

DESCRIPTION

Title of Invention: POWDER COATING COMPOSITION, COATING FILM, AND COATED BODY

Technical Field

[0001]

The present invention relates to a powder coating composition, a coating film, and a coated body.

Background Art

[0002]

As a powder coating having weatherability and adhesion to a base, a thermosetting powder coating containing a fluorine resin, a non-fluorine resin, and a pigment is conventionally known. Use of a brilliant pigment as the pigment in such a powder coating enables formation of a coating film with brilliance (for example, refer to PTL 1). As the method for forming such a coating film, for example, an electrostatic powder coating method is employed.

[0003]

Incidentally, in general, resin particles and a brilliant pigment (for example, a metal pigment) that constitute a powder coating are significantly different in charging ratio. Therefore, when electrostatic powder coating is performed using a powder coating containing a resin powder and a brilliant pigment, a separation phenomenon is likely to occur between the resin powder and

the brilliant pigment during coating. There is a problem in that, if this separation phenomenon occurs, design quality of the resulting coating film tends to deteriorate.

Furthermore, if the separation phenomenon occurs, the pigment content in the powder coating is likely to change before and after application. The change in this pigment content is likely to cause a change in the color tone between a coating film obtained by using a powder coating after collection and reuse and a coating film obtained by using a powder coating before reuse, resulting in a problem of difficulty of recycling (collection and reuse) of the powder coating.

[0004]

To address this issue, various proposals have been made. For example, PTL 2 and PTL 3 disclose a method of bonding the surface of a thermosetting resin powder to a brilliant pigment with a binding agent having adhesiveness (bonding method) in order to prevent the separation phenomenon between the thermosetting resin powder and the metal pigment. PTL 2 and PTL 3 disclose in Examples that a terpene-based resin is used as the binding agent.

[0005]

Furthermore, PTL 4 discloses a bonding method for, in particular, a fluorine resin powder among resin powders. Specifically, PTL 4 discloses a method in which, in a powder

coating containing a resin powder that includes a fluorine resin and a non-fluorine resin, a brilliant pigment, and a binder, the surface of the thermosetting resin powder is bonded to the brilliant pigment using a binder that includes a surfactant having a melting point of 25°C or higher. PTL 4 discloses in Examples that a fluoro-based halogen-containing solvent is used as a solvent of the binding agent.

Citation List

Patent Literature

[0006]

PTL 1: Japanese Unexamined Patent Application
Publication No. 2011-12119

PTL 2: Japanese Unexamined Patent Application
Publication No. 2004-175813

PTL 3: Japanese Patent No. 3926270

PTL 4: Japanese Patent No. 6841235

Summary of Invention

Technical Problem

[0007]

When the terpene-based resin used in Examples of PTL 2 and PTL 3 is used as the binding agent having adhesiveness, it is necessary to dissolve the terpene-based resin in a low-polarity solvent such as n-heptane. However, in general, such a low-polarity solvent also dissolves fluorine

resins; therefore, use of such a low-polarity solvent for thermosetting resin powder particles including a fluorine resin is likely to cause a problem. Specifically, if the low-polarity solvent is used for thermosetting resin powder particles including a fluorine resin, the fluorine resin partially dissolves and the thermosetting resin powder particles are bound together, which may result in an increase in the particle size of the thermosetting resin powder, a decrease in coating workability, and degradation of appearance of the resulting coating film.

[0008]

In general, the fluoro-based halogen-containing solvent used in Examples of PTL 4 dissolves fluorine resins. Therefore, use of the fluoro-based halogen-containing solvent for thermosetting resin powder particles including a fluorine resin may result in an increase in the particle size of the thermosetting resin powder, a decrease in coating workability, and degradation of appearance of the resulting coating film, as in the case where the low-polarity solvent of PTL 2 and PTL 3 is used.

[0009]

There is also a problem in that when a powder coating contains a resin having a carboxyl group, use of the binders disclosed in PTL 2 to PTL 4 tends to degrade the gloss of the appearance of the coating film.

[0010]

For a powder coating composition that contains resin-containing powder particles, a brilliant pigment, and a binder and that is used for the bonding method, it is desirable to contain a solvent that dissolves the binder but does not dissolve a resin of the resin-containing powder particles. In contrast, the powder coating compositions disclosed in PTL 2 to PTL 4 can be used for the bonding method only when they relate to combinations of specific resins and specific binders. In the industry, a bonding method that is widely applicable to various types of resin-containing powder particles has been desired from the viewpoint of flexibility in designing a powder coating composition.

[0011]

The present invention has been made in view of the problems described above. An object of the present invention is to provide a powder coating composition that is capable of forming a coating film having gloss and excellent brilliance and that has excellent recyclability. Another object of the present invention is to provide a coating film and a coated body that are formed by using the powder coating composition.

Solution to Problem

[0012]

The present inventors have found that, in a powder coating composition containing resin-containing powder particles, a brilliant pigment, and a binder, when a specific Hansen solubility sphere is formed using Hansen solubility parameters (HSP) (δ_d , δ_p , δ_h), and the binder is a resin that dissolves or disperses in a solvent whose interaction distance R_a is 20 or more, the interaction distance R_a being a distance with respect to the center coordinates of the specific Hansen solubility sphere, a powder coating composition that is capable of forming a coating film having gloss and excellent brilliance and that has excellent recyclability is provided. Thus, the present inventors have successfully developed the powder coating composition and completed the present invention.

[0013]

(1) A powder coating composition according to the present invention is a powder coating composition containing resin-containing powder particles (A), a brilliant pigment (B), and a binder (C), wherein the binder (C) is a resin that dissolves or disperses in a solvent (D) whose interaction distance R_a is 20 or more when center coordinates (δ_d , δ_p , δ_h) in a Hansen solubility sphere (HSS) for determining solubility with respect to a solvent to be mixed are set to (19.0, 7.0, 5.0), that has a Tg of 30°C or higher, and that has a weight-average molecular weight of

1,000 to 100,000.

[0014]

(2) The binder (C) is preferably a resin that dissolves or disperses in a solvent (D) whose interaction distance R_a is 30 or more.

[0015]

(3) The binder (C) preferably has a T_g of 40°C or higher.

[0016]

(4) A resin (A1) constituting the resin-containing powder particles (A) is preferably a resin obtained by reacting at least one binder resin (A11) selected from the group consisting of fluorine resins, polyester resins, and acrylic resins with at least one curing agent (A12) selected from the group consisting of epoxy group-containing compounds or polymers thereof, amide compounds, and isocyanate compounds.

[0017]

(5) The solvent (D) is preferably at least one solvent selected from the group consisting of water, ethylene glycol, and methanol.

[0018]

(6) The solvent (D) is preferably a mixed solvent of water and a water-soluble organic solvent.

[0019]

(7) The brilliant pigment (B) is preferably composed of flaky aluminum particles.

[0020]

(8) A coating film according to the present invention is formed using the above powder coating composition.

[0021]

(9) A coated body according to the present invention includes a base and a coating film formed on a surface of the base using the above powder coating composition.

Advantageous Effects of Invention

[0022]

The present invention can provide a powder coating composition that is capable of forming a coating film having gloss and excellent brilliance and that has excellent recyclability. In addition, the present invention can provide a coating film formed by using the powder coating composition and a coated body including the coating film.

Brief Description of Drawings

[0023]

[Fig. 1] Fig. 1 is a drawing for explaining a method for creating a Hansen solubility sphere having specific center coordinates and a specific interaction radius R_0 on a Hansen 3D graph using HSP (δ_d , δ_p , δ_h).

[Fig. 2] Fig. 2 is a drawing showing a solvent group that dissolves a resin (imaginary resin X) used for forming

a specific Hansen solubility sphere and a solvent group that does not dissolve the resin (imaginary resin X).

[Fig. 3] Fig. 3 is a drawing showing a solvent group that dissolves a resin (imaginary resin X) used for forming the specific Hansen solubility sphere, a solvent group that does not dissolve the resin (imaginary resin X), and a solvent located at an interaction distance R_a from center coordinates (CC) of the specific Hansen solubility sphere.

Description of Embodiments

[0024]

Hereinafter, embodiments of the present invention will be described with reference to the drawings. It should be noted that the shapes and sizes of the drawings are changed as appropriate for convenience of explanation. Therefore, the shapes of the drawings do not limit the present invention.

[0025]

[Powder coating composition]

A powder coating composition according to the present invention contains resin-containing powder particles (A), a brilliant pigment (B), and a binder (C).

[0026]

(Resin-containing powder particles (A))

The resin-containing powder particles (A) include at least a resin (A1). The resin (A1) includes at least a

binder resin (A11) and may include a curing agent (A12) as necessary. The curing agent (A12) is a compound or a polymer that reacts with the binder resin (A11).

Preferably, the curing agent (A12) does not react during preparation of the resin-containing powder particles (A) but reacts when a film is formed using the powder coating composition.

[0027]

The resin-containing powder particles (A) are prepared so as to include the resin (A1) by, for example, melt-kneading a mixture including at least the binder resin (A11) and the curing agent (A12) that is blended as necessary, and subsequently cooling and pulverizing the kneaded product. The mixture may further include, for example, an additive (A2) such as a surface conditioner or a lubricant and a color pigment (A3) as necessary.

[0028]

When the mixture further includes the additive (A2), the obtained resin-containing powder particles (A) include the resin (A1) and a component derived from the additive (A2). The "component derived from the additive (A2)" as used herein means the additive (A2) itself or a reaction product between the additive (A2) and another component.

[0029]

When the mixture further includes the color pigment

(A3), the obtained resin-containing powder particles (A) include the resin (A1) and the color pigment (A3).

[0030]

When the mixture further includes the additive (A2) and the color pigment (A3), the obtained resin-containing powder particles (A) include the resin (A1), a component derived from the additive (A2), and the color pigment (A3).

[0031]

<Binder resin (A11)>

As the binder resin (A11), for example, at least one selected from the group consisting of fluorine resins, polyester resins, and acrylic resins is used, and a plurality of binders may be blended in combination.

[0032]

The fluorine resins used for the binder resin (A11) are fluorine-containing copolymers obtained by polymerizing or copolymerizing fluorine-containing monomers.

[0033]

The fluorine resins used are each, for example, a resin that is solid at room temperature and has a softening point of 50°C to 150°C.

[0034]

Examples of the fluorine-containing monomers that can be used include vinyl fluoride, vinylidene fluoride, trifluoroethylene, tetrafluoroethylene,

bromotrifluoroethylene, chlorotrifluoroethylene, pentafluoropropylene, hexafluoropropylene, (per)fluoroalkyl trifluorovinyl ethers [where the (per)fluoroalkyl group has 1 to 18 carbon atoms].

[0035]

The fluorine resin may be a resin obtained by copolymerizing a fluorine-containing monomer and a polymerizable monomer other than fluorine-containing monomers. As the polymerizable monomer, vinyl ethers, olefins, allyl ethers, vinyl esters, allyl esters, (meth)acrylic acid esters, crotonic acid esters, and the like are used.

[0036]

Examples of polymerizable monomers that can be used include:

alkyl vinyl ethers such as methyl vinyl ether, ethyl vinyl ether, butyl vinyl ether, isobutyl vinyl ether, cyclohexyl vinyl ether, and chloroethyl vinyl ether;
olefins such as ethylene, propylene, 1-butene, isobutylene, cyclohexene, vinyl chloride, and vinylidene chloride;
styrene-based monomers such as styrene and α -methylstyrene;
alkyl allyl ethers such as methyl allyl ether, ethyl allyl ether, butyl allyl ether, and cyclohexyl allyl ether;
fatty acid vinyl esters such as vinyl acetate, vinyl propionate, vinyl butyrate, vinyl isobutyrate, vinyl

valerate, vinyl hexanoate, vinyl octanoate, and vinyl versatate;

fatty acid allyl esters such as allyl propionate and allyl acetate;

(meth)acrylic acid esters such as methyl (meth)acrylate, ethyl (meth)acrylate, butyl (meth)acrylate, and cyclohexyl (meth)acrylate;

(meth)acrylic acid amides such as (meth)acrylamide; cyano group-containing monomers such as acrylonitrile and 2,4-dicyanobutene-1; and dienes such as isoprene and butadiene.

[0037]

The fluorine resin may have a reactive site that reacts with the curing agent or the like. The fluorine resin may be a copolymer of at least one of the foregoing fluorine-containing monomers and the foregoing polymerizable monomers, and a reactive group-containing monomer.

[0038]

As the reactive group-containing monomer, monomers containing a functional group such as a hydroxyl group, a carboxyl group, an amide group, an amino group, a nitrile group, a glycidyl group, or an isocyanate group are used. Examples of reactive group-containing monomers that can be used include hydroxyl group-containing monomers, carboxyl group-containing monomers, amino group-containing

monomers, amide group-containing monomers, nitrile group-containing monomers, glycidyl group-containing monomers, and isocyanate group-containing monomers.

[0039]

Examples of the hydroxyl group-containing monomers that can be used include:

allyl alcohol;

hydroxyalkyl vinyl ethers such as 2-hydroxyethyl vinyl ether, 3-hydroxypropyl vinyl ether, 4-hydroxybutyl vinyl ether, and 4-hydroxycyclohexyl vinyl ether;

hydroxyalkyl allyl ethers such as 2-hydroxyethyl allyl ether, 3-hydroxypropyl allyl ether, 4-hydroxybutyl allyl ether, and 4-hydroxycyclohexyl allyl ether;

hydroxyalkyl (meth)acrylates such as 2-hydroxyethyl (meth)acrylate;

esters of hydroxyalkyl carboxylic acids with vinyl alcohol, such as vinyl hydroxyacetate, vinyl hydroxyisobutyrate, vinyl hydroxypropionate, vinyl hydroxybutyrate, vinyl hydroxyvalerate, and vinyl hydroxycyclohexylcarboxylate; and hydroxyalkyl allyl esters such as hydroxyethyl allyl ester, hydroxypropyl allyl ester, hydroxybutyl allyl ester, and hydroxyisobutyl allyl ester.

[0040]

Examples of the carboxyl group-containing monomers that can be used include (meth)acrylic acid and carboxyalkyl

allyl esters. Examples of the amino group-containing monomers that can be used include aminoalkyl vinyl ethers and aminoalkyl allyl ethers. Examples of the amide group-containing monomers that can be used include (meth)acrylamide and N-methyl(meth)acrylamide. Examples of the nitrile group-containing monomers that can be used include (meth)acrylonitrile. Examples of the glycidyl group-containing monomers that can be used include glycidyl allyl ether and glycidyl (meth)acrylate. Examples of the isocyanate group-containing monomers that can be used include vinyl isocyanate and isocyanate ethyl acrylate.

[0041]

The fluorine resin used in the present invention preferably has a fluorine content of 10% to 70% by mass.

[0042]

When a curing agent that reacts with a hydroxyl group is used as the curing agent component (A12), the hydroxyl value of the fluorine resin is preferably 10 to 100 mgKOH/g, more preferably 30 to 70 mgKOH/g.

[0043]

When a curing agent that reacts with a carboxyl group is used as the curing agent component (A12), the acid value of the fluorine resin is preferably 1 to 80 mgKOH/g, more preferably 10 to 60 mgKOH/g.

[0044]

The polyester resins used for the binder resin (A11) are each a resin that is obtained by reacting a carboxylic acid with a polyhydric alcohol by a publicly known method and is solid at room temperature. The polyester resin preferably has a softening point of 100°C to 150°C.

[0045]

Examples of carboxylic acid components that include a carboxylic acid and can be used include polycarboxylic acids such as phthalic acid, isophthalic acid, terephthalic acid, naphthalenedicarboxylic acid, succinic acid, glutaric acid, adipic acid, pimelic acid, suberic acid, azelaic acid, sebacic acid, 1,9-nonanedicarboxylic acid, 1,10-decanedicarboxylic acid, 1,12-dodecanedicarboxylic acid, 1,2-octadecanedicarboxylic acid, maleic acid, fumaric acid, cyclohexanedicarboxylic acid, hexahydrophthalic acid, tetrahydrophthalic acid, trimellitic acid, and pyromellitic acid; lower alkyl esters and anhydrides of any of these polycarboxylic acids; and hydroxycarboxylic acids such as malic acid, tartaric acid, 1,2-hydroxystearic acid, and parahydroxybenzoic acid.

[0046]

Examples of the polyhydric alcohol that can be used include ethylene glycol, diethylene glycol, triethylene glycol, 1,2-propanediol, 1,3-propanediol, 1,3-butanediol, 1,4-butanediol, 1,5-pentanediol, 1,6-hexanediol, 1,9-

nonanediol, 1,10-decanediol, neopentyl glycol, spiroglycol, 1,4-cyclohexanedimethanol, trimethylolethane, trimethylolpropane, glycerin, and pentaerythritol.

[0047]

The polyester resin can be produced using the carboxylic acid component and the polyhydric alcohol as raw materials by a common procedure for producing a polyester resin for a powder coating. For example, the polyester resin can be produced by performing esterification or transesterification reaction at 200°C to 280°C in accordance with a common procedure using the foregoing raw materials in an appropriate combination at an appropriate blending ratio, subsequently performing polycondensation reaction under reduced pressure using a catalyst at 230°C to 290°C, and subsequently performing depolymerization reaction with an alcohol component.

[0048]

The polyester resin preferably has a number-average molecular weight of 8,000 or less and a weight-average molecular weight of 10,000 to 20,000 from the viewpoint of controlling the melt viscosity.

[0049]

When a curing agent that reacts with a hydroxyl group is used as the curing agent component (A12), the hydroxyl value of the polyester resin is preferably 20 to 100

mgKOH/g, more preferably 30 to 80 mgKOH/g.

[0050]

When a curing agent that reacts with a carboxyl group is used as the curing agent component (A12), the acid value of the polyester resin is preferably 1 to 80 mgKOH/g, more preferably 10 to 60 mgKOH/g.

[0051]

Regarding a powder coating containing a fluorine resin and a polyester resin, when the melt viscosity of the polyester resin used is 3.5 Pa·s (190°C) or less, and a slope determined from the Arrhenius plot of the viscosity and the temperature in a range of 100°C to 120°C is 15,000 or more in the case where the melt viscosity is measured with a rheometer from 200°C at a temperature decrease rate of 10°C/min, a fluorine resin component tends to be unevenly distributed on the surface layer of a coating film in the formation of the coating film. When the fluorine resin component is unevenly distributed on the surface layer of the coating film in this manner, the coating film has good weatherability.

[0052]

The slope is calculated, for example, by the following method. First, the viscosity is measured using a rheometer ARES manufactured by TA Instruments under the measurement conditions of a parallel plate with a diameter of 40 mm, a

gap width of 1.0 mm, a frequency of 9.42 rad/s, and a strain of 1.0%. Next, the reciprocal $1/T$ of the temperature T (K) and the logarithm $\ln V$ of the viscosity V are plotted on the horizontal axis and the vertical axis, respectively, on a graph using the obtained measurement results (Arrhenius plot). The slope of the obtained straight line in the range of 100°C to 120°C is then determined, and this value is used as the slope.

[0053]

The slope is more preferably 16,000 to 20,000 from the viewpoint of the ease of the layer separation of the coating film.

[0054]

Each of the acrylic resins used for the binder resin (A11) is a resin that is solid at room temperature and is a polymer of an acrylic acid ester or a methacrylic acid ester. Examples of the acrylic resin that can be used include polymers obtained by polymerizing one or a plurality of acrylic components selected from acrylic acid, methacrylic acid, and esters, amides, nitriles, and the like thereof. As the acrylic resin, a polymer obtained by polymerizing an acrylic component and, for example, a non-acrylic component such as styrene is also used. The acrylic resin preferably has a softening point of 100°C to 150°C, a number-average molecular weight of 8,000 or less, and a

weight-average molecular weight of 10,000 to 20,000 from the viewpoint of controlling the melt viscosity.

[0055]

Examples of the acrylic component that can be used include (meth)acrylate monomers such as methyl (meth)acrylate, ethyl (meth)acrylate, n-propyl (meth)acrylate, isopropyl (meth)acrylate, n-butyl (meth)acrylate, sec-butyl (meth)acrylate, isobutyl (meth)acrylate, tert-butyl (meth)acrylate, hexyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, octyl (meth)acrylate, nonyl (meth)acrylate, decyl (meth)acrylate, dodecyl (meth)acrylate, n-amyl (meth)acrylate, isoamyl (meth)acrylate, lauryl (meth)acrylate, stearyl (meth)acrylate, cyclohexyl (meth)acrylate, phenyl (meth)acrylate, benzyl (meth)acrylate, methoxyethyl (meth)acrylate, ethoxyethyl (meth)acrylate, methoxypropyl (meth)acrylate, and ethoxypropyl (meth)acrylate; and functional group-containing monomers such as 2-hydroxyethyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, 3-hydroxypropyl (meth)acrylate, 4-hydroxybutyl (meth)acrylate, 2-aminoethyl (meth)acrylate, dimethylaminoethyl (meth)acrylate, 3-aminopropyl (meth)acrylate, 2-butylaminoethyl (meth)acrylate, glycidyl (meth)acrylate, and allyl glycidyl ether. Examples of the acrylic component that can be used further include acrylic acid and

methacrylic acid; amide monomers such as acrylamide and methacrylamide; and alkoxysilyl group-containing monomers such as γ -(meth)acryloxypropyltrimethoxysilane, γ -(meth)acryloxypropyltriethoxysilane, β -(meth)acryloxyethyltrimethoxysilane, β -(meth)acryloxyethyltriethoxysilane, γ -(meth)acryloxypropylmethyldimethoxysilane, γ -(meth)acryloxypropylmethyldiethoxysilane, γ -(meth)acryloxypropylmethyldipropoxysilane, γ -(meth)acryloxybutylphenyldimethoxysilane, γ -(meth)acryloxypropyldimethylmethoxysilane, and γ -(meth)acryloxypropyldiethylmethoxysilane.

[0056]

The ratio of the acrylic component to all the components constituting the acrylic resin is, for example, 40% to 100% by mass.

[0057]

Examples of the non-acrylic component that can be used include carboxyl group-containing monomers such as fumaric acid, maleic acid, maleic anhydride, itaconic acid, itaconic anhydride, crotonic acid, and vinyl versatic acid; aromatic monomers such as styrene, methylstyrene, chlorostyrene, methoxystyrene, and vinyltoluene; olefin monomers such as ethylene and propylene; vinyl monomers such as vinyl acetate and vinyl chloride; amide monomers such as maleic acid

amide; alkoxysilyl group-containing monomers such as vinyltrimethoxysilane, vinyltriethoxysilane, vinylmethyldimethoxysilane, and vinylmethyldiethoxysilane; dialkyl fumarate; allyl alcohol; vinylpyridine; and butadiene.

[0058]

When a curing agent that reacts with a hydroxyl group is used as the curing agent component (A12), the hydroxyl value of the acrylic resin is preferably 20 to 100 mgKOH/g, more preferably 30 to 80 mgKOH/g.

[0059]

When a curing agent that reacts with a carboxyl group is used as the curing agent component (A12), the acid value of the acrylic resin is preferably 1 to 80 mgKOH/g, more preferably 10 to 60 mgKOH/g.

[0060]

<Curing agent (A12)>

As the curing agent (A12), at least one selected from the group consisting of epoxy group-containing compounds or polymers thereof, amide compounds, and isocyanate compounds is used.

[0061]

Such an epoxy group-containing compound is preferably a compound having a plurality of epoxy groups in its molecule, and a typical example thereof is triglycidyl isocyanurate.

Examples of such an epoxy group-containing polymer (hereinafter, also referred to as an epoxy resin) include bisphenol epoxy resins such as bisphenol A epoxy resins and bisphenol F epoxy resins, naphthalene epoxy resins, biphenyl epoxy resins, novolac epoxy resins, cycloaliphatic epoxy resins, glycidylamine resins, heterocyclic epoxy resins, and polyfunctional epoxy resins. These may be used alone or in combination.

[0062]

Examples of the epoxy resin that can be used include solid epoxy resins synthesized from bisphenol A and an epihalohydrin such as epichlorohydrin and solid epoxy resins obtained by elongation reaction between bisphenol A and an epoxy resin derived from bisphenol A, a dihydric phenol, and an epihalohydrin.

[0063]

Examples of usable epoxy resins that are available on the market include jER1004, jER1004F, jER1007, and jER4005P manufactured by Mitsubishi Chemical Corporation, EPICLON3050 and EPICLON4050 manufactured by DIC Corporation, Epotohto YD014D manufactured by NIPPON STEEL Chemical & Material Co., Ltd., and EPONANYA NPES-904 manufactured by Nan Ya Plastics Corporation.

[0064]

The softening point of the epoxy resin is not

particularly limited but is preferably 60°C to 150°C. The epoxy equivalent of the epoxy resin is also not particularly limited but is preferably 400 to 3,000.

[0065]

As the epoxy resin, a mixture of a plurality of epoxy resins having different epoxy equivalents may be used. When a plurality of epoxy resins are mixed, an epoxy resin having an epoxy equivalent of 1,000 or less and an epoxy resin having an epoxy equivalent of 1,000 or more are preferably combined.

[0066]

In the epoxy resin, the difference in epoxy equivalent between an epoxy resin having a minimum epoxy equivalent (A-min) and an epoxy resin having a maximum epoxy equivalent (A-max) is typically 300 or more, preferably 500 or more, more preferably 800 or more.

[0067]

As the amide compounds, for example, β -hydroxyalkylamides are used. Such a β -hydroxyalkylamide is preferably a β -hydroxyalkylamide having two or more functional groups per molecule from the viewpoints of low-temperature curability and water resistance of the coating film obtained by coating. The β -hydroxyalkylamide is more preferably N,N-di(β -hydroxyethyl)acetamide, bis(β -hydroxyethyl)adipamide, bis(β -hydroxypropyl)adipamide,

bis[N,N-di(β -hydroxyethyl)]adipamide, or bis[N,N-di(β -hydroxypropyl)]adipamide from the viewpoints of low-temperature curability and water resistance of the coating film obtained by coating. The β -hydroxyalkylamide preferably has 0.5 to 1.5 equivalents of hydroxylamide groups relative to carboxyl groups in the resin.

[0068]

As the isocyanate compounds, for example, blocked isocyanate compounds are used. Isocyanate compounds that are solid at room temperature are preferably used.

[0069]

Such a blocked isocyanate compound can be produced by reacting an aliphatic, aromatic, or araliphatic diisocyanate with a low-molecular-weight compound having active hydrogen to obtain a polyisocyanate, and then reacting the polyisocyanate with a blocking agent to perform masking and is therefore easy to produce.

[0070]

Examples of the diisocyanate that can be used include tolylene diisocyanate, 4,4'-diphenylmethane diisocyanate, xylylene diisocyanate, hexamethylene diisocyanate, 4,4'-methylenebis(cyclohexyl isocyanate), methylcyclohexane diisocyanate, bis(isocyanatomethyl)cyclohexane, isophorone diisocyanate, dimer acid diisocyanate, and lysine diisocyanate.

[0071]

Examples of the low-molecular-weight compound having active hydrogen that can be used include water, ethylene glycol, propylene glycol, trimethylolpropane, glycerin, sorbitol, ethylenediamine, ethanolamine, diethanolamine, hexamethylenediamine, isocyanurate, uretdione, hydroxyl group-containing low-molecular-weight polyesters, and polycaprolactone.

[0072]

Examples of the blocking agent that can be used include alcohols such as methanol, ethanol, and benzyl alcohol; phenols such as phenol and cresol; lactams such as caprolactam and butyrolactam; oximes such as cyclohexanone, oxime, and methyl ethyl ketoxime.

[0073]

For example, as specific examples of the blocked isocyanate, isophorone diisocyanates blocked with ϵ -caprolactam (VESTAGON B1530 manufactured by Evonik Industries AG and Crelan UI manufactured by Bayer AG) and the like are used.

[0074]

The softening point of the isocyanate compound is preferably 10°C to 120°C, more preferably 40°C to 100°C. If the softening point is lower than 10°C, the powder coating composition may be cured in a room-temperature environment

or granular lumps may be formed. On the other hand, if the softening point exceeds 120°C, in producing the powder coating composition by melt-kneading, it is difficult to uniformly disperse the isocyanate compound in the powder coating composition, and performances such as smoothness, coating film strength, and moisture resistance of a coating film to be formed may be impaired.

[0075]

The isocyanate compound preferably has 0.05 to 1.5 equivalents, more preferably 0.8 to 1.2 equivalents of isocyanate groups relative to hydroxyl groups in the resin. If the equivalent of isocyanate groups is less than 0.05, the degree of curing of the powder coating composition is insufficient, and coating film performances such as adhesiveness, coating film hardness, and chemical resistance may degrade. If the equivalent of isocyanate groups exceeds 1.5, the coating film may be brittle, and heat resistance, chemical resistance, moisture resistance, etc. may decrease. Furthermore, since blocked isocyanates are expensive, excessive use of a blocked isocyanate tends to increase the cost.

[0076]

The resin (A1) constituting the resin-containing powder particles (A) preferably includes at least one binder resin (A11) selected from the group consisting of fluorine resins,

polyester resins, and acrylic resins and at least one curing agent (A12) selected from the group consisting of epoxy group-containing compounds or polymers thereof, amide compounds, and isocyanate compounds.

[0077]

The resin (A1) constituting the resin-containing powder particles (A) more preferably includes at least one binder resin (A11) selected from the group consisting of fluorine resins and polyester resins and a curing agent (A12) composed of an isocyanate compound.

[0078]

The resin (A1) constituting the resin-containing powder particles (A) more preferably includes a binder resin (A11) composed of a polyester resin and a curing agent (A12) composed of an epoxy group-containing compound or a polymer thereof.

[0079]

The resin (A1) constituting the resin-containing powder particles (A) more preferably includes a binder resin (A11) composed of a polyester resin and a curing agent (A12) composed of an amide compound.

[0080]

<Additive (A3)>

Examples of the additive (A3) that can be used include plasticizers, curing accelerators, crosslinking accelerator

catalysts, surface conditioners, ultraviolet absorbers, light stabilizers, antioxidants, fluidity modifiers, anti-sagging agents, and antifoaming agents which are additives for general coatings.

[0081]

<Color pigment (A4)>

Examples of the color pigment (A4) that can be used include inorganic pigments such as titanium oxide, yellow iron oxide, titanium yellow, colcothar (red iron oxide), lithopone, and antimony oxide; and organic pigments such as Hansa Yellow 5G, Permanent Yellow FGL, Phthalocyanine Blue, Indanthrene Blue RS, Permanent Red F5RK, and Brilliant Fast Scarlet G.

[0082]

As described above, the resin-containing powder particles (A) are prepared so as to include the resin (A1) by, for example, melt-kneading a mixture including at least the binder resin (A11) and the curing agent (A12) and subsequently cooling and pulverizing the kneaded product.

[0083]

The resin-containing powder particles (A) may further include a component derived from the additive (A2), the color pigment (A3), etc. as necessary in addition to the resin (A1).

[0084]

The 50% volume-average particle size of the resin-containing powder particles (A) is, for example, 15 to 100 μm , preferably 20 to 70 μm , more preferably 30 to 50 μm .

[0085]

(Brilliant pigment (B))

Examples of the brilliant pigment (B) that can be used include aluminum powder pigments, nickel powder pigments, stainless steel powder pigments, copper powders, bronze powders, gold powders, silver powders, mica pigments, graphite pigments, glass flake pigments, flaked plastic pigments, and scaly iron oxide pigments. As an aluminum powder pigment, for example, flaky aluminum particles are used. The brilliant pigment (B) is preferably composed of flaky aluminum particles because high brilliance is achieved.

[0086]

The 50% volume-average particle size of the brilliant pigment (B) is, for example, 3 to 100 μm , preferably 5 to 80 μm , more preferably 15 to 60 μm .

[0087]

The aspect ratio of the brilliant pigment (B) is, for example, 2 to 60, preferably 3 to 40, more preferably 5 to 25.

[0088]

(Binder (C))

The binder (C) is a resin for binding (bonding) the resin-containing powder particles (A) and the brilliant pigment (B) together. The binder (C) is used by being dissolved or dispersed in a solvent (D) so as to have fluidity when binding (bonding) of the resin-containing powder particles (A) and the brilliant pigment (B) is performed.

[0089]

The binder (C) constituting the powder coating composition according to the present invention is configured to be used together with a solvent (D) that does not dissolve the resin (A1) constituting the resin-containing powder particles (A) but dissolves or disperses the binder (C) when binding (bonding) of the resin-containing powder particles (A) and the brilliant pigment (B) is performed.

[0090]

Specifically, the binder (C) is a resin that dissolves or disperses in a solvent (D) whose interaction distance R_a is in a specific range, the interaction distance R_a being a distance from specific center coordinates $(\delta_d, \delta_p, \delta_h) = (19.0, 7.0, 5.0)$ of a Hansen solubility sphere on a Hansen 3D graph, and that has a T_g and a weight-average molecular weight in specific ranges.

[0091]

More specifically, the binder (C) is a resin that

dissolves or disperses in a solvent (D) whose interaction distance R_a is 20 or more when the center coordinates (δ_d , δ_p , δ_h) in a Hansen solubility sphere for determining solubility with respect to a solvent to be mixed are set to (19.0, 7.0, 5.0), that has a Tg of 30°C or higher, and that has a weight-average molecular weight of 1,000 to 100,000.

[0092]

The Hansen 3D graph, the Hansen solubility sphere, the center coordinates (δ_d , δ_p , δ_h), and the interaction distance R_a are formed and calculated on the basis of HSP (δ_d , δ_p , δ_h). These concepts will be described below with reference to the drawings.

[0093]

<Hansen solubility parameters (HSP)>

Fig. 1 is a drawing for explaining a method for creating a Hansen solubility sphere having specific center coordinates and a specific interaction radius R_0 on a Hansen 3D graph using HSP (δ_d , δ_p , δ_h).

[0094]

Hansen HSP (δ_d , δ_p , δ_h) of a certain substance X are parameters defined by a formula (1) below.

[0095]

[Math. 1]

$$\delta^2 = \left(\frac{\Delta E^V}{V} \right) = \left(\frac{\Delta E_d^V}{V} \right) + \left(\frac{\Delta E_p^V}{V} \right) + \left(\frac{\Delta E_h^V}{V} \right)$$

$$= \delta_d^2 + \delta_p^2 + \delta_h^2 \quad \cdot \cdot \cdot (1)$$

(δ : Hildebrand solubility parameter (SP) $[\text{KJ}/\text{cm}^3]^{1/2}$ of substance X, ΔE^V : molar energy of vaporization $[\text{KJ}/\text{mol}]$ of substance X, V : molar molecular volume $[\text{cm}^3/\text{mol}]$ of substance X, ΔE_d^V : molar energy of vaporization $[\text{KJ}/\text{mol}]$ of dispersion force term of substance X, ΔE_p^V : molar energy of vaporization $[\text{KJ}/\text{mol}]$ of dipole interaction force term of substance X, ΔE_h^V : molar energy of vaporization $[\text{KJ}/\text{mol}]$ of hydrogen-bonding force term of substance X, δ_d : dispersion force term of HSP of substance X, δ_p : dipole interaction force term of HSP of substance X, δ_h : hydrogen-bonding force term of HSP of substance X)

[0096]

In the present invention, as for the above substance X, an imaginary resin X is set as a resin applicable to many resins (A1) constituting the resin-containing powder particles (A). Specifically, in the present invention, this imaginary resin X is set as a resin located at specific center coordinates $(\delta_d, \delta_p, \delta_h) = (19.0, 7.0, 5.0)$ in a Hansen solubility sphere. In the present invention, since the specific center coordinates $(\delta_d, \delta_p, \delta_h) = (19.0, 7.0, 5.0)$ are set as the center coordinates of the Hansen

solubility sphere, the brilliant pigment can be bonded to various types of resin-containing powder particles.

[0097]

As illustrated in Fig. 1, the HSP (δ_d , δ_p , δ_h) are denoted on a Hansen 3D graph G having three axes of a δ_d axis, a δ_p axis, and a δ_h axis. On the Hansen 3D graph G, the HSP (δ_d , δ_p , δ_h) are denoted at a point XC in Fig. 1.

[0098]

In the present invention, as specific numerical values of the point XC (δ_d , δ_p , δ_h) in Fig. 1, (δ_d , δ_p , δ_h) = (19.0, 7.0, 5.0) of the imaginary resin X are used as described above, and these parameters (δ_d , δ_p , δ_h) = (19.0, 7.0, 5.0) are set as center coordinates CC of a Hansen solubility sphere HSS.

[0099]

In the present invention, the Hansen solubility sphere HSS is created using (δ_d , δ_p , δ_h) = (19.0, 7.0, 5.0) of the imaginary resin X as the center coordinates CC. The Hansen solubility sphere HSS is the smallest sphere including only solvents that dissolve the imaginary resin X. The smallest sphere is calculated as a smallest sphere including only solvents that dissolve the imaginary resin X when a test or simulation to examine whether or not the imaginary resin X dissolves in various solvents is performed.

[0100]

The radius of the Hansen solubility sphere HSS is defined as an interaction radius R_0 . The interaction radius R_0 is, in an interaction distance R_a which is defined by a formula (2) below and is a distance from the center coordinates CC on the Hansen 3D graph G, the radius of the smallest Hansen solubility sphere HSS including only solvents that dissolve the imaginary resin X. In the formula (2) below, a component 1 is the imaginary resin X, and a component 2 is a solvent. In the present invention, on the basis of the results of the "test or simulation to examine whether or not the imaginary resin X dissolves in various solvents" described above, it has been found that the interaction radius R_0 of the imaginary resin X can be set to less than 20 (provided that 0 is excluded).

[0101]

[Math. 2]

$$R_a = \left[4 \cdot (\delta_{d,2} - \delta_{d,1})^2 + (\delta_{p,2} - \delta_{p,1})^2 + (\delta_{h,2} - \delta_{h,1})^2 \right]^{1/2} \quad \dots (2)$$

(R_a : interaction distance, $\delta_{d,1}$: dispersion force term of HSP of component 1 (imaginary resin X), $\delta_{d,2}$: dispersion force term of HSP of component 2 (solvent), $\delta_{p,1}$: dipole interaction force term of HSP of component 1 (imaginary resin X), $\delta_{p,2}$: dipole interaction force term of HSP of component 2 (solvent), $\delta_{h,1}$: hydrogen-bonding force term of HSP of component 1 (imaginary resin X), $\delta_{h,2}$: hydrogen-

bonding force term of HSP of component 2 (solvent))

[0102]

Incidentally, in general, $\Delta\delta$ defined by a formula (3) below, that is, the distance $\Delta\delta$ between solubility parameters (HSP) $(\delta_{d,1}, \delta_{p,1}, \delta_{h,1})$ of the component 1 (imaginary resin X) on the Hansen 3D graph G and HSP $(\delta_{d,2}, \delta_{p,2}, \delta_{h,2})$ of the component 2 (solvent) on the Hansen 3D graph G serves as an indicator that indicates solubility between the component 1 (imaginary resin X) and the component 2 (solvent). The smaller $\Delta\delta$, the easier it is for the two components to dissolve. The larger $\Delta\delta$, the more difficult it is for the two components to dissolve.

[0103]

[Math. 3]

$$\Delta \delta = \left[(\delta_{d,2} - \delta_{d,1})^2 + (\delta_{p,2} - \delta_{p,1})^2 + (\delta_{h,2} - \delta_{h,1})^2 \right]^{1/2} \quad \dots (3)$$

($\Delta\delta$: distance between solubility parameters HSP $(\delta_{d,1}, \delta_{p,1}, \delta_{h,1})$ of component 1 (imaginary resin X) on Hansen 3D graph G and HSP $(\delta_{d,2}, \delta_{p,2}, \delta_{h,2})$ of component 2 (solvent) on Hansen 3D graph G, $\delta_{d,1}$: dispersion force term of HSP of component 1 (imaginary resin X), $\delta_{d,2}$: dispersion force term of HSP of component 2 (solvent), $\delta_{p,1}$: dipole interaction force term of HSP of component 1 (imaginary resin X), $\delta_{p,2}$: dipole interaction force term of HSP of component 2 (solvent), $\delta_{h,1}$: hydrogen-bonding force term of HSP of component 1 (imaginary

resin X), $\delta_{h,2}$: hydrogen-bonding force term of HSP of component 2 (solvent))

[0104]

Fig. 2 is a drawing showing a solvent group that dissolves the resin (imaginary resin X) used for forming a specific Hansen solubility sphere and a solvent group that does not dissolve the resin (imaginary resin X).

[0105]

In Fig. 2, solvents indicated by plots "o (open circles)" are located inside a Hansen solubility sphere HSS having center coordinates CC and an interaction radius R_0 and dissolve the imaginary resin X. Solvents indicated by plots "□ (open squares)" are located outside the Hansen solubility sphere HSS and do not dissolve the imaginary resin X.

[0106]

Fig. 3 is a drawing showing a solvent group that dissolves the resin (imaginary resin X) used for forming the specific Hansen solubility sphere, a solvent group that does not dissolve the resin (imaginary resin X), and a solvent located at an interaction distance R_a from the center coordinates CC of the specific Hansen solubility sphere.

[0107]

In Fig. 3, solvents indicated by plots o are located inside the Hansen solubility sphere HSS having the center

coordinates CC and the interaction radius R_0 and dissolve the imaginary resin X. Solvents indicated by plots $\square$ are located outside the Hansen solubility sphere HSS and do not dissolve the imaginary resin X. Furthermore, among the solvents indicated by the plots $\square$, a solvent indicated by a plot DD is located outside the Hansen solubility sphere HSS, and the interaction distance R_a thereof is significantly larger than the interaction radius R_0 ; therefore, this solvent certainly does not dissolve the imaginary resin X.

[0108]

The binder (C) is a resin that dissolves or disperses in a solvent (D) whose interaction distance R_a is 20 or more, preferably a solvent (D) whose interaction distance R_a is 25 or more, more preferably a solvent (D) whose interaction distance R_a is 30 or more. The solvent (D) will be described later.

[0109]

The Tg of the binder (C) is 30°C or higher, preferably 40°C or higher, more preferably 45°C or higher. If the Tg is lower than 30°C, the binder exhibits adhesiveness even after the solvent is volatilized; therefore, sufficient binding properties between the resin-containing powder particles and the brilliant pigment are not obtained, and furthermore, the resin-containing powder particles (A) are bound to one another by the binder remaining on the surfaces

of the powder particles, resulting in an increase in the particle size of the resin-containing powder particles (A).
[0110]

The weight-average molecular weight of the binder (C) is 1,000 to 100,000, preferably 2,000 to 70,000, more preferably 2,000 to 50,000. If the weight-average molecular weight of the binder (C) is less than 1,000, sufficient binding properties between the resin-containing powder particles and the brilliant pigment are less likely to be obtained. If the weight-average molecular weight of the binder (C) exceeds 100,000, solubility or dispersibility in the solvent tends to be poor. It should be noted that further use of an emulsifier, a dispersant, or the like enables dispersibility of the binder to be enhanced; however, in this case, binding properties between the resin-containing powder particles and the brilliant pigment are likely to decrease.

[0111]

(Solvent (D))

The solvent (D) is a solvent that dissolves or disperses the binder (C). As the solvent (D), for example, at least one solvent selected from the group consisting of water, ethylene glycol, and methanol is used. The solvent (D) is preferably a mixed solvent of water and a water-soluble organic solvent because the binder is easily

wettable to the surfaces of the resin-containing powder particles, while insolubility for the resin-containing powder particles is sufficiently maintained.

[0112]

(Operation)

In the powder coating composition according to the present invention, binding (bonding) of the resin-containing powder particles (A) and the brilliant pigment (B) can be performed with the binder (C) by preparing a solution or a dispersion in which the binder (C) is dissolved or dispersed in the solvent (D) in advance, then adding the resulting solution or dispersion to the resin-containing powder particles (A) and sufficiently mixing the resulting mixture, and then completely volatilizing the solvent (D).

[0113]

Here, examples of the method of "adding the solution or dispersion in which the binder (C) is dissolved or dispersed in the solvent (D) to the resin-containing powder particles (A) and sufficiently mixing the resulting mixture" include a method of "adding dropwise the solution or dispersion in which the binder (C) is dissolved or dispersed in the solvent (D) little by little at a specific rate, while stirring the resin-containing powder particles (A)" and a "method of atomizing the solution or dispersion in which the binder (C) is dissolved or dispersed in the solvent (D) into

mist using a spray nozzle or the like, while stirring the resin-containing powder particles (A)".

[0114]

The method of completely volatilizing the solvent (D) is preferably a method using vacuum suction. The temperature at which the solvent is volatilized is preferably 0°C to 80°C. When the temperature is in the range of 0°C to 80°C, a powder coating composition in a good binding (bonding) state is easily obtained.

[0115]

It should be noted that the solvent (D) dissolves or disperses the binder (C) but dissolves neither the resin-containing powder particles (A) nor the resin (A1) constituting the resin-containing powder particles (A). Accordingly, even when the solvent (D) is blended, there is no possibility of an increase in the particle size of the resin-containing powder particles (A), degradation of coating workability, or deterioration of the appearance of the coating film due to binding of the resin-containing powder particles (A).

[0116]

Therefore, the powder coating composition according to the present invention is capable of forming a coating film having gloss and excellent brilliance and has excellent recyclability.

[0117]

Furthermore, in the powder coating composition according to the present invention, as a resin applicable to many resins (A1) constituting the resin-containing powder particles (A), a specific imaginary resin X is set, and a specific Hansen solubility sphere having specific center coordinates $CC (\delta_d, \delta_p, \delta_h) = (19.0, 7.0, 5.0)$ is set. Thus, when a solvent (D) that is present outside this specific Hansen solubility sphere is used as the solvent of the binder (C), the binder (C) can be dissolved or dispersed without dissolving many resins (A1) that are present inside the Hansen solubility sphere. Accordingly, in the present invention, the brilliant pigment can be bonded to various types of resin-containing powder particles.

[0118]

(Advantage)

According to the powder coating composition according to the present invention, it is possible to provide a powder coating composition that is capable of forming a coating film having high brilliance and gloss and that has excellent recyclability.

[0119]

[Coating film]

A coating film according to the present invention is formed by using the powder coating composition according to

the present invention. As the method for forming the coating film, for example, an electrostatic powder coating method, a corona-charging or tribo-charging powder coating method, or the like is employed.

[0120]

The thickness of the coating film is not particularly limited but is preferably 20 to 1,000 μm , more preferably 20 to 500 μm , still more preferably 20 to 300 μm . When the coating film is a coating film of members for high-rise buildings, such as an aluminum curtain wall, the thickness of the coating film is preferably 20 to 90 μm . When the coating film is a coating film of members that require high weatherability, such as outdoor units of air conditioners installed along the coast, traffic light poles, and signs, the thickness of the coating film is preferably 100 to 200 μm .

[0121]

The method for forming the coating film is not particularly limited. A usable method for forming the coating film is, for example, a method of coating a base with a powder coating composition according to the present invention to form a molten film composed of a melt of the powder coating composition, and subsequently cooling the molten film to form a coating film.

[0122]

The molten film composed of a melt of the powder coating composition is obtained by, for example, a method of forming the molten film simultaneously with the coating of a base with the powder coating composition or a method of applying the powder coating composition to a base and then melting the powder coating composition on the base by heating.

[0123]

When the powder coating composition contains a curing agent, almost immediately after the powder coating composition is melted by heating, curing reaction of the reactive component in the composition may start. In this case, the method for forming the coating film is preferably a method of performing melting of the powder coating composition by heating and application of the powder coating composition to a base almost at the same time, or a method of applying the powder coating composition to a base and then melting the powder coating composition by heating.

[0124]

A heating temperature for melting the powder coating composition by heating and for maintaining the heated molten state for a predetermined time (hereinafter, also referred to as a "baking temperature") and a heating maintaining time (hereinafter, also referred to as a "baking time") are appropriately set in accordance with the types and

composition of raw material components of the powder coating composition, the thickness of the desired coating film, etc.
[0125]

When the powder coating composition does not contain a curing agent, the baking temperature is 160°C to 300°C. When the powder coating composition contains a curing agent, the baking temperature is preferably set in accordance with the reaction temperature of the curing agent. The baking temperature in the case of using a curing agent is preferably 120°C to 240°C.
[0126]

The reaction temperature of the curing agent is determined by measuring a change in the modulus of elasticity of the powder coating composition. The change in the modulus of elasticity can be measured, for example, using a rheometer such as a rheometer ARES manufactured by TA Instruments Japan Inc.
[0127]

The baking time is preferably 2 to 60 minutes. With regard to this, when the powder coating composition does not contain a curing agent, the baking time is more preferably 5 to 60 minutes, still more preferably 10 to 50 minutes. When the powder coating composition contains a curing agent, the baking time is more preferably 2 to 50 minutes, still more preferably 5 to 40 minutes.

[0128]

Examples of the coating method used in the method for forming a coating film include an electrostatic coating method, an electrostatic spraying method, an electrostatic dipping method, an atomization method, a fluidized bed dipping method, a spray coating method, a spray method, a thermal spraying method, and a plasma spraying method. Of these, an electrostatic coating method using a powder coating gun is preferable in view of excellent surface smoothness of the molten film. A corona charging coating gun, a triboelectric charging coating gun, or the like is used as the powder coating gun. Herein, the corona charging coating gun means a gun that sprays a powder coating composition after corona-discharge treatment. The triboelectric charging coating gun means a gun that sprays a powder coating composition after triboelectric charging treatment.

[0129]

The cooling temperature of the molten film is preferably 20°C to 25°C. When the powder coating composition according to the present invention contains a curing agent, a coating film to be formed is a cured film. The cooling after baking may be either rapid cooling or slow cooling and is preferably slow cooling from the viewpoint that the coating film is less likely to be peeled off from

the base.

[0130]

(Advantage)

The coating film according to the present invention can be formed by using a powder coating composition that is capable of forming a coating film having high brilliance and gloss and that has excellent recyclability.

[0131]

[Coated body]

A coated body according to the present invention includes a base and a coating film formed on a surface of the base using the powder coating composition according to the present invention.

[0132]

(Base)

For example, a base made of metal (such as iron, stainless steel, aluminum, copper, titanium, brass, or an aluminum alloy), steel, or cast iron is preferably used as the base. Alloy steel, special steel, or carbon steel is used as the steel.

[0133]

Specific examples of the base made of an aluminum alloy include architectural sashes and architectural panels. Specific examples of the base made of carbon steel include railway bridges, road bridges, gas tanks, oil tanks, steel

towers, and springs.

[0134]

The coated body according to the present invention is obtained by, using the powder coating composition according to the present invention, performing the method for forming a coating film described in the section of the coating film according to the present invention.

[0135]

(Advantage)

The coated body according to the present invention can be formed by using a powder coating composition that is capable of forming a coating film having gloss and excellent brilliance and that has excellent recyclability.

EXAMPLES

[0136]

Hereinafter, the present invention will be described in more detail with reference to Examples, but the present invention is not limited to these Examples. It should be noted that, regarding the description of Examples and Comparative Examples, "parts" and "%" are based on mass.

[0137]

The following raw materials were used in Examples and Comparative Examples described below.

[0138]

<1. Raw materials of powder coating composition>

(1) Raw materials of resin-containing powder particles (A)

(1-1) Binder resin (A11)

·Fluorine resin 1: LUMIFLON LF710F, Hydroxyl group-containing fluorine resin (hydroxyl value: 46 mgKOH/g, manufactured by AGC Inc.)

·Polyester resin 1: UPICA Coat GV560, Hydroxyl group-containing polyester resin (hydroxyl value: 50 mgKOH/g, acid value: 5 mgKOH/g, softening point: 125°C, manufactured by Mitsubishi Gas Chemical Next Company, Inc.)

·Polyester resin 2: CRYLCOAT 1683-0, Carboxylic acid-containing polyester resin (acid value: 50 mgKOH/g, manufactured by DAICEL-ALLNEX LTD.)

·Polyester resin 3: CRYLCOAT 2630-2, Carboxylic acid-containing polyester resin (acid value: 33 mgKOH/g, manufactured by DAICEL-ALLNEX LTD.)

[0139]

(1-2) Curing agent (A12)

·Curing agent 1: ϵ -Caprolactam blocked isocyanate (trade name: VESTAGON B1530, manufactured by Evonik Degussa Corporation)

·Curing agent 2: Bis-A epoxy resin (trade name: jER (registered trademark) 1004, manufactured by Mitsubishi Chemical Corporation)

·Curing agent 3: β -Hydroxylalkylamide (trade name: Primid XL-552, manufactured by EMS-CHEMIE AG)

[0140]

(1-3) Additive (A3)

·Additive 1: Silica-based surface conditioner (trade name: BYK360P, manufactured by BYK)

·Lubricant 1: Amorphous silicon dioxide (trade name: SYLYSIA 358, manufactured by FUJI SILYSIA CHEMICAL LTD.)

[0141]

(2) Brilliant pigment (B)

·Aluminum flake 1: PCF7620A (manufactured by Toyo Aluminium K.K.)

[0142]

(3) Binder (C)

·Binder 1: Joncryl JDX-C3000 (manufactured by BASF, Acrylic resin, active ingredient 100% by mass, Tg 57°C, weight-average molecular weight 10,000)

·Binder 2: PLAS COAT Z-730 (manufactured by Goo Chemical Co., Ltd., Aqueous polyester resin solution, active ingredient 25% by mass, Tg 46°C, weight-average molecular weight 3,000)

·Binder 3: BURNOCK WD-551P (manufactured by DIC Corporation, Water-based hydroxyl group-containing acrylic resin dispersion, active ingredient 40% by mass, Tg 40°C, weight-average molecular weight 28,000)

·Binder 4: WATERSOL EFD-5580 (manufactured by DIC Corporation, Water-based acrylic resin dispersion, active

ingredient 40% by mass, Tg 15°C, weight-average molecular weight 70,000)

·Binder 5: JER 1001 (manufactured by Mitsubishi Chemical Corporation, Epoxy resin, active ingredient 100% by mass, Tg 64°C, weight-average molecular weight 3,000)

·Binder 6: HA 3509 (manufactured by Resonac Holdings Corporation, Acrylic resin solution, active ingredient 55% by mass, Tg 50°C, weight-average molecular weight 7,500)

·Binder 7: YS POLYSTER TH130 (manufactured by Yasuhara Chemical Co., Ltd., Terpene phenolic resin, active ingredient 100% by mass, Tg 130°C, weight-average molecular weight 1,500)

[0143]

(4) Solvent (D)

·Solvent 1: Ion-exchanged water

·Solvent 2: Mixture of 75 wt% of ion-exchanged water and 25 wt% of methanol (manufactured by Kanto Chemical Co., Inc.)

·Solvent 3: Mixture of 50 wt% of ion-exchanged water and 50 wt% of methanol (manufactured by Kanto Chemical Co., Inc.)

·Solvent 4: Mixture of 25 wt% of ion-exchanged water and 75 wt% of methanol (manufactured by Kanto Chemical Co., Inc.)

·Solvent 5: Methanol (manufactured by Kanto Chemical Co., Inc.)

·Solvent 6: Ethylene glycol (manufactured by Kanto Chemical Co., Inc.)

·Solvent 7: Xylene (manufactured by Kanto Chemical Co., Inc.)
·Solvent 8: n-Heptane (manufactured by Kanto Chemical Co., Inc.)
·Solvent 9: Perfluoro(methylcyclohexane) (manufactured by FUJIFILM Wako Pure Chemical Corporation)
[0144]

For each binder (C), NV (%), which is a ratio of a mass of a coating after drying to a mass of the coating before drying, the glass transition temperature T_g (°C), and the weight-average molecular weight M_w are shown in Table 2.
[0145]

[Test Example 1]

For each solvent (D), HSP (δ_d , δ_p , δ_h) were calculated using Hansen solubility parameter calculation software "Hansen Solubility Parameters in Practice (HSPiP)". It should be noted that the HSP for the solvent (D) are ($\delta_{d,2}$, $\delta_{p,2}$, $\delta_{h,2}$) in the above formulae (2) and (3) but are simply expressed as (δ_d , δ_p , δ_h) in Test Examples and the following Examples and Comparative Examples.

Furthermore, for each solvent (D), the interaction distance R_a , which is the distance from the specific center coordinates CC of (δ_d , δ_p , δ_h) = (19.0, 7.0, 5.0) on the 3D graph G, was calculated.

The HSP (δ_d , δ_p , δ_h) and the interaction distance R_a are

shown in Table 2.

[0146]

[Table 1]

Raw material class		Raw material abbreviation	Trade name
Resin-containing powder particles (A)	Binder resin (A11)	Fluorine resin 1	LUMIFLON LF710F, Hydroxyl group-containing fluorine resin (manufactured by AGC Inc.)
		Polyester resin 1	UPICA Coat GV560, Hydroxyl group-containing polyester resin (manufactured by Mitsubishi Gas Chemical Next Company, Inc.)
		Polyester resin 2	CRYLCOAT 1683-0, Carboxylic acid-containing polyester resin (manufactured by DAICEL-ALLNEX LTD.)
		Polyester resin 3	CRYLCOAT 2630-2, Carboxylic acid-containing polyester resin (manufactured by DAICEL-ALLNEX LTD.)
	Curing agent (A12)	Curing agent 1	ε-Caprolactam blocked isocyanate (trade name: VESTAGON B1530, manufactured by Evonik Degussa Corporation)
		Curing agent 2	Bis-A epoxy resin (trade name: jER 1004, manufactured by Mitsubishi Chemical Corporation)
		Curing agent 3	β-Hydroxylalkylamide (trade name: Primid XL-552, manufactured by EMS-CHEMIE AG)
	Additives (A2)	Additive 1	Silica-based surface conditioner (trade name: BYK360P, manufactured by BYK)
		Lubricant 1	Amorphous silicon dioxide (SYLYSIA 358, manufactured by FUJI SILYSIA CHEMICAL LTD.)
Brilliant pigment (B)		Aluminum flake 1	PCF7620A (manufactured by Toyo Aluminium K.K.)

[0147]

[Table 2]

Raw material class	Raw material abbreviation	Trade name	NV (%)	T _g (°C)	Mw	HSP			Interaction distance Ra with respect to (19.0, 7.0, 5.0)
						δ _d	δ _p	δ _h	
Binder (C)	Binder 1	Water-soluble acrylic resin, Copolymer of (meth)acrylic acid and (meth)acrylic acid alkyl ester (JONCRYL JDX-C3000/manufactured by BASF)	100	57	10000	-	-	-	-
	Binder 2	Water-soluble polyester resin (PLAS COAT Z-730/manufactured by Goo Chemical Co., Ltd.)	25	45	3000	-	-	-	-
	Binder 3	Water-based acrylic resin dispersion BURNOCK WD-551P/manufactured by DIC Corporation	40	46	28000	-	-	-	-
	Binder 4	Water-based epoxy ester resin dispersion WATERSOL EFD-5580/manufactured by DIC Corporation	40	15	70000	-	-	-	-
	Binder 5	Solvent-based epoxy resin jER 1001/manufactured by Mitsubishi Chemical Corporation	100	64	3000	-	-	-	-
	Binder 6	Solvent-based acrylic resin HA 3509/manufactured by Resonac Holdings Corporation	55	50	7500	-	-	-	-
	Binder 7	Terpene-phenolic resin YS POLYSTER TH130/manufactured by Yasuhara Chemical Co., Ltd.	100	130	1500	-	-	-	-
Solvent (D)	Solvent 1	Water 100%	-	-	-	15.5	16.0	42.3	39.0
	Solvent 2	Water/Methanol 75/25	-	-	-	15.3	15.1	37.3	34.1
	Solvent 3	Water/Methanol 50/50	-	-	-	15.1	14.2	32.3	29.3
	Solvent 4	Water/Methanol 25/75	-	-	-	14.9	13.2	27.3	24.6
	Solvent 5	Methanol 100%	-	-	-	14.7	12.3	22.3	20.0
	Solvent 6	Ethylene glycol	-	-	-	17.4	11.3	27.2	22.8
	Solvent 7	Xylene	-	-	-	17.8	1.0	3.1	6.7
	Solvent 8	n-Heptane	-	-	-	15.3	0.0	0.0	11.3
	Solvent 9	Perfluoro(methylcyclohexane)	-	-	-	12.4	0.0	0.0	15.8

[0148]

[Test Example 2]

(Solubility evaluation test)

The solid content of each of the binders 1, 2, and 5 to 7 was brought to 100% in a reduced-pressure environment at 25°C and 760 mmHg (gauge pressure), and 0.01 g of each

binder was then weighed. Next, the weighed binders 1, 2, and 5 to 7 were each mixed with 10 mL of each of the solvents 1 to 9 and stirred at 25°C for 30 minutes. After the stirring was finished, each of the resulting products was left to stand for 24 hours, and the state of the resulting product was visually evaluated. The evaluation results are shown in Table 3. The evaluation criteria are as described below.

It should be noted that each of the binders 3 and 4 is in a state where a resin component is dispersed in water (solvent 1); therefore, if the solid content of the binder is brought to 100%, a film is formed, and thus solubility of the original resin cannot be determined. Therefore, regarding the binder 3, 0.04 g of the binder (solid content 0.01 g) was weighed, methanol was then added such that the mixing ratio of water/methanol was equal to that of each of the solvents 2 and 3, and the dispersion state was evaluated. Regarding the binder 4, 0.018 g of the binder (solid content 0.01 g) was weighed, methanol was then added such that the mixing ratio of water/methanol was equal to that of each of the solvents 2 and 3, and the dispersion state was evaluated.

[0149]

<Evaluation>

The evaluation was performed as follows.

A (Excellent): The resulting product is a clear liquid, and the binder is dissolved.

B (Good): The resulting product is cloudy, and the binder is in a dispersed state (No precipitate is generated).

C (Poor): The resulting product is in a state where a precipitate is generated from the time of stirring.

-: The dispersion evaluation is not performed.

[0150]

[Table 3]

		Solvent (D)								
		Solvent 1	Solvent 2	Solvent 3	Solvent 4	Solvent 5	Solvent 6	Solvent 7	Solvent 8	Solvent 9
		Water (Ra = 39.0)	Water/Methanol 75/25 (Ra = 34.1)	Water/Methanol 50/50 (Ra = 29.3)	Water/Methanol 25/75 (Ra = 24.6)	Methanol (Ra = 20.0)	Ethylene glycol (Ra = 22.8)	Xylene (Ra = 6.7)	n-Heptane (Ra = 11.3)	Perfluoro(methylcyclohexane) (Ra = 15.8)
	Binder 1	A (Dissolved)	A (Dissolved)	A (Dissolved)	A (Dissolved)	A (Dissolved)	A (Dissolved)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)
	Binder 2	A (Dissolved)	A (Dissolved)	A (Dissolved)	A (Dissolved)	A (Dissolved)	A (Dissolved)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)
	Binder 3	B (Dispersed)	B (Dispersed)	B (Dispersed)	-	-	-	-	-	-
	Binder 4	B (Dispersed)	B (Dispersed)	B (Dispersed)	-	-	-	-	-	-
Binder (C)	Binder 5	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	A (Dissolved)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)
	Binder 6	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	A (Dissolved)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)
	Binder 7	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	C (Insoluble/Precipitated)	A (Dissolved)	A (Dissolved)	A (Dissolved)

[0151]

[Examples 1 to 36 and Comparative Examples 1 to 15]

(1. Preparation of powder coating compositions)

<1-1: Preparation of resin-containing powder particles (A)>

(1) 1-1-1: Preparation of powder particles containing fluorine resin and polyester resin

Powder particles (A) containing a fluorine resin and a polyester resin were obtained by using the raw materials listed in Tables 1 and 2 and mixing the components so as to have the mixing ratio shown in Tables 4 and 5. Specifically, a high-speed mixer was charged with the fluorine resin, the polyester resin, the curing agent (blocked isocyanate), the additive, and the lubricant, and mixing was performed for one minute. Subsequently, kneading was performed with a single-screw kneader (manufactured by BUSS AG) at a temperature adjusted to 120°C, and the discharged kneaded product was cold-rolled with cooling rolls. Subsequently, the resulting product was pulverized with a pin mill and classified through a 150-mesh screen to obtain powder particles (A) (50% volume-average particle size: about 35 μm) serving as a raw material of powder coating compositions (Coatings 1 to 17).

[0152]

(2) 1-1-2: Preparation of powder particles containing

polyester resin and epoxy resin

Powder particles (A) containing a polyester resin and an epoxy resin were obtained by using the raw materials listed in Tables 1 and 2 and mixing the components so as to have the mixing ratio shown in Table 6 and 7. Specifically, a high-speed mixer was charged with the polyester resin, the epoxy resin, and the additive, and mixing was performed for one minute. Subsequently, kneading was performed with a single-screw kneader (manufactured by BUSS AG) at a temperature adjusted to 120°C, and the discharged kneaded product was cold-rolled with cooling rolls. Subsequently, the resulting product was pulverized with a pin mill and classified through a 150-mesh screen, and the lubricant was added thereto to obtain powder particles (A) (50% volume-average particle size: about 35 μm) serving as a raw material of powder coating compositions (Coatings 18 to 34). [0153]

(3) 1-1-3: Preparation of powder particles containing polyester resin and amide compound

Powder particles (A) containing a polyester resin and an amide compound were obtained by using the raw materials listed in Tables 1 and 2 and mixing the components so as to have the mixing ratio shown in Tables 8 and 9. Specifically, a high-speed mixer was charged with the polyester resin, the amide compound, the additive, and the

lubricant, and mixing was performed for one minute. Subsequently, kneading was performed with a single-screw kneader (manufactured by BUSS AG) at a temperature adjusted to 120°C, and the discharged kneaded product was cold-rolled with cooling rolls. Subsequently, the resulting product was pulverized with a pin mill and classified through a 150-mesh screen to obtain powder particles (A) (50% volume-average particle size: about 35 µm) serving as a raw material of powder coating compositions (Coatings 35 to 51).

[0154]

<1-2: Preparation of binder liquids>

A binder and a binder solvent were mixed so as to have the mixing ratios shown in Tables 4 to 9 to prepare binder liquids for use in the production of the powder coating compositions (Coatings 1 to 51).

[0155]

<1-3: Preparation of powder coating compositions (Coatings 1 to 51)>

To each of the powder particles (A) obtained by the above-described method, the brilliant pigment (PCF7620A, manufactured by Toyo Aluminium K.K., average particle size 21 µm, resin-coated aluminum powder) was added so as to have the mixing ratios shown in Tables 4 to 9 and mixed with a laboratory spoon to prepare homogeneous mixtures.

Next, the binder liquids obtained by the above-

described method were added to the corresponding mixtures, and the resulting mixtures were air-dried for one hour while being kneaded. The mixtures were each charged in a 1 L volumetric flask and vacuum-dried at room temperature for 20 minutes using an evaporator while rotation and mixing were performed for 30 minutes. The powders obtained in this manner were each classified through a screen with an opening size of 100 μm . Thus, the powder coating compositions (Coatings 1 to 51) were obtained.

[0156]

(2. Characteristic evaluation)

For the obtained powder coating compositions (Coatings 1 to 51), characteristic evaluation was performed. The results of each evaluation test are shown in Tables 4 to 9. In the evaluation tests of brilliance and surface smoothness, test pieces each prepared as described below were used.

[0157]

<2-1: Method for preparing test piece>

Electrostatic coating using each of the powder coatings was performed on a surface of an aluminum plate (base) that had been subjected to chromate treatment using an electrostatic coating machine (trade name: GX3600C, manufactured by Onoda Cement Co., Ltd.) equipped with a powder coating gun. The resulting aluminum plate was held

in an atmosphere at 200°C for 20 minutes. The aluminum plate was left to stand to be cooled to room temperature. Thus, an aluminum plate (test piece) having a coating film (cured film) with a thickness of 55 to 65 μm was obtained.
[0158]

<2-2: Evaluations>

A layer separation property, brilliance, surface smoothness, and recyclability were measured and evaluated as described below.
[0159]

(1) Layer separation property

For the coating films of Examples 1 to 12 and Comparative Examples 1 to 5, a cross section of each of the coating films was observed with a microscope (KEYENCE CORPORATION) to evaluate whether or not the inside of the coating film was separated into upper and lower layers. Similarly, a cross section of each of the coating films was observed with a scanning electron microscope (Ultra-high-resolution analytical scanning electron microscope SU-70, Hitachi High-Tech Corporation) to check the distribution of fluorine elements (fluorine resin) in the cross section of the coating film by elemental analysis.
[0160]

The evaluation was performed as follows.

B (Good): Fluorine elements were unevenly distributed

on the surface layer of the coating film.

C (Poor): Uneven distribution of fluorine elements on the surface layer of the coating film was not observed.

[0161]

(2) Brilliance

The evaluation was performed as follows.

For each test piece, color unevenness of the coating film was visually evaluated on the basis of the following criteria.

B (Good): The occurrence of color unevenness was 20% or less of the total area of the test piece.

C (Poor): The occurrence of color unevenness was more than 20% of the total area of the test piece.

[0162]

(3) Surface smoothness

The evaluation was performed as follows.

The state of the surface of the coating film after preparation of the test plate was visually evaluated.

A (Excellent): No abnormality

B (Good): Orange peel

C (Poor): Roughened surface

[0163]

(4) Recyclability

The evaluation was performed as follows.

Each coating that was not applied in the first coating

was reapplied. For each test piece, color unevenness of the coating film was visually evaluated on the basis of the following criteria.

B (Good): The occurrence of color unevenness was 20% or less of the total area of the test piece.

C (Poor): The occurrence of color unevenness was more than 20% of the total area of the test piece.

[0164]

The results are shown in Tables 4 to 9.

[0165]

[Table 4]

Experimental example number		Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8
Sample number		Coating 1	Coating 2	Coating 3	Coating 4	Coating 5	Coating 6	Coating 7	Coating 8
Resin-containing powder particles (A)	Fluorine resin 1 (parts by mass)	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00
	Polyester resin 1 (parts by mass)	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00
	Curing agent 1 (parts by mass)	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	Additive 1 (parts by mass)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	Lubricant 1 (parts by mass)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Brilliant pigment (B)	Aluminum flake 1 (parts by mass)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Total of (A) and (B) (parts by mass)		98.10	98.10	98.10	98.10	98.10	98.10	98.10	98.10
Binder (C)	Binder 1 (parts by mass)	3.00	-	-	3.00	3.00	3.00	3.00	-
	Binder 2 (parts by mass)	-	12.00	-	-	-	-	-	12.00
	Binder 3 (parts by mass)	-	-	7.50	-	-	-	-	-
	Binder 4 (parts by mass)	-	-	-	-	-	-	-	-
	Binder 5 (parts by mass)	-	-	-	-	-	-	-	-
	Binder 6 (parts by mass)	-	-	-	-	-	-	-	-
	Binder 7 (parts by mass)	-	-	-	-	-	-	-	-
Solvent (D)	NV (%) of adhesive	100	25	40	100	100	100	100	25
	Solvent 1 (Ra = 39.0) (parts by mass)	10.00	10.00	10.00	-	-	-	-	-
	Solvent 2 (Ra = 34.1) (parts by mass)	-	-	-	10.00	-	-	-	-
	Solvent 3 (Ra = 29.3) (parts by mass)	-	-	-	-	10.00	-	-	-
	Solvent 4 (Ra = 24.6) (parts by mass)	-	-	-	-	-	10.00	-	-
	Solvent 5 (Ra = 20.0) (parts by mass)	-	-	-	-	-	-	10.00	10.00
	Solvent 6 (Ra = 22.8) (parts by mass)	-	-	-	-	-	-	-	-
	Solvent 7 (Ra = 6.7) (parts by mass)	-	-	-	-	-	-	-	-
	Solvent 8 (Ra = 11.3) (parts by mass)	-	-	-	-	-	-	-	-
Characteristics	Solvent 9 (Ra = 15.8) (parts by mass)	-	-	-	-	-	-	-	-
	Layer separation property	B	B	B	B	B	B	B	B
	Brilliance	B	B	B	B	B	B	B	B
	Surface smoothness	A	A	A	A	A	A	B	A
	Recyclability	B	B	B	B	B	B	B	B

[0166]

[Table 5]

Experimental example number		Example 9	Example 10	Example 11	Example 12	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
Sample number		Coating 9	Coating 10	Coating 11	Coating 12	Coating 13	Coating 14	Coating 15	Coating 16	Coating 17
Resin-containing powder particles (A)	Fluorine resin 1 (parts by mass)	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00
	Polyester resin 1 (parts by mass)	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00
	Curing agent 1 (parts by mass)	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	Additive 1 (parts by mass)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	Lubricant 1 (parts by mass)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Brilliant pigment (B)	Aluminum flake 1 (parts by mass)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Total of (A) and (B) (parts by mass)		98.10	98.10	98.10	98.10	98.10	98.10	98.10	98.10	98.10
Binder (C)	Binder 1 (parts by mass)	-	3.00	-	-	-	-	-	-	-
	Binder 2 (parts by mass)	-	-	12.00	-	-	-	-	-	-
	Binder 3 (parts by mass)	7.50	-	-	7.50	-	-	-	-	-
	Binder 4 (parts by mass)	-	-	-	-	7.50	-	-	-	-
	Binder 5 (parts by mass)	-	-	-	-	-	3.00	-	-	-
	Binder 6 (parts by mass)	-	-	-	-	-	-	5.45	-	-
	Binder 7 (parts by mass)	-	-	-	-	-	-	-	3.00	3.00
Solvent (D)	NV (%) of adhesive	40	100	25	40	40	100	55	100	100
	Solvent 1 (Ra = 39.0) (parts by mass)	-	-	-	-	10.00	-	-	-	-
	Solvent 2 (Ra = 34.1) (parts by mass)	-	-	-	-	-	-	-	-	-
	Solvent 3 (Ra = 29.3) (parts by mass)	-	-	-	-	-	-	-	-	-
	Solvent 4 (Ra = 24.6) (parts by mass)	-	-	-	-	-	-	-	-	-
	Solvent 5 (Ra = 20.0) (parts by mass)	10.00	-	-	-	-	-	-	-	-
	Solvent 6 (Ra = 22.8) (parts by mass)	-	10.00	10.00	10.00	-	-	-	-	-
	Solvent 7 (Ra = 6.7) (parts by mass)	-	-	-	-	-	10.00	10.00	-	-
	Solvent 8 (Ra = 11.3) (parts by mass)	-	-	-	-	-	-	-	10.00	-
Characteristics	Solvent 9 (Ra = 15.8) (parts by mass)	-	-	-	-	-	-	-	-	10.00
	Layer separation property	B	B	B	B	C	C	C	C	C
	Brilliance	B	B	B	B	C	C	C	C	C
	Surface smoothness	A	B	A	A	C	C	C	C	C
	Recyclability	B	B	B	B	C	C	C	C	C

[0167]

[Table 6]

Experimental example number		Example 13	Example 14	Example 15	Example 16	Example 17	Example 18	Example 19	Example 20
Sample number		Coating 18	Coating 19	Coating 20	Coating 21	Coating 22	Coating 23	Coating 24	Coating 25
Resin-containing powder particles (A)	Polyester resin 2 (parts by mass)	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00
	Curing agent 2 (parts by mass)	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
	Additive 1 (parts by mass)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	Lubricant 1 (parts by mass)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Brilliant pigment (B)	Aluminum flake 1 (parts by mass)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Total of (A) and (B) (parts by mass)		98.10	98.10	98.10	98.10	98.10	98.10	98.10	98.10
Binder (C)	Binder 1 (parts by mass)	3.00	-	-	3.00	3.00	3.00	3.00	-
	Binder 2 (parts by mass)	-	12.00	-	-	-	-	-	12.00
	Binder 3 (parts by mass)	-	-	7.50	-	-	-	-	-
	Binder 4 (parts by mass)	-	-	-	-	-	-	-	-
	Binder 5 (parts by mass)	-	-	-	-	-	-	-	-
	Binder 6 (parts by mass)	-	-	-	-	-	-	-	-
	Binder 7 (parts by mass)	-	-	-	-	-	-	-	-
Solvent (D)	NV (%) of adhesive	100	25	40	100	100	100	100	25
	Solvent 1 (Ra = 39.0) (parts by mass)	10.00	10.00	10.00	-	-	-	-	-
	Solvent 2 (Ra = 34.1) (parts by mass)	-	-	-	10.0	-	-	-	-
	Solvent 3 (Ra = 29.3) (parts by mass)	-	-	-	-	10.0	-	-	-
	Solvent 4 (Ra = 24.6) (parts by mass)	-	-	-	-	-	10.0	-	-
	Solvent 5 (Ra = 20.0) (parts by mass)	-	-	-	-	-	-	10.00	10.00
	Solvent 6 (Ra = 22.8) (parts by mass)	-	-	-	-	-	-	-	-
	Solvent 7 (Ra = 6.7) (parts by mass)	-	-	-	-	-	-	-	-
	Solvent 8 (Ra = 11.3) (parts by mass)	-	-	-	-	-	-	-	-
Characteristics	Solvent 9 (Ra = 15.8) (parts by mass)	-	-	-	-	-	-	-	-
	Brilliance	B	B	B	B	B	B	B	B
	Surface smoothness	A	A	A	A	A	A	B	B
	Recyclability	B	B	B	B	B	B	B	B

[0168]

[Table 7]

Experimental example number		Example 21	Example 22	Example 23	Example 24	Comparative Example 6	Comparative Example 7	Comparative Example 8	Comparative Example 9	Comparative Example 10
Sample number		Example 21	Example 22	Example 23	Example 24	Comparative Example 6	Comparative Example 7	Comparative Example 8	Comparative Example 9	Comparative Example 10
Resin-containing powder particles (A)	Polyester resin 2 (parts by mass)	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00
	Curing agent 2 (parts by mass)	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
	Additive 1 (parts by mass)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	Lubricant 1 (parts by mass)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Brilliant pigment (B)	Aluminum flake 1 (parts by mass)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Total of (A) and (B) (parts by mass)		98.10	98.10	98.10	98.10	98.10	98.10	98.10	98.10	98.10
Binder (C)	Binder 1 (parts by mass)	-	3.00	-	-	-	-	-	-	-
	Binder 2 (parts by mass)	-	-	12.00	-	-	-	-	-	-
	Binder 3 (parts by mass)	7.50	-	-	7.50	-	-	-	-	-
	Binder 4 (parts by mass)	-	-	-	-	7.50	-	-	-	-
	Binder 5 (parts by mass)	-	-	-	-	-	3.00	-	-	-
	Binder 6 (parts by mass)	-	-	-	-	-	-	5.45	-	-
	Binder 7 (parts by mass)	-	-	-	-	-	-	-	3.00	3.00
NV (%) of adhesive		40	100	25	40	40	100	55	100	100
Solvent (D)	Solvent 1 (Ra = 39.0) (parts by mass)	-	-	-	-	10.00	-	-	-	-
	Solvent 2 (Ra = 34.1) (parts by mass)	-	-	-	-	-	-	-	-	-
	Solvent 3 (Ra = 29.3) (parts by mass)	-	-	-	-	-	-	-	-	-
	Solvent 4 (Ra = 24.6) (parts by mass)	-	-	-	-	-	-	-	-	-
	Solvent 5 (Ra = 20.0) (parts by mass)	10.00	-	-	-	-	-	-	-	-
	Solvent 6 (Ra = 22.8) (parts by mass)	-	10.00	10.00	10.00	-	-	-	-	-
	Solvent 7 (Ra = 6.7) (parts by mass)	-	-	-	-	-	10.00	10.00	-	-
	Solvent 8 (Ra = 11.3) (parts by mass)	-	-	-	-	-	-	-	10.00	-
	Solvent 9 (Ra = 15.8) (parts by mass)	-	-	-	-	-	-	-	-	10.00
Characteristics	Brilliance	B	B	B	B	C	C	C	B	B
	Surface smoothness	A	B	A	A	C	C	C	C	C
	Recyclability	B	B	B	B	C	C	C	B	B

[0169]

[Table 8]

Experimental example number		Example 25	Example 26	Example 27	Example 28	Example 29	Example 30	Example 31	Example 32
Sample number		Coating 35	Coating 36	Coating 37	Coating 38	Coating 39	Coating 40	Coating 41	Coating 42
Resin-containing powder particles (A)	Polyester resin 3 (parts by mass)	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00
	Curing agent 3 (parts by mass)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	Additive 1 (parts by mass)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	Lubricant 1 (parts by mass)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Brilliant pigment (B)	Aluminum flake 1 (parts by mass)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Total of (A) and (B) (parts by mass)		98.10	98.10	98.10	98.10	98.10	98.10	98.10	98.10
Binder (C)	Binder 1 (parts by mass)	3.00	-	-	3.0	3.0	3.0	3.00	-
	Binder 2 (parts by mass)	-	12.00	-	-	-	-	-	12.00
	Binder 3 (parts by mass)	-	-	7.50	-	-	-	-	-
	Binder 4 (parts by mass)	-	-	-	-	-	-	-	-
	Binder 5 (parts by mass)	-	-	-	-	-	-	-	-
	Binder 6 (parts by mass)	-	-	-	-	-	-	-	-
	Binder 7 (parts by mass)	-	-	-	-	-	-	-	-
NV (%) of adhesive		100	25	40	100	100	100	100	25
Solvent (D)	Solvent 1 (Ra = 39.0) (parts by mass)	10.00	10.00	10.00	-	-	-	-	-
	Solvent 2 (Ra = 34.1) (parts by mass)	-	-	-	10.0	-	-	-	-
	Solvent 3 (Ra = 29.3) (parts by mass)	-	-	-	-	10.0	-	-	-
	Solvent 4 (Ra = 24.6) (parts by mass)	-	-	-	-	-	10.0	-	-
	Solvent 5 (Ra = 20.0) (parts by mass)	-	-	-	-	-	-	10.00	10.00
	Solvent 6 (Ra = 22.8) (parts by mass)	-	-	-	-	-	-	-	-
	Solvent 7 (Ra = 6.7) (parts by mass)	-	-	-	-	-	-	-	-
	Solvent 8 (Ra = 11.3) (parts by mass)	-	-	-	-	-	-	-	-
	Solvent 9 (Ra = 15.8) (parts by mass)	-	-	-	-	-	-	-	-
Characteristics	Brilliance	B	B	B	B	B	B	B	B
	Surface smoothness	A	A	A	A	A	A	B	A
	Recyclability	B	B	B	B	B	B	B	B

[0170]

[Table 9]

Experimental example number		Example 33	Example 34	Example 35	Example 36	Comparative Example 11	Comparative Example 12	Comparative Example 13	Comparative Example 14	Comparative Example 15
Resin-containing powder particles (A)	Sample number	Coating 43	Coating 44	Coating 45	Coating 46	Coating 47	Coating 48	Coating 49	Coating 50	Coating 51
	Polyester resin 3 (parts by mass)	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00
	Curing agent 3 (parts by mass)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	Additive 1 (parts by mass)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	Lubricant 1 (parts by mass)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Brilliant pigment (B)	Aluminum flake 1 (parts by mass)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Total of (A) and (B) (parts by mass)		98.10	98.10	98.10	98.10	98.10	98.10	98.10	98.10	98.10
Binder (C)	Binder 1 (parts by mass)	-	3.00	-	-	-	-	-	-	-
	Binder 2 (parts by mass)	-	-	12.00	-	-	-	-	-	-
	Binder 3 (parts by mass)	7.50	-	-	7.50	-	-	-	-	-
	Binder 4 (parts by mass)	-	-	-	-	7.50	-	-	-	-
	Binder 5 (parts by mass)	-	-	-	-	-	3.00	-	-	-
	Binder 6 (parts by mass)	-	-	-	-	-	-	-	-	-
	Binder 7 (parts by mass)	-	-	-	-	-	-	5.45	-	-
	NV (%) of adhesive	40	100	25	40	40	100	55	3.00	3.00
Solvent (D)	Solvent 1 (Ra = 39.0) (parts by mass)	-	-	-	-	10.00	-	-	-	-
	Solvent 2 (Ra = 34.1) (parts by mass)	-	-	-	-	-	-	-	-	-
	Solvent 3 (Ra = 29.3) (parts by mass)	-	-	-	-	-	-	-	-	-
	Solvent 4 (Ra = 24.6) (parts by mass)	-	-	-	-	-	-	-	-	-
	Solvent 5 (Ra = 20.0) (parts by mass)	10.00	-	-	-	-	-	-	-	-
	Solvent 6 (Ra = 22.8) (parts by mass)	-	10.00	10.00	10.00	-	-	-	-	-
	Solvent 7 (Ra = 6.7) (parts by mass)	-	-	-	-	-	10.00	10.00	-	-
	Solvent 8 (Ra = 11.3) (parts by mass)	-	-	-	-	-	-	-	10.00	-
	Solvent 9 (Ra = 15.8) (parts by mass)	-	-	-	-	-	-	-	-	10.00
Characteristics	Brilliance	B	B	B	B	C	C	C	B	B
	Surface smoothness	A	B	A	A	C	C	C	C	C
	Recyclability	B	B	B	B	C	C	C	B	B

[0171]

Referring to Examples and Comparative Examples, the powder coating compositions of Examples were found to be good in terms of all of the brilliance, surface smoothness, and recyclability.

Reference Signs List

[0172]

CC center coordinates

G Hansen 3D graph

HSS Hansen solubility sphere

R_0 interaction radius

R_a interaction distance

CLAIMS

[Claim 1]

A powder coating composition comprising resin-containing powder particles (A); a brilliant pigment (B); and a binder (C),

wherein the binder (C) is

a resin that dissolves or disperses in a solvent (D) whose interaction distance R_a is 20 or more when center coordinates (δ_d , δ_p , δ_h) in a Hansen solubility sphere for determining solubility with respect to a solvent to be mixed are set to (19.0, 7.0, 5.0), that has a Tg of 30°C or higher, and that has a weight-average molecular weight of 1,000 to 100,000.

[Claim 2]

The powder coating composition according to claim 1, wherein the binder (C) is a resin that dissolves or disperses in a solvent (D) whose interaction distance R_a is 30 or more.

[Claim 3]

The powder coating composition according to claim 1, wherein the binder (C) has a Tg of 40°C or higher.

[Claim 4]

The powder coating composition according to claim 1, wherein a resin (A1) constituting the resin-containing powder particles (A) is a resin obtained by reacting at

least one binder resin (A11) selected from the group consisting of fluorine resins, polyester resins, and acrylic resins with at least one curing agent (A12) selected from the group consisting of epoxy group-containing compounds or polymers thereof, amide compounds, and isocyanate compounds.

[Claim 5]

The powder coating composition according to claim 1, wherein the solvent (D) is at least one solvent selected from the group consisting of water, ethylene glycol, and methanol.

[Claim 6]

The powder coating composition according to claim 1, wherein the solvent (D) is a mixed solvent of water and a water-soluble organic solvent.

[Claim 7]

The powder coating composition according to claim 1, wherein the brilliant pigment (B) is composed of flaky aluminum particles.

[Claim 8]

A coating film formed using the powder coating composition according to any one of claims 1 to 7.

[Claim 9]

A coated body comprising:

a base; and

a coating film formed on a surface of the base using

the powder coating composition according to any one of claims 1 to 7.