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(54) Title: SILICONE RESIN COMPOSITION FOR WATER REPELLENT COATING

(57) Abstract: A silicone resin composition for a water-repellent coating comprising (A) 100 weight parts of a polyorganosiloxane described by average formula $(R_2SiO_{2/2})_w(RSiO_{3/2})_x(SiO_{4/2})_y(O_{1/2}R^1)_z$ where R is a C₁ to C₁₀ monovalent hydrocarbon group, R¹ is hydrogen atom or a C₁ to C₆ saturated hydrocarbon group, w is a number from 0 to 0.2, x is a number from 0.4 to 0.9, y is a number from 0.1 to 0.6, z is a number from 0.1 to 0.5, and w+x+y = 1; (B) 20 to 150 weight parts of an alcohol-based solvent; (C) 100 to 1000 weight parts of a hydrocarbon-based solvent and/or a dimethylsiloxane described by formula Me₃SiO(Me₂SiO)_nSiMe₃, where Me is a methyl group, and n is 0 or 1; (D) 1 to 100 weight parts of an alkoxysilane and/or a silane coupling agent; and (E) 0.1 to 20 weight parts of a condensation catalyst.



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DESCRIPTION

SILICONE RESIN COMPOSITION FOR WATER REPELLENT COATING

5 FIELD OF THE INVENTION

The present invention relates to a silicone resin composition for a water-repellent coating, and more particularly to a silicone resin composition for a water-repellent coating capable of forming high-hardness coating films with excellent water repellency when cured.

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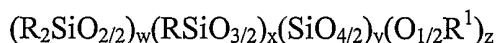
BACKGROUND AND PRIOR ART

In conventional practice, curable silicone resin compositions are widely used as coating agents for providing the surfaces of various inorganic materials with water repellency or water resistance. Such silicone resin compositions for coatings use primarily
15 polymethylsilsesquioxanes composed of siloxane units (hereinafter "T-units") described by formula $\text{CH}_3\text{SiO}_{3/2}$, and methylsilicone resins composed of T-units and siloxane units (hereinafter "D-units") described by formula $(\text{CH}_3)_2\text{SiO}_{2/2}$. Such silicone resins are disadvantageous, however, in that the coating agent used for the base fails to provide adequate film hardness. A coating agent obtained by adding colloidal silica has also
20 been proposed for use in forming high-hardness films[see Japanese Patent Application Publication(Kokai) No.Hei 2-8273]. This agent, however, has inadequate storage stability and requires further improvement.

It is an object of the present invention to provide a silicone resin composition for a water-repellent coating that has excellent storage stability and is capable of forming
25 high-hardness coating films with excellent water repellency when cured.

SUMMARY OF THE INVENTION

A silicone resin composition for a water-repellent coating comprising
(A) 100 weight parts of a polyorganosiloxane described by average formula



where R is a C₁ to C₁₀ monovalent hydrocarbon group, R¹ is hydrogen atom or a C₁ to C₆ saturated hydrocarbon group, w is a number from 0 to 0.2, x is a number from 0.4 to 0.9, y is a number from 0.1 to 0.6, z is a number from 0.1 to 0.5, and (w + x + y) = 1;

5 (B) 20 to 150 weight parts of an alcohol-based solvent;

(C) 100 to 1000 weight parts of a hydrocarbon-based solvent and/or a dimethylsiloxane described by formula Me₃SiO(Me₂SiO)_nSiMe₃, where Me is a methyl group, and n is 0 or 1;

(D) 1 to 100 weight parts of an alkoxysilane and/or a silane coupling agent; and

10 (E) 0.1 to 20 weight parts of a condensation catalyst.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described in detail.

The polyorganosiloxane of component (A) is a silicone resin whose average constituent
15 units are expressed by the formula (R₂SiO_{2/2})_w(RSiO_{3/2})_x(SiO_{4/2})_y(O_{1/2}R¹)_z. In this formula, R is a C₁ to C₁₀ monovalent hydrocarbon group such as methyl, ethyl, propyl, or other alkyl group; vinyl, allyl, 5-hexenyl, or other alkenyl group; or phenyl or other aryl group, of which methyl is preferred. R¹ is hydrogen atom or a C₁ to C₆ saturated hydrocarbon group. Methyl, ethyl, propyl, and other alkyl groups can be cited as
20 examples of saturated hydrocarbon groups, of which methyl and ethyl are preferred. In the formula, w is a number from 0 to 0.2, x is a number from 0.4 to 0.9, y is a number from 0.1 to 0.6, z is a number from 0.1 to 0.5, and (w + x + y) = 1. In particular, an x-value of 0.6 to 0.9 is preferred.

The polyorganosiloxane of component (A) can be produced by the hydrolysis and
25 condensation of, for example, a diorganodialkoxysilane described by formula R₂Si(OR¹)₂, an organotrialkoxysilane described by formula RSi(OR¹)₃, and a tetraalkoxysilane described by formula Si(OR¹)₄. Examples of suitable diorganodialkoxysilanes include dimethyldimethoxysilane, dimethyldiethoxysilane, and dimethyldiisopropoxysilane. Examples of suitable organotrialkoxysilanes include
30 methyltrimethoxysilane, methyltriethoxysilane, methyltriisopropoxysilane, ethyltrimethoxysilane, and ethyltriethoxysilane. Examples of suitable tetraalkoxysilanes

include tetramethoxysilane, tetraethoxysilane, and tetraisopropoxysilane. The tetraalkoxysilanes may be replaced by partial hydrolysates thereof. Such partial hydrolysates are marketed, for example, by Tama Chemicals under the registered trade names of Silicate 40 and Silicate 45. The tetraalkoxysilanes may be replaced by
5 colloidal silica completely or in part. Although water-dispersed colloidal silica and colloidal silica dispersed in an organic solvent are cited as examples of suitable colloidal silica, products obtained by dispersing colloidal silica in methanol, isopropanol, and other alcohols are preferred over such water-dispersed types. The colloidal silica should preferably have a mean grain size of 5 to 100 μm . In particular, combined use of a
10 colloidal silica with a mean grain size of 20 μm or less and a colloidal silica whose mean grain size is greater than 20 μm is preferred, and the mixing ratio thereof should preferably be such that the proportion of the colloidal silica whose mean grain size exceeds 20 μm is 20 to 95 wt%. A method in which an organotrialkoxysilane and a diorganodialkoxysilane are hydrolyzed in the presence of colloidal silica is cited with
15 respect to the use of colloidal silica. In preferred practice, the organotrialkoxysilane and diorganodialkoxysilane are added to the colloidal silica, water is then added in a timely manner, and the system is heated and condensed.

The alcohol-based solvent of component (B) is a diluting solvent designed to improve
20 the dispersibility and storage stability of the polyorganosiloxane (component (A)). Specific examples include methanol, ethanol, isopropanol, butanol, and isobutanol. These alcohol-based solvents may also contain small amounts of water.

Component (B) should be added in an amount of 20 to 150 weight parts, and preferably 50 to 140 weight parts, per 100 weight parts of component (A). This is because adding
25 less than 20 weight parts component (B) has an adverse effect on the dispersion stability of component (A), whereas adding more than 150 weight parts sometimes causes whitening and impairs coating properties during application.

The hydrocarbon-based solvent of component (C) and/or the dimethylsiloxane described
30 by formula $\text{Me}_3\text{SiO}(\text{Me}_2\text{SiO})_n\text{SiMe}_3$ are diluting solvents designed to provide better coating properties. In the formula, Me is a methyl group, and n is 0 or 1. Examples of

suitable hydrocarbon-based solvents include toluene, xylene, and other aromatic hydrocarbons; hexane, octane, heptane, ligroin, and other aliphatic hydrocarbons; and chloroform, methylene chloride, carbon tetrachloride, chlorobenzene, and other chlorinated hydrocarbon solvents. These solvents can be used singly or as mixtures of two or more components. Combined use of such hydrocarbon-based solvents and dimethylsiloxane is preferred, and the mixing ratio (weight) thereof should preferably fall within a range of 95:5 to 40:60. Component (C) is added in an amount of 100 to 1000 weight parts per 100 weight parts of component (A). This is because adding less than 100 weight parts has an adverse effect on the smoothness of the coating film.

10

The alkoxysilane and silane coupling agent of component (D) are components designed to improve the adhesion of the inventive coating film. Examples of suitable alkoxysilanes include methyltrimethoxysilane, methyltriethoxysilane, methyltriisopropoxysilane, ethyltrimethoxysilane, ethyltriethoxysilane, and other alkyltrialkoxysilanes; and tetramethoxysilane, tetraethoxysilane, tetraisopropoxysilane, and other tetraalkoxysilanes. Examples of suitable silane coupling agents include 3-aminopropyltrimethoxysilane, 3-aminopropyltriethoxysilane, 3-(2-aminoethyl)aminopropyltrimethoxysilane, 3-(2-aminoethyl)aminopropyltriethoxysilane, 3-(2-aminoethyl)aminopropylmethyldimethoxysilane, 3-(2-aminoethyl)aminopropylmethyldiethoxysilane, and other aminosilane coupling agents; and 3-glycidoxypropyltrimethoxysilane, 3-glycidoxypropylmethyldimethoxysilane, and other epoxysilane coupling agents; as well as 3-mercaptopropyltrimethoxysilane, 3-methacryloxypropyltrimethoxysilane, and the like. These alkoxysilanes and silane coupling agents may be used jointly, and the mixing ratio (weight) thereof should preferably fall within a range of 100:0 to 10:90. Component (D) is added in an amount of 1 to 100 weight parts per 100 weight parts of component (A). This is because adding less than 1 weight part fails to improve the adhesion of the present composition, whereas adding more than 100 weight parts has an adverse effect on the curability of the coating film.

30

The condensation catalyst of component (E) may be a conventionally known silicone resin condensation catalyst such as dibutyltin diacetate, dibutyltin dioctoate, dibutyltin dilaurate, dibutyltin dimalate, dioctyltin dilaurate, dioctyltin dimalate, tin octylate, or another organotin compound; isopropyltriisostearoyl titanate,

- 5 isopropyltris(dioctylpyrophosphate) titanate, bis(dioctylpyrophosphate) oxyacetate titanate, tetraalkyl titanate, or another organotitanate compound; tetrabutyl zirconate, tetrakis(acetylacetonate) zirconium, tetraisobutyl zirconate, butoxytris(acetylacetonate) zirconium, zirconium naphthenate, or another organozirconium compound; tris(ethylacetoacetate) aluminum, tris(acetylacetonate) aluminum, or another
- 10 organoaluminum compound; zinc naphthenate, cobalt naphthenate, cobalt octylate, or another organometallic compound; or diethanolamine, triethanolamine, or another amine-based catalyst devoid of organosilicon compounds. Component (E) should preferably be added in an amount of 0.1 to 20 weight parts, and preferably 1 to 10 weight parts, per 100 weight parts of component (A). This is because adding less
- 15 than 0.1 weight part of component (E) has an adverse effect on the curing properties of the present composition, whereas adding more than 20 weight parts impairs storage stability.

- Although the present composition comprises the above-described components (A) to (E),
- 20 a polyoxyalkylene-modified silicone (F) should preferably be added as well. The polyoxyalkylene-modified silicone is a linear siloxane having polyoxyalkylene groups at the ends of molecular chains or in side chains of the linear siloxane. These groups are polyoxyethylene groups or groups resulting from block or random bonding of oxypropylene groups and/or oxyethylene groups. Methyl groups should preferably serve
- 25 as the groups that are attached to silicon atoms and are not polyoxyalkylene groups. These may be partially substituted by phenyl groups and other hydrocarbon groups. The polyoxyalkylene-modified silicone should preferably have a viscosity of 100 to 100,000 mPa·s at 25°C. Component (F) is added in an amount of 0.1 to 20 weight parts per 100 weight parts of component (A). This is because adding less than 0.1 weight part
- 30 component (F) has no discernible effect, whereas adding more than 20 weight parts impairs the storage stability of the present compositions.

Organic solvents other than components (B) and (C); coloring pigments, anticorrosive pigments, and other pigments; antimicrobials agents; antifouling agents; and the like may also be appropriately added as needed to the present composition. Examples of
5 organic solvents other than components (B) and (C) include methyl ethyl ketone, methyl isobutyl ketone, and other ketone-based solvents, as well as diethyl ether and other ether-based solvents.

The present silicone resin composition for a water-repellent coating is characterized in
10 that excellent storage stability and applicability can be achieved and that a hard film with excellent water repellency and a pencil hardness of 5H or greater can be formed by applying the composition to the surface of a substrate and heating the resulting coating. Examples of suitable substrates include glass, ceramic, metal (such as iron, stainless steel, and aluminum), and other inorganic substrates, as well as plastic, wood, and other
15 organic substrates. The substrates may be shaped as plates, blocks, films, or powders. Of these, iron powder, ferrite powder, and other inorganic powders are preferred for the proposed water-repellent coating agent. In particular, carrier nuclear particles for electrostatic image development can be coated with the proposed water-repellent coating agent. The material may be applied by spray coating, roll coating, or dip coating. The
20 coated material is commonly heated at a temperature of 50 to 350°C.

EXAMPLE

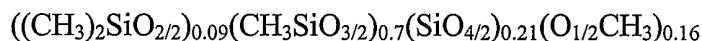
The present invention will now be described in detail through working examples. In the working examples, "parts" refers to weight parts, and "viscosity" denotes values
25 measured at 25°C.

Working Example 1.

Dimethyldimethoxysilane (20 g), methyltrimethoxysilane (180 g), and methanol-dispersed colloidal silica (mean grain size: 13 μm ; solid silica content: 30 wt%; amount
30 added: 80 g) were introduced and mixed inside a flask, and water (36 g) was then admixed. The system was stirred for 2 hours under heating and refluxing. The product

was then cooled, yielding 315 g of a methanol solution containing 132 g of polymethylsiloxane. Gas chromatographic analysis demonstrated the absence of methyltrimethoxysilane in the methanol solution. It was also determined by ^{29}Si -NMR and ^{13}C -NMR analyses that the resulting polymethylsiloxane was a branched

5 polymethylsiloxane whose average constituent units were described by formula



Toluene (230 parts), hexamethyldisiloxane (79 parts), methyltrimethoxysilane (12 parts), 3-(2-aminoethyl)aminopropylmethyldimethoxysilane (1 part), and dibutyltin dilaurate (4 parts) were admixed into 239 parts of the polymethylsiloxane methanol solution
10 (polymethylsiloxane content: 100 parts), yielding a silicone resin composition for a water-repellent coating.

The resulting composition was a transparent solution that formed a uniform film when poured onto a glass slide. The film was placed in an oven at a temperature of 200°C for 30 minutes. The film was allowed to cool and was measured for pencil hardness, which
15 was found to be 8H. The contact angle of the film with water was 100°.

Working Example 2.

Methyltrimethoxysilane (200 g) and methanol-dispersed colloidal silica (mean grain size: 13 μm ; solid silica content: 30 wt%; amount added: 80 g) were introduced and
20 mixed inside a flask, and water (36 g) was then admixed. The system was stirred for 2 hours under heating and refluxing. The product was then cooled, yielding 315 g of a methanol solution containing 132 g of polymethylsiloxane. Gas chromatographic analysis revealed the absence of methyltrimethoxysilane in the methanol solution. It was also determined by ^{29}Si -NMR and ^{13}C -NMR analyses that the resulting
25 polymethylsiloxane was a branched polymethylsiloxane whose average constituent units were expressed by the formula

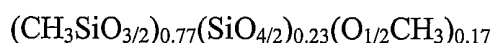


Toluene (235 parts), hexamethyldisiloxane (80 parts), methyltrimethoxysilane (13 parts), and dibutyltin dilaurate (4 parts) were admixed into 239 parts of the polymethylsiloxane
30 methanol solution (polymethylsiloxane content: 100 parts), yielding a silicone resin composition for a water-repellent coating.

The resulting composition was a transparent solution with a specific gravity of 0.91 at 25°C, a viscosity of 1.2 mm²/s, and a refractive index of 1.426. A uniform film was obtained when the solution was poured onto a glass slide. The film was also placed in an oven at 200°C for 30 minutes. The film was allowed to cool and was measured for pencil hardness, which was found to be 8H. The contact angle of the film with water was 99°.

Working Example 3.

Methyltrimethoxysilane (200 g), a methanol-dispersed colloidal silica (solid silica content: 40 wt%; amount added: 55 g) with a mean grain size of 23 μm, and a methanol-dispersed colloidal silica (solid silica content: 25 wt%; amount added : 8 g) with a mean grain size of 10 μm were introduced and mixed inside a flask, and water (36 g) was then admixed. The system was stirred for 2 hours under heating and refluxing. The product was then cooled, yielding 298 g of a methanol solution containing 132 g of polymethylsiloxane. Gas chromatographic analysis revealed the absence of methyltrimethoxysilane in the methanol solution. It was determined by ²⁹Si-NMR and ¹³C-NMR analyses that the resulting polymethylsiloxane was a branched polymethylsiloxane whose average constituent units were expressed by the formula

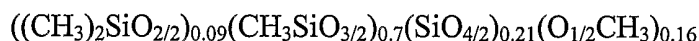


Toluene (235 parts), hexamethyldisiloxane (75 parts), methyltrimethoxysilane (12 parts), and dibutyltin dilaurate (3.5 parts) were admixed into 226 parts of the polymethylsiloxane methanol solution (polymethylsiloxane content: 100 parts), yielding a silicone resin composition for a water-repellent coating.

The resulting composition was a transparent solution whose specific gravity at 25°C was 0.91. A uniform film was obtained when the solution was poured onto a glass slide. The film was placed in an oven at 200°C for 30 minutes. The film was allowed to cool and was measured for pencil hardness, which was found to be 9H. The contact angle of the film with water was 100°.

Working Example 4.

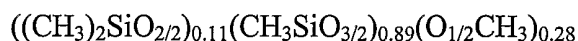
Methyltrimethoxysilane (180 g), partially hydrolyzed tetraethoxysilane (viscosity: 3 mm²/s; specific gravity: 1.05; SiO₂ content: 40 wt%; amount added: 15 g), methanol-dispersed colloidal silica (mean grain size: 13 μm; solid silica content: 30 wt%; amount added : 60 g), and dimethyldimethoxysilane (20 g) were introduced and mixed inside a
 5 flask, and water (36 g) was then admixed. The system was stirred for 2 hours under heating and refluxing. The product was then cooled, yielding 310 g of a methanol solution containing 132 g of polymethylsiloxane. Gas chromatographic analysis revealed the absence of methyltrimethoxysilane in the methanol solution. It was determined by ²⁹Si-NMR and ¹³C-NMR analyses that the resulting polymethylsiloxane
 10 was a branched polymethylsiloxane whose average constituent units were expressed by the formula



Toluene (230 parts), hexamethyldisiloxane (77 parts), methyltrimethoxysilane (12 parts), 3-(2-aminoethyl)aminopropylmethyldimethoxysilane (1 part), polyoxyethylene-modified
 15 dimethylsiloxane (polyoxyethylene chain content: 47 wt%; viscosity: 270 mm²/s; specific gravity: 1.03; amount added: 2 parts), and dibutyltin dilaurate (4 parts) were admixed into 239 parts of the polymethylsiloxane methanol solution (polymethylsiloxane content: 100 parts), yielding a silicone resin composition for a water-repellent coating.
 20 The resulting composition was a transparent solution that formed a uniform film when poured onto a glass slide. The film was also placed in an oven at 200°C for 30 minutes. The film was allowed to cool and was measured for pencil hardness, which was found to be 7H. The contact angle of the film with water was 102°.

25 Comparative Example 1.

A methanol solution containing 108 g of polymethylsiloxane was obtained in an amount of 235 g in the same manner as in Working Example 1 except that the methanol-dispersed colloidal silica (mean grain size: 13 μm, solid silica content: 30 wt%) used in Working Example 1 was dispensed with. It was determined by ²⁹Si-NMR and ¹³C-NMR
 30 analyses that the resulting polymethylsiloxane was a branched polymethylsiloxane whose average constituent units were described by formula



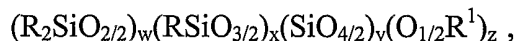
Toluene (230 parts), hexamethyldisiloxane (79 parts), methyltrimethoxysilane (12 parts), 3-(2-aminoethyl)aminopropylmethyldimethoxysilane (1 part), and dibutyltin dilaurate (4 parts) were admixed into 217 parts of the polymethylsiloxane methanol solution
5 (polymethylsiloxane content: 100 parts), yielding a silicone resin composition for a water-repellent coating.

The resulting composition was a transparent solution that formed a uniform film when poured onto a glass slide. The film was also placed into an oven at 200°C for 30 minutes. The film was allowed to cool and was measured for pencil hardness, which
10 was found to be 3H, indicating that the hardness was lower than that achieved when the present composition was formed into a film. The contact angle of the film with water was 100°.

CLAIMS

1. A silicone resin composition for a water-repellent coating comprising

(A) 100 weight parts of a polyorganosiloxane described by average formula



5 where R is a C₁ to C₁₀ monovalent hydrocarbon group, R¹ is a hydrogen atom or a C₁ to C₆ saturated hydrocarbon group, w is a number from 0 to 0.2, x is a number from 0.4 to 0.9, y is a number from 0.1 to 0.6, z is a number from 0.1 to 0.5, and (w + x + y) = 1;

(B) 20 to 150 weight parts of an alcohol-based solvent;

(C) 100 to 1000 weight parts of a hydrocarbon-based solvent and/or a dimethylsiloxane
10 described by formula Me₃SiO(Me₂SiO)_nSiMe₃, where Me is a methyl group, and n is 0 or 1;

(D) 1 to 100 weight parts of an alkoxysilane and/or a silane coupling agent; and

(E) 0.1 to 20 weight parts of a condensation catalyst.

2. The silicone resin composition for a water-repellent coating of Claim 1, where the
15 (SiO_{4/2}) units in component (A) are derived from colloidal silica.

3. The silicone resin composition for a water-repellent coating of Claim 2, where the polyorganosiloxane of component (A) is obtained by the hydrolysis and condensation of an organotrialkoxysilane in the presence of colloidal silica.

4. The silicone resin composition for a water-repellent coating of Claim 2, where the
20 polyorganosiloxane of component (A) is obtained by the hydrolysis and condensation of an organotrialkoxysilane and a diorganodialkoxysilane in the presence of colloidal silica.

5. The silicone resin composition for a water-repellent coating of Claim 2 comprising a colloidal silica having a mean grain size greater than 20 μm and a colloidal silica having a mean grain size of 20 μm or less.

25 6. The silicone resin composition for a water-repellent coating of Claim 1 further comprising (F) 0.1 to 20 weight parts of a polyoxyalkylene-modified silicone.

7. The silicone resin composition for a water-repellent coating of Claim 1, where x has a value of 0.6 to 0.9.

8. The silicone resin composition for a water-repellent coating of Claim 2, where the colloidal silica has a mean grain size of 5 to 100 μm .
- 5 9. The silicone resin composition for a water-repellent coating of Claim 1 comprising 50 to 140 weight parts of component (B) per 100 weight parts of component (A).
10. The silicone resin composition for a water-repellent coating of Claim 1 where component (C) comprises a mixture of a hydrocarbon-based solvent and
- 10 dimethylsiloxane in a weight ratio within a range of 95:5 to 40:60.
11. The silicone resin composition for a water-repellent coating of Claim 1 further comprising (F) 0.1 to 20 weight parts of a polyoxyalkylene-modified silicone having a viscosity of 100 to 100,000 $\text{mPa}\cdot\text{s}$ at 25°C.