has good tensile properties. In accordance with JIS K6251, the modulus of elasticity in tension is preferably 220 MPa or more, the tensile strength is preferably 10 MPa or more and more preferably 11 MPa or more, and the tensile elongation is preferably 280% or more, more preferably 300% or more, and still  
 5 more preferably 350% or more. The D-hardness, the modulus of elasticity in tension, the tensile strength, and the tensile elongation can be measured by the methods described in Experimental Examples below.

[0053] The flame-retardant resin composition of the first aspect is a resin composition having good heat resistance. Therefore, for example, the heat deformation rate determined  
 10 in accordance with JIS C3005 is preferably 10% or less, more preferably 5% or less, and still more preferably less than 1%. The heat deformation rate can be measured by the method described in Experimental Examples below.

[0054] The flame-retardant resin composition of the first aspect is a resin composition having good low-temperature performance. Therefore, for example, the brittleness  
 15 temperature determined in accordance with JIS K7216 is preferably -15°C or less, more preferably -20°C or less, and still more preferably -25°C or less. The brittleness temperature can be measured by the method described in Experimental Examples below.

[0055] Since the flame-retardant resin composition of the first aspect has a low specific gravity, it is relatively easy to handle the resulting flame-retardant cables during the laying  
 20 operation, and the transport cost can be reduced. The flame-retardant resin composition of the first aspect preferably has a specific gravity of less than 1.15, and more preferably less than 1.10.

[0056] Even when the flame-retardant resin composition of the first aspect is immersed in hot water, the volume resistance does not significantly change. Therefore, for example,  
 25 the ratio of volume resistance at 500 V after a long time (for example, one month) has passed since immersion in hot water (for example, at 80°C) to initial volume resistance (hereinafter, referred to as a change in volume resistance) is preferably  $10^{-3}$  times or more, and more preferably  $10^{-2}$  times or more. The change in the volume resistance is a ratio represented by (volume resistance after immersion in hot water)/(initial volume resistance).  
 30 When the flame-retardant resin composition of the first aspect is used as an insulating layer, in order to achieve sufficient insulating properties, the initial volume resistance and the volume resistance after immersion in hot water for a long time are preferably  $1.0 \times 10^{14}$

$\Omega\cdot\text{cm}$  or more and  $1.0 \times 10^{18} \Omega\cdot\text{cm}$  or less.

[0057] The flame-retardant resin composition of the first aspect can be produced by mixing the components (A) to (C) 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.

[0058] The flame-retardant resin composition of the first aspect can be suitably used for forming an insulating layer or a semiconducting layer of a flame-retardant cable, for example, for forming an insulating coating of an insulated electric wire or a cover (sheath) of a cable. However, the applications of the flame-retardant resin composition are not limited thereto. When the term "insulating coating" is simply used, the insulating coating means not only an insulating coating of an insulated electric wire but also an insulating material for, for example, a cover (sheath) of a cable.

[0059] With the flame-retardant resin composition of the first aspect, it is possible to form an insulating layer or a semiconducting layer of a flame-retardant cable, in particular, an insulated electric wire/cable, of the second aspect, the insulating layer or semiconducting layer being good in terms of flame retardancy, tensile properties, external scratch resistance, heat resistance (low heat deformation rate), and low-temperature performance (low brittleness temperature), having a low specific gravity, and further having volume resistance stability.

[0060] 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 layer, in particular, an insulating layer or a semiconducting layer, formed of the flame-retardant resin composition of the first aspect. The flame-retardant cable, in particular, the insulated electric wire/cable, of the second aspect is good in terms of flame retardancy, tensile properties, external scratch resistance, heat resistance (low heat deformation rate), and low-temperature performance (low brittleness temperature), has a low specific gravity, and further has volume resistance stability.

[0061] The term "insulated electric wire" refers to an electric wire that includes a conductor wire formed of a metal such as copper or aluminum and an insulating layer (such as an insulating coating) formed of an insulating material covering the outer surface

of the conductor wire. The conductor wire may include a single wire or a plurality of wires such as a stranded wire. A flame-retardant insulated electric wire includes an insulating layer or semiconducting layer formed of the flame-retardant resin composition of the first aspect. The layer can be formed by a method similar to a method for forming an insulating layer or a semiconducting layer in a known flame-retardant cable such as an insulated electric wire under conditions similar to those for such a known method. For example, the layer can be formed by coating a conductor wire with the flame-retardant resin composition of the first aspect by extrusion.

[0062] The term "cable" refers to a product in which an outer periphery of a single insulated electric wire or a bundle of a plurality of insulated electric wires is covered with an insulating cover (sheath). The cable may include, inside thereof, a metal layer and a semiconducting layer such as a shielding layer and a water-shielding layer, as required. When the term "insulating coating" is simply used as described above, the meaning of the insulating coating also includes a cover (sheath) of a cable.

[0063] In the second aspect, a layer, in particular, an insulating layer or a semiconducting layer, included in a flame-retardant cable is formed of the flame-retardant resin composition of the first aspect. Accordingly, the insulating layer or the semiconducting layer is good in terms of flame retardancy, tensile properties, external scratch resistance, heat resistance (low heat deformation rate), and low-temperature performance (low brittleness temperature), has a low specific gravity, and further has volume resistance stability. According to an embodiment of the present invention, a flame-retardant resin composition that can achieve all these properties at the same time can be provided. Therefore, a flame-retardant cable including an insulating layer or semiconducting layer formed of the flame-retardant resin composition is easily laid by a user and satisfies required physical properties such as heat resistance. Furthermore, when the flame-retardant cable is immersed in hot water, a significant change in the volume resistance is unlikely to occur. Therefore, the flame-retardant cable can exhibit a stable insulating property or stable semiconductivity.

[0064] 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.

## EXAMPLES

(Materials)

[0065] Materials used in Experimental Examples (Examples and Comparative Examples) below will be described.

[Ethylene-ethyl acrylate copolymer]

- 5 ·EEA: ethyl acrylate content 15% by mass, melting point 100°C

[Ethylene-vinyl acetate copolymer]

·EVA: vinyl acetate content 25% by mass, melting point 77°C

[Low-density polyethylene resin]

- 10 ·LDPE (low-density polyethylene): density 0.92 g/mL, MFR 1.4 g/10 min (The MFR was measured at 190°C and under a load of 21.6 kg. Hereinafter the same.)

·LLDPE (linear low-density polyethylene): density 0.92 g/mL, MFR 0.6 g/10 min

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

[Medium- or high-density polyethylene]

- 15 ·HDPE 1 (high-density polyethylene): density 0.951 g/mL, MFR 0.8 g/10 min

·HDPE 2 (high-density polyethylene): density 0.958 g/mL, MFR 0.1 g/10 min

·HDPE 3 (high-density polyethylene): density 0.943 g/mL, MFR 0.2 g/10 min

·MDPE (medium-density polyethylene): density 0.936 g/mL, MFR 0.5 g/10 min

[Metal phosphinate]

- 20 ·Metal phosphinate: Aluminum diethyl phosphinate, density 1.35 g/mL, phosphorus content 23% to 24% by mass, mean particle size 20 to 40  $\mu\text{m}$

[Carbon black]

·Carbon black 1: furnace black, arithmetic mean particle size 38 nm, nitrogen adsorption specific surface area 49 m<sup>2</sup>/g

- 25 ·Carbon black 2: Ketjenblack, arithmetic mean particle size 39.5 nm, nitrogen adsorption specific surface area 800 m<sup>2</sup>/g

[Inorganic filler]

·Aluminum hydroxide: mean particle size 1.0  $\mu\text{m}$ , surface-untreated product

·Calcium carbonate: mean particle size 1.8  $\mu\text{m}$ , specific surface area 12,000 cm<sup>2</sup>/g

- 30 (Preparation of sheet for test piece preparation)

[0066] 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)

[0067] Methods for measuring physical properties, the methods being used in Experimental Examples (Examples and Comparative Examples) below, will be described.

5 ·Oxygen index

[0068] Test pieces were prepared from the sheets 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 [0069] 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.).

·Modulus of elasticity in tension, tensile strength, and tensile elongation

15 [0070] Test pieces were prepared from the sheets 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 200 mm/min.

·Brittleness temperature

[0071] Tensile test pieces were prepared from the sheets having a thickness of 2 mm. The brittleness temperature was measured in accordance with JIS K7216 using a  
20 measuring apparatus manufactured by Toyo Seiki Seisaku-sho Ltd. The measurement was performed up to a temperature of -25°C.

·Heat deformation rate

[0072] The heat deformation rate was measured in accordance with JIS C3005 with a measuring apparatus manufactured by Yasuda Seiki seisakusho Ltd. using the sheets  
25 having a thickness of 1 mm. 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.

·Volume resistance and change in volume resistance

[0073] Sheets having a thickness of 1 mm were dried in a thermostatic chamber at 80°C. Initial volume resistance of each of the sheets was measured at room temperature at a  
30 voltage of 500 V. The sheet was then immersed in hot water at 80°C for one month. After water droplets on the surface of the sheet were wiped off, volume resistance was again measured at room temperature. A change in the volume resistance was calculated from

these measured values. 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 calculated from the measured value. The change in the volume resistance is  
5 a ratio represented by (volume resistance after immersion in hot water for one month)/(initial volume resistance).

·Specific gravity

[0074] The specific gravity was measured by an ethanol method using an electronic balance manufactured by A & D Company, Limited.

10 Table 1

|                                   |                                                                                                                  | Experimental<br>Example 1 | Experimental<br>Example 2 | Experimental<br>Example 3 | Experimental<br>Example 4 | Experimental<br>Example 5 | Experimental<br>Example 6 |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| Composition<br>[parts by<br>mass] | EEA                                                                                                              | 30                        | 30                        | 20                        | 10                        | 30                        | —                         |
|                                   | EVA                                                                                                              | —                         | —                         | —                         | —                         | —                         | 30                        |
|                                   | HDPE1                                                                                                            | 20                        | 20                        | 20                        | 20                        | 40                        | 20                        |
|                                   | HDPE2                                                                                                            | —                         | —                         | —                         | —                         | —                         | —                         |
|                                   | HDPE3                                                                                                            | —                         | —                         | —                         | —                         | —                         | —                         |
|                                   | MDPE                                                                                                             | —                         | —                         | —                         | —                         | —                         | —                         |
|                                   | LLDPE                                                                                                            | 50                        | 40                        | 50                        | 60                        | 20                        | 40                        |
|                                   | LDPE                                                                                                             | —                         | —                         | —                         | —                         | —                         | —                         |
|                                   | MAH—LLDPE                                                                                                        | —                         | 10                        | 10                        | 10                        | 10                        | 10                        |
|                                   | Metal phosphinate                                                                                                | 20                        | 20                        | 20                        | 20                        | 20                        | 20                        |
|                                   | Aluminum hydroxide                                                                                               | —                         | —                         | —                         | —                         | —                         | —                         |
|                                   | Calcium carbonate                                                                                                | —                         | —                         | —                         | —                         | —                         | —                         |
|                                   | Carbon black 1                                                                                                   | 7                         | 7                         | 7                         | 7                         | 7                         | 7                         |
|                                   | Carbon black 2                                                                                                   | —                         | —                         | —                         | —                         | —                         | —                         |
| Ratio<br>[mass%]                  | Ratio of metal phosphinate                                                                                       | 15.7                      | 15.7                      | 15.7                      | 15.7                      | 15.7                      | 15.7                      |
|                                   | Ratio of carbon black                                                                                            | 5.5                       | 5.5                       | 5.5                       | 5.5                       | 5.5                       | 5.5                       |
| Physical<br>properties            | Oxygen index                                                                                                     | 36                        | 37                        | 37                        | 37                        | 37                        | 37                        |
|                                   | D-hardness                                                                                                       | 50                        | 51                        | 52                        | 53                        | 54                        | 51                        |
|                                   | Modulus of elasticity in<br>tension [MPa]                                                                        | 220                       | 230                       | 240                       | 270                       | 280                       | 230                       |
|                                   | Tensile strength [MPa]                                                                                           | 12.1                      | 12.3                      | 11.8                      | 11.4                      | 11.8                      | 11.3                      |
|                                   | Tensile elongation [%]                                                                                           | 460                       | 480                       | 430                       | 390                       | 380                       | 460                       |
|                                   | Brittleness temperature<br>[°C]                                                                                  | <−25                      | <−25                      | <−25                      | <−25                      | <−25                      | <−25                      |
|                                   | Heat deformation rate [%]                                                                                        | 0                         | 0                         | 0                         | 0                         | 0                         | 0                         |
|                                   | Volume resistance at<br>500 V [ $\Omega \cdot \text{cm}$ ]                                                       | $1.80 \times 10^{16}$     | $1.70 \times 10^{16}$     | $1.50 \times 10^{16}$     | $1.60 \times 10^{16}$     | $1.70 \times 10^{16}$     | $1.40 \times 10^{16}$     |
|                                   | Volume resistance at 500 V<br>After immersion in hot water<br>at 80°C for one month [ $\Omega \cdot \text{cm}$ ] | $1.50 \times 10^{16}$     | $1.50 \times 10^{16}$     | $1.40 \times 10^{16}$     | $1.80 \times 10^{16}$     | $1.40 \times 10^{16}$     | $1.50 \times 10^{16}$     |
|                                   | Change in volume<br>resistance [times]                                                                           | $8.33 \times 10^{-1}$     | $8.82 \times 10^{-1}$     | $9.33 \times 10^{-1}$     | 1.13                      | $8.24 \times 10^{-1}$     | 1.07                      |
|                                   | Specific gravity                                                                                                 | 1.05                      | 1.05                      | 1.05                      | 1.06                      | 1.05                      | 1.05                      |

Table 2

|                                   |                                                                                                                  | Experimental<br>Example 7 | Experimental<br>Example 8 | Experimental<br>Example 9 | Experimental<br>Example 10 | Experimental<br>Example 11 | Experimental<br>Example 12 |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------|---------------------------|---------------------------|---------------------------|----------------------------|----------------------------|----------------------------|
| Composition<br>[parts by<br>mass] | EEA                                                                                                              | 30                        | 30                        | 30                        | 30                         | 30                         | 30                         |
|                                   | EVA                                                                                                              | —                         | —                         | —                         | —                          | —                          | —                          |
|                                   | HDPE1                                                                                                            | —                         | —                         | —                         | 20                         | 20                         | 50                         |
|                                   | HDPE2                                                                                                            | 20                        | —                         | —                         | —                          | —                          | —                          |
|                                   | HDPE3                                                                                                            | —                         | 20                        | —                         | —                          | —                          | —                          |
|                                   | MDPE                                                                                                             | —                         | —                         | 20                        | —                          | —                          | —                          |
|                                   | LLDPE                                                                                                            | 40                        | 40                        | 40                        | 40                         | 40                         | 10                         |
|                                   | LDPE                                                                                                             | —                         | —                         | —                         | —                          | —                          | —                          |
|                                   | MAH—LLDPE                                                                                                        | 10                        | 10                        | 10                        | 10                         | 10                         | 10                         |
|                                   | Metal phosphinate                                                                                                | 20                        | 20                        | 20                        | 20                         | 20                         | 20                         |
|                                   | Aluminum hydroxide                                                                                               | —                         | —                         | —                         | —                          | —                          | —                          |
|                                   | Calcium carbonate                                                                                                | —                         | —                         | —                         | —                          | —                          | —                          |
|                                   | Carbon black 1                                                                                                   | 7                         | 7                         | 7                         | —                          | —                          | 7                          |
|                                   | Carbon black 2                                                                                                   | —                         | —                         | —                         | 5                          | 21                         | —                          |
| Ratio<br>[mass%]                  | Ratio of metal phosphinate                                                                                       | 15.7                      | 15.7                      | 15.7                      | 16.0                       | 14.2                       | 15.7                       |
|                                   | Ratio of carbon black                                                                                            | 5.5                       | 5.5                       | 5.5                       | 4.0                        | 14.9                       | 5.5                        |
| Physical<br>properties            | Oxygen index                                                                                                     | 37                        | 38                        | 38                        | 37                         | 38                         | 35                         |
|                                   | D-hardness                                                                                                       | 53                        | 51                        | 51                        | 51                         | 53                         | 54                         |
|                                   | Modulus of elasticity in<br>tension [MPa]                                                                        | 250                       | 230                       | 230                       | 220                        | 260                        | 280                        |
|                                   | Tensile strength [MPa]                                                                                           | 11.9                      | 12.6                      | 12.7                      | 12.4                       | 11.9                       | 10.7                       |
|                                   | Tensile elongation [%]                                                                                           | 410                       | 490                       | 520                       | 490                        | 360                        | 280                        |
|                                   | Brittleness temperature<br>[°C]                                                                                  | <−25                      | <−25                      | <−25                      | <−25                       | <−25                       | >−20                       |
|                                   | Heat deformation rate [%]                                                                                        | 0                         | 0                         | 0                         | 0                          | 0                          | 0                          |
|                                   | Volume resistance at<br>500 V [ $\Omega \cdot \text{cm}$ ]                                                       | $1.70 \times 10^{16}$     | $1.60 \times 10^{16}$     | $1.80 \times 10^{16}$     | 8000                       | 300                        | $1.80 \times 10^{16}$      |
|                                   | Volume resistance at 500 V<br>After immersion in hot water<br>at 80°C for one month [ $\Omega \cdot \text{cm}$ ] | $1.50 \times 10^{16}$     | $1.60 \times 10^{16}$     | $1.70 \times 10^{16}$     | 8000                       | 300                        | $1.70 \times 10^{16}$      |
|                                   | Change in volume<br>resistance [times]                                                                           | $8.82 \times 10^{-1}$     | 1.00                      | $9.44 \times 10^{-1}$     | 1.00                       | 1.00                       | $9.44 \times 10^{-1}$      |
|                                   | Specific gravity                                                                                                 | 1.05                      | 1.04                      | 1.03                      | 1.04                       | 1.06                       | 1.06                       |

Table 3

|                                   |                                                                                                                  | Experimental<br>Example 13 | Experimental<br>Example 14 | Experimental<br>Example 15 | Experimental<br>Example 16 | Experimental<br>Example 17 | Experimental<br>Example 18 |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Composition<br>[parts by<br>mass] | EEA                                                                                                              | 30                         | 30                         | 30                         | —                          | 30                         | 30                         |
|                                   | EVA                                                                                                              | —                          | —                          | —                          | —                          | —                          | —                          |
|                                   | HDPE1                                                                                                            | —                          | —                          | —                          | 40                         | 20                         | 20                         |
|                                   | HDPE2                                                                                                            | —                          | —                          | —                          | —                          | —                          | —                          |
|                                   | HDPE3                                                                                                            | —                          | —                          | —                          | —                          | —                          | —                          |
|                                   | MDPE                                                                                                             | —                          | —                          | —                          | —                          | —                          | —                          |
|                                   | LLDPE                                                                                                            | 60                         | 60                         | 60                         | 10                         | 40                         | 40                         |
|                                   | LDPE                                                                                                             | —                          | —                          | —                          | —                          | —                          | —                          |
|                                   | MAH—LLDPE                                                                                                        | 10                         | 10                         | 10                         | 50                         | 10                         | 10                         |
|                                   | Metal phosphinate                                                                                                | 20                         | 20                         | 20                         | 20                         | 11                         | 18                         |
|                                   | Aluminum hydroxide                                                                                               | —                          | 20                         | —                          | —                          | —                          | —                          |
|                                   | Calcium carbonate                                                                                                | —                          | —                          | 20                         | —                          | —                          | —                          |
|                                   | Carbon black 1                                                                                                   | 7                          | 7                          | 7                          | 7                          | 7                          | 1                          |
|                                   | Carbon black 2                                                                                                   | —                          | —                          | —                          | —                          | —                          | —                          |
| Ratio<br>[mass%]                  | Ratio of metal phosphinate                                                                                       | 15.7                       | 13.6                       | 13.6                       | 15.7                       | 9.3                        | 15.1                       |
|                                   | Ratio of carbon black                                                                                            | 5.5                        | 4.8                        | 4.8                        | 5.5                        | 5.9                        | 0.8                        |
| Physical<br>properties            | Oxygen index                                                                                                     | 37                         | 37                         | 35                         | 31                         | 29                         | 29                         |
|                                   | D-hardness                                                                                                       | 49                         | 50                         | 50                         | 55                         | 51                         | 50                         |
|                                   | Modulus of elasticity in<br>tension [MPa]                                                                        | 200                        | 240                        | 225                        | 290                        | 230                        | 220                        |
|                                   | Tensile strength [MPa]                                                                                           | 11.3                       | 12.4                       | 12.1                       | 10.4                       | 11.6                       | 11.3                       |
|                                   | Tensile elongation [%]                                                                                           | 420                        | 410                        | 390                        | 110                        | 510                        | 420                        |
|                                   | Brittleness temperature<br>[°C]                                                                                  | <-25                       | <-25                       | <-25                       | >-15                       | <-25                       | <-25                       |
|                                   | Heat deformation rate [%]                                                                                        | 1                          | 0                          | 0                          | 0                          | 1                          | 1                          |
|                                   | Volume resistance at<br>500 V [ $\Omega \cdot \text{cm}$ ]                                                       | $1.70 \times 10^{16}$      | $6.40 \times 10^{15}$      | $1.10 \times 10^{16}$      | $2.10 \times 10^{16}$      | $2.10 \times 10^{16}$      | $2.70 \times 10^{16}$      |
|                                   | Volume resistance at 500 V<br>After immersion in hot water<br>at 80°C for one month [ $\Omega \cdot \text{cm}$ ] | $1.70 \times 10^{16}$      | $5.50 \times 10^{10}$      | $4.50 \times 10^{11}$      | $2.20 \times 10^{16}$      | $2.10 \times 10^{16}$      | $2.30 \times 10^{16}$      |
|                                   | Change in volume<br>resistance [times]                                                                           | 1.00                       | $8.59 \times 10^{-8}$      | $4.09 \times 10^{-5}$      | 1.05                       | 1.00                       | $8.52 \times 10^{-1}$      |
|                                   | Specific gravity                                                                                                 | 1.04                       | 1.12                       | 1.12                       | 1.07                       | 1.03                       | 1.04                       |

[0075] Referring to the results shown in Tables 1 to 3, in Experimental Examples 1 to 9 and 12, an oxygen index of 30 or more, a modulus of elasticity in tension of 220 MPa or more, a tensile strength of 10 MPa or more, a tensile elongation of 280% or more, a D-hardness of 50 or more, a heat deformation rate of 10% or less, a brittleness temperature of -15°C or less, and a specific gravity of less than 1.15 are obtained. Thus, it is clear that high performances are exhibited in terms of the flame retardancy, tensile properties, external scratch resistance, heat deformation rate, low-temperature performance, and

specific gravity. The volume resistance is  $1.0 \times 10^{15} \Omega \cdot \text{cm}$  or more. This result clearly shows that good insulating properties are obtained by using furnace black as carbon black. The volume resistance after immersion in hot water at  $80^\circ\text{C}$  for one month does not significantly decrease from the initial value and is stable with time. This result shows that  
5 good volume resistance stability is also achieved.

[0076] The results in Experimental Examples 10 and 11 show that use of Ketjenblack as carbon black can exhibit semiconductivity in addition to flame retardancy, tensile properties, external scratch resistance, heat deformation rate, low-temperature performance, low specific gravity, and volume resistance stability.

10 [0077] In contrast, in Experimental Example 13, in which a medium- or high-density polyethylene resin is not incorporated, the hardness is low. In Experimental Examples 14 and 15, in which an inorganic filler is incorporated instead of a medium- or high-density polyethylene resin, although the hardness is high, the volume resistance significantly decreases. In Experimental Example 16, in which neither an ethylene-ethyl acrylate  
15 copolymer nor an ethylene-vinyl acetate copolymer is incorporated, the oxygen index is low, and flame retardancy is insufficient. Even when an ethylene-ethyl acrylate copolymer, a low-density polyethylene resin, a medium- or high-density polyethylene resin, a metal phosphinate, and carbon black are contained, in Experimental Example 17, in which the ratio of the metal phosphinate is low, and Experimental Example 18, in which the ratio of  
20 the carbon black is low, the oxygen index is low, and flame retardancy is insufficient. These results clearly show that each of Experimental Examples 13 to 18, which does not satisfy the features specified in the present invention, does not achieve the objects of the present invention.

## CLAIMS

1. A flame-retardant resin composition comprising:

a resin;

5 a metal phosphinate; and

carbon black,

wherein the resin includes an ethylene-ethyl acrylate copolymer or an ethylene-vinyl acetate copolymer, and a polyethylene resin,

10 the polyethylene resin includes a low-density polyethylene resin having a density of 0.9 g/mL or more and less than 0.93 g/mL and a medium- or high-density polyethylene resin having a density of 0.93 g/mL or more,

a content of the metal phosphinate is 10% by mass or more and 25% by mass or less relative to a total amount of the resin composition, and

15 a content of the carbon black is 1.5% by mass or more and 20% by mass or less relative to the total amount of the resin composition.

2. The flame-retardant resin composition according to Claim 1,

20 wherein the resin includes 10 parts by mass or more and 45 parts by mass or less of the ethylene-ethyl acrylate copolymer or the ethylene-vinyl acetate copolymer and 55 parts by mass or more and 90 parts by mass or less of the polyethylene resin relative to 100 parts by mass of the resin in total, and

25 the polyethylene resin includes 15 parts by mass or more and 80 parts by mass or less of the low-density polyethylene resin and 10 parts by mass or more and 40 parts by mass or less of the medium- or high-density polyethylene resin relative to 100 parts by mass of the resin in total.

3. The flame-retardant resin composition according to Claim 1 or 2, wherein the medium- or high-density polyethylene resin has a density of 0.942 g/mL or more.

4. The flame-retardant resin composition according to any one of Claims 1 to 3, wherein the polyethylene resin includes 1 part by mass or more and 15 parts by mass or less of a maleic anhydride-modified polyethylene resin relative to 100 parts by mass of the resin in total.

5

5. The flame-retardant resin composition according to any one of Claims 1 to 4, wherein the carbon black is furnace black or acetylene black, and a content of the carbon black is 1.5% by mass or more and 8% by mass or less relative to the total amount of the resin composition.

10

6. A flame-retardant cable comprising a layer formed of the flame-retardant resin composition according to any one of Claims 1 to 4.

7. A flame-retardant cable comprising an insulating layer formed of the flame-retardant resin composition according to Claim 5.

15