

TRANSPARENT SILICONE FILM-FORMING COMPOSITION AND METHOD FOR CURING SAME

FIELD OF THE INVENTION

This invention relates to a transparent and opaque silicone film-forming composition which is applied on a transparent substrate such as plastics and glass used for windows of buildings and vehicles including train, cars, etc. to form a bright, hard and transparent film without insufficient color uniformity or a colored transparent film, and a method for curing same.

More particularly, this invention relates to a silicone film-forming composition which forms a hard-coat protective film or fashionable film on the surface of window glass of buildings and cars, or plastics such as acrylics and polycarbonates or metals such as aluminum and, at the same time, exhibits ultraviolet and infrared protective properties, and a method for curing same.

BACKGROUND OF THE INVENTION

It has been conventional to apply UV-absorber loaded plastic films or paints on building or car windows for the purpose of mainly protecting ultraviolet light.

Further, infrared screening agents have been similarly used for the purpose of increasing air conditioning efficiency of buildings or cars.

In the case of these conventional films containing UV-absorbing or IR-screening agents, however, an applying technique or cost thereof becomes a problem, while it is troublesome to cut off them into a desired shape and also difficult to apply them to a complicated part. Further, such films inconveniently keep bubbles when they are applied, while they leave an adhesive when they are torn off. Therefore, it is not sufficiently easy for anyone to handle these films.

Furthermore, a defect of conventional compositions containing UV-absorbing and/or IR-screening agents is that color shading is occurred due to insufficient coating uniformity, a coated film is hardly cured at room temperature and strength of the film is weak.

In addition, a curing effect is restricted by a solvent solved in a high polar solvent, which causes interference fringes on the film surface after curing and stickiness of the film surface after drying when a large amount of catalyst is excessively added. Further, the catalyst added more than some definite amount would result in various difficulties such as embrittlement of the film and retardation of curing speed due to deposition of the catalyst or other functional reagents. Even if the film is hardened through curing, the film exhibits less

flexible follow-up properties so that peeling of the coated film is occurred due because expansion coefficient thereof is different from that of the substrate. Due to less constant catalytic activity of conventional catalysts, curing time has varied widely case by case, which makes it difficult to control hardness of the film. On the other hand, there has not
5 been present any composition that has strong adhesion properties to the surface of glass, transparent plastics, metals etc., and that is cured at ordinary temperatures to form a transparent protective film of pencil hardness more than 6H so as to exhibit a flaw protection effect.

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SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a novel transparent silicone film-forming composition and a method for curing same.

Further object of the present invention is to provide a silicone film-forming composition which yields an ultraviolet absorbing and/or infrared screening and
15 transparent or colored transparent film of convenience in handling and excellent in appearance, and is easy to control curing time and hardness thereof depending on concentration of a curing catalyst.

Another object of the present invention is to provide a transparent silicone film-forming composition which is rapidly cured on a coated surface to form a hard film
20 thereon, and a method for curing same.

Yet another object of the present invention is to provide a transparent silicone film-forming composition which yields a rapidly curable and room temperature-curable film of excellent leveling properties without causing insufficient coating and color uniformity, hardness thereof being increased in a short time period after curing, and a method for
25 curing same.

It has been found by the inventors that a rapidly curable film of high coating properties and excellent curing characteristics at room temperature can be formed from a transparent silicone film-forming composition comprising a reaction product (A) prepared by reacting alkoxy silane having an epoxy group (a), alkoxy silane having an amino group
30 with active hydrogen (b), and alkoxy silane (c) in a mass ratio of 3 to 7:4 to 8:1 to 5, followed by further adding thereto monoalkoxy silane (d) and/or glycid silane (e) in a mass

ratio of 0.1% to 20% to the alkoxysilane (c), an acid catalyst (B), a finely ground ITO cocatalyst (C) and at least one solvent (D) selected from organic solvents.

Hardness of the film may be increased in a short period of time after curing. The present invention is based on the above mentioned fact. As the thus formed film is quite
 5 adhesive to a soft substrate and contains metal particles therein, the film is conveniently conformable to expansion and shrinkage of the substrate in spite of glassy properties thereof.

The transparent silicone film-forming composition of the present invention may further comprise one or more than two components (E) selected from ultraviolet absorbing
 10 agents and infrared screening agents and/or a dye and/or pigment (F).

The most characteristic feature of the present invention resides in the finely ground ITO cocatalyst (C), which allows to rapidly cure the silicone film-forming composition comprising a reaction product (A) of alkoxysilane having an epoxy group (a), alkoxysilane
 15 having an amino group with active hydrogen (b) and alkoxysilane (c) and an acid catalyst (B) even at room temperature.

PREFERRED EMBODIMENTS OF THE INVENTION

A component (A) used in the present invention is a reaction product (A) prepared by reacting alkoxysilane having an epoxy group (a), alkoxysilane having an amino group
 20 with active hydrogen (b), and alkoxysilane (c) in a mass ratio of 3 to 7:4 to 8:1 to 5, followed by further adding thereto monoalkoxysilane (d) and/or glycidysilane (e) in a mass ratio of 0.1% to 20% to the alkoxysilane (c).

The alkoxysilane having an epoxy group (a) in the component (A) includes γ -glycidoxypropyltrimethoxysilane, γ -glycidoxypropylmethyldimethoxysilane, etc.
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The alkoxysilane having an amino group with active hydrogen (b) includes γ -aminopropyltriethoxysilane, N-(β -aminoethyl)- γ -aminopropyltrimethoxysilane, N-(β -aminoethyl)- γ -aminopropyldimethoxysilane, etc., although N-(β -aminoethyl)- γ -aminopropyltrimethoxysilane [$\text{H}_2\text{N}(\text{CH}_2)_2\text{NH}(\text{CH}_2)_3\text{Si}(\text{Ome})_3$] is more preferably used.

When N-(β -aminoethyl)- γ -aminopropyltrimethoxysilane [$\text{H}_2\text{N}(\text{CH}_2)_3\text{NH}(\text{CH}_2)_3\text{Si}(\text{OMe})_3$] is used as a constituent of the component (A), the present composition
 30 yields a hard film after curing, which is suitable for window glass of cars because no flaw

is caused through opening and shutting of the window.

In mixing alkoxysilane having an epoxy group (a) and alkoxysilane having an amino group with active hydrogen (b) (the thus prepared mixture will be referred to as Mixture 1), a mixing ratio of both constituents (a) and (b) is preferably in the range of (a) :
5 (b) = 5:5 to 9:1, and more preferably (a) : (b) = 5:5 to 8:2 in the mass ratio, respectively.

In mixing alkoxysilane having an epoxy group (a) and alkoxysilane having an amino group with active hydrogen (b) (the thus prepared mixture will be referred to as Mixture II), a formulating ratio of constituents (b) and alkoxysilane (c) may be increased or decreased based on each molar ratio by weight depending on desired ultimate hardness
10 and drying rate of a composition to be obtained.

In the case of Mixture I, if the mass ratio of alkoxysilane having an epoxy group is more than 9, it takes time to cure the thus obtained transparent silicone film-forming composition after coating thereof, while the surface hardness of the film to be formed is low. If the mass ratio of alkoxysilane having an amino group with active hydrogen is more
15 than 4, weather resistance of the thus obtained transparent silicone film-forming composition is

reduced.

In the case of Mixture II, the drying rate is accelerated as the ratio of the constituent (c) increases, however, which tends to cause cure shrinkage marks on the film after coating, while an increase in the constituent (b) tends to affect an organic functional agent to be added afterward. Considering what is described above, it is important to polymerize these constituents on the basis of equimolar ratio so as to form a weather resistant film and to improve hardness thereof sufficiently. Preferably, a formulating ratio of constituents (a), (b) and (c) is in the range of 3 to 7 : 4 to 8 : 1 to 5, each of which is not always an integer.

The transparent silicone film-forming composition used in the present invention may comprise tri- or dialkoxysilane (c) and monoalkoxysilane (d) and/or glycidysilane (e) other than alkoxysilane having an epoxy group (a) and alkoxysilane having an amino group with active hydrogen (b).

In other words, the component (A) may be a reaction product of alkoxysilane having an epoxy group (a) and alkoxysilane having an amino group with active hydrogen (b), with tri- or dialkoxysilane (c) and monoalkoxysilane (d) and/or glycidysilane (e).

In this reaction, such a constituent (c) of the component (A) is trialkoxysilane or dialkoxysilane and typically includes trimethoxymethylsilane, dimethoxydimethylsilane, trimethoxyethylsilane, dimethoxydiethylsilane, triethoxyethylsilane, etc. It has been confirmed that the component performs to improve surface hardness of a cured film.

Monoalkoxysilane (d) as a constituent of the component (A) includes methoxysilane, ethoxysilane, propoxysilane, butoxysilane, etc.

When alkoxysilane having an epoxy group (a), alkoxysilane having an amino group with active hydrogen (b) and tri- or dialkoxysilane (c) are reacted, preferably the thus obtained product is a product prepared by reacting these constituents (a), (b) and (c) in a mass ratio of (a) : (b) : (c) = 3 to 7 : 4 to 8 : 1 to 5. It is more preferable to form a further product by adding afterward 0.1 to 20 % of monoalkoxysilane (d) and /or glycidysilane (e) in a mass ratio to the constituents (c) so as to fit for various uses.

The most preferable range of such constituents is (a) : (b) : (c) = 5 to 7 : 6 to 8 : 3 to 8. With regard to other constituents, it is preferable to add (d) and/or (e) in a mass ratio of 0.1 to 20 % to the constituents (c), respectively.

If the mass ratio of alkoxysilane having an epoxy group (a) is high, it takes time to cure the thus obtained transparent film-forming composition so that the surface hardness of film is reduced. On the other hand, if the mass ratio of alkoxysilane having an amino group with active hydrogen (b) is high, the weather resistance of film formed from the transparent or translucent film-forming composition is reduced.

4 August 2004

Further, if the mass ratio of tri- or dialkoxysilane (c) is high, the curing rate of film formed from the transparent or translucent film-forming composition is accelerated to reduce the coating workability.

An acid catalyst used in the present invention includes any compound such as sulfuric acid, nitric acid, organophosphorus compounds and p-toluenesulfonic acid, which can promote hydrolysis of a hydrophilic alkoxy silane having a hydroxyl group at room temperature to form silanol of higher reactivity, and then promote condensation-polymerization thereof, although boron trifluoride is preferably used as the catalyst.

A finely ground ITO cocatalyst, Indium-Tin Oxide, as the component (C) of the present composition allows to rapidly cure the silicone film-forming composition comprising a reaction product (A) of alkoxy silane having an epoxy group (a) and alkoxy silane having an amino group with active hydrogen (b) and an acid catalyst (B) even at room temperature. It is considered that ITO plays a role as a cocatalyst for curing when the silicone film-forming composition is cured in the presence of the acid catalyst.

It has become clear that hardness of the thus cured film goes up to pencil hardness of 6H to 9H or more.

Further, the finely ground ITO cocatalyst does not result in any haze nor turbidity, and lack of transparency nor surface lubricating properties.

In general, commercially available ITO having particle size of 10 to 30 nm is preferably used.

A solvent used in the present invention basically includes alcoholic solvents, Cellosolve solvents, hydrophilic solvents having more than two functional groups and organic polar solvents, and typically those solvents such as isobutyl alcohol, diethylene glycol diethyl ether, diisobutyl ketone, propylene glycol monoethyl ether acetate, dipropylene glycol monomethyl ether propanol, etc.

The above mentioned propylene glycol monoethyl ether acetate includes 1-ethoxy-2-propylacetate and 2-ethoxy-1-propylacetate, while a mixture of 2-propyl- and 1-propylacetates in an ratio of 90 % or more and 10 % or less, respectively.

The organic polar solvents may basically include any organic solvents of high polarity, although dipropylene glycol monomethyl ether propanol, (2-methoxymethyl-ethoxy)dimethylformamide or N-methylpyrrolidone is preferably used.

There may be used organic acid, alcohol, ketone, etc. to improve solubility of acid catalysts and dyes.

A wide range of ultraviolet absorbing agents may be used in the present invention. When properties of film tearing off by alkaline reagents, i.e. alkali-repellency, is required, there may be selected an alkali soluble ultraviolet absorbing agent from benzophenone- or

benzotriazole type.

Typically, such a ultraviolet absorbing agent includes 2-hydroxy-4-methoxybenzophenone, 2,4-dihydroxybenzophenone, 2,2',4,4'-tetrahydroxybenzophenone, 2-hydroxy-4-methoxybenzophenone-5-sulfonic acid, etc.

For the purpose of providing alkali-repellency, there may be used a benzophenone type other than those agents described above or benzotriazole type as a ultraviolet absorbing agent.

An infrared screening agent used in the present invention may be inorganic- or organic type agents. There are two kinds of infrared screening agents; infrared reflecting- and infrared absorbing types.

The infrared reflecting type includes, for example, perylene black pigments available from BASF and other companies, while with regard to the infrared absorbing agent, there may be preferably used organic pigments such as aniline or polyaniline type available from Nippon Carlit Co., Ltd., or cyanine or phthalocyanine type available from Nippon Shokubai Co., Ltd.; and inorganic compounds such as zinc oxide, ITO and ATO, or metal complexes of Cu, Ag, Fe and Mn and other copper complex, which is available from Kureha Chemical Co., Ltd. as ULA-02 or ULA-01 and is effective in the wave range from 600 nm.

An amount of the ultraviolet absorbing agent and/or infrared screening agent used in the present invention as the component (E) is 1 to 45 % by mass of the transparent or translucent film-forming composition (A). If the ultraviolet absorbing agent and/or infrared screening agent is less than 1 % by mass, the ultraviolet absorbing effect becomes weak and the film repellency is decreased. On the other hand, an amount thereof more than 45 % by mass not only decreases the resistance to water and chemicals such as an oil film cleaner but causes a blooming or bronzing phenomenon. Thus, an amount of 1.5 to 20 % by mass is desirable from a viewpoint of practice.

The component (F) used in the present invention is selected from dyes and/or pigments of high weather resistance. Examples of useful dyes include a direct dye such as C. I. Direct Yellow 98, C. I. Direct Red 220 and C. I. Direct Blue 77, and an acid dye such as C. I. Acid Yellow 112, C. I. Acid Red 256 and C. I. Acid Blue 182. While, examples of useful pigments include an inorganic pigment such as C. I. Pigment Yellow 157, C. I. Pigment Red 101 and C. I. Pigment Blue 29 and an organic pigment such as C. I. Pigment Yellow 154, C. I. Pigment Red 122 and C. I. Pigment Blue 15:1. Such dye and/or pigment may be used independently or in combination thereof. There may be properly used fluorescent pigments for assuming fluorescent colors, luminescent pigments which continuously glow after discontinuing irradiation, pearlescent pigments for assuming a pearl effect, thermochromic pigments which change a color depending on temperature, hydrophilic pigments for

4 August 2004

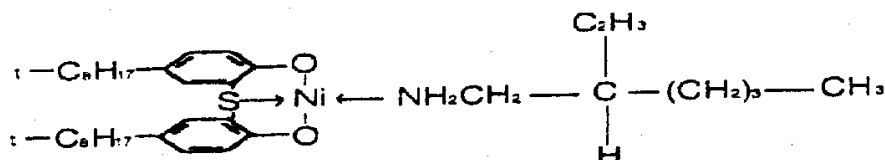
providing hydrophilic properties, functional pigments which reflect infrared light or heat rays, etc., if necessary. Various pigments are included as in the following: a fluorescent pigment comprising Acid Yellow 73 dissolved in an acrylic resin; a luminescent pigment comprising strontium aluminate as the chief ingredient; a pearlescent pigment comprising mica coated with titanium dioxide as the chief ingredient; a thermo-color pigment comprising microcapsulated Rhodamine B lactam / isooctyl gallate / cetyl alcohol, a hydrophilic pigment comprising silica and titania as the chief ingredient; and the like.

In the transparent silicone film-forming composition of the present invention, it is preferable to add a stabilizing agent (G) for an odd electron pair of nitrogen atom, which would probably be derived from the alkoxy silane having an amino group with active hydrogen, so as to prevent a reaction of the odd electron pair with the ultraviolet absorbing agent, infrared screening agent, dye, etc.

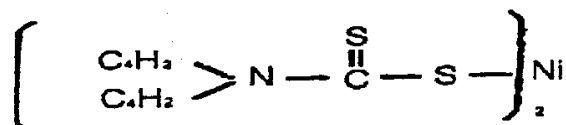
Such a stabilizing agent (G) includes various kinds of compounds in which salicylic acid, fumaric acid, crotonic acid, succinic acid, tartaric acid, p-hydroxybenzoic acid, pyrogallol, resorcinol, etc. are preferably used.

The stabilizing agent (G) may either be used in single or in combination.

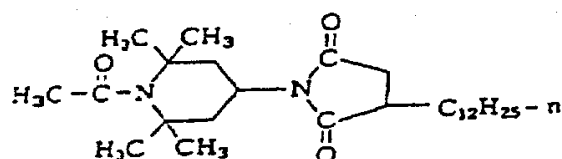
A photo-stabilizing agent used in the present invention includes [2,2'-Thiobis(4-tert-octylphenolate)]-2-ethylhexylamine nickel (trade name of Viosorb; molecular weight: 635) represented by the following chemical formula:



and nickel dibutyl dithiocarbamate (trade name of Antigene NBC; molecular weight: 407) represented by the following chemical formula:



Further, another photo-stabilizing agent used in the present invention includes [N-acetyl-3-dodecyl-1-(2,2,6,6-tetramethyl-4-piperidiny) pyrrolidone-2,5-dione (trade name of Sanduvor 3058) represented by the following chemical formula:



It is necessary to remove dirt of oil, wax, etc. on the surface of a transparent substrate such as glass before coating. Although there are various conventional manners for removing such an oil film, an oil film stripping compound is used in a desirable manner.

5 The transparent silicone film-forming composition of the present invention may be applied by means of a brush, felt, non-woven fabric, spray gun, etc.

It is desirable to apply the present composition in the direction of gravity so that non-uniformity of coating is seldom resulted in.

Further, the transparent silicone film-forming composition may be applied by
10 means of a spray gun in which its nozzle opening and closing time is controlled by a computerized nozzle valve.

The present composition is applied on a transparent substrate such as glass at room temperature to form a hard film of dry to touch hardness within 0.3 to 1 hour and then yield a beautiful, transparent and solid cured film having pencil hardness of 6H to 9H or
15 more after drying for 12 to 24 hours.

In the case of a specific transparent silicone film-forming composition of the present invention which comprises an alkali soluble ultraviolet absorbing agent, a cured film formed by applying the composition on a substrate such as glass can be repeatedly applied after peeling the film from the substrate when color degradation or a decrease in
20 ultraviolet absorbing effect is happened. An alkali agent is used as a stripping agent in such a case.

Preferably, pH of the alkali agent is more than 9, because permeability thereof into the film would decrease at pH 9 or less. One or more than two kinds of nonionic surfactants may be added to the alkali agent if penetration thereof or cleaning of the film is
25 hardly done by the agent alone.

Examples of the alkali agent include anionic surfactants: sodium- or potassium bicarbonate, sesquicarbonate, carbonate, metasilicate, orthosilicate, phosphate, pyrophosphate, tripolyphosphate, metaborate, borate, etc; a water soluble amnioalcohol such as triethanolamine, diethanolamine, monoethanolamine, methyldiethanolamine,
30 ethyldiethanolamine and monoisopropanolamine; and aqueous ammonium. The alkali agent may be prepared by dissolving one or more than two of the above mentioned

compound in water to adjust a pH value to more than 9.

Further, the alkali agent may be combined with an abrasive agent, or used together with a sponge or another suitable material containing such an abrasive agent to slightly rub the film surface.

- 5 Embodiments of the present invention will be summarized as in the following:
- (1) A transparent silicone film-forming composition comprising a reaction
product (A) prepared by reacting alkoxysilane having an epoxy group (a),
alkoxysilane having an amino group with active hydrogen (b), and
alkoxysilane (c) in a mass ratio of 3 to 7:4 to 8:1 to 5, followed by further
10 adding thereto monoalkoxysilane (d) and/or glycidysilane (e) in a mass ratio
of 0.1% to 20% to the alkoxysilane (c), an acid catalyst (B), a finely ground
ITO cocatalyst (C) and at least one solvent (D) selected from organic
solvents.
- (2) A transparent silicone film-forming composition described in the above
15 item 1 in which alkoxysilane having an amino group with active hydrogen
(b) is γ -aminopropyltriethoxysilane.
- (3) A transparent silicone film-forming composition described in either one of
the above items 1 and 2 further comprising one or more components (E)
selected from ultraviolet absorbing agents, infrared screening- and infrared
20 absorbing agents and/or dye and/or pigment (F).
- (4) A transparent silicone film-forming composition described in any one of the
above items 1 to 3 comprising one or more kinds of solvent selected from
alcoholic-, ketone type-, and ether type solvents, and solvents having two or
more functional groups as the organic solvent (D).
- 25 (5) A transparent silicone film-forming composition described in any one of the
above items 1 to 4 comprising one or more kinds of organic acid compound
selected from salicylic acid, fumaric acid, crotonic acid, succinic acid and
tartaric acid or an organophosphorus compound or photo-stabilising agent
as a stabilising agent (G).
- 30 (6) A method for curing a transparent silicone film-forming composition
comprising curing a film-forming component of a transparent silicone film-

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forming composition as described in any one of the above items 1 to 5 using an acid catalyst and a finely ground ITO cocatalyst as a curing catalyst.

- (7) A method for curing a transparent silicone film-forming composition comprising separating and keeping an acid catalyst (B), a finely ground ITO cocatalyst (C), at least one solvent (D) selected from organic solvents, one or more compounds selected from ultraviolet absorbing agents, infrared screening- and infrared absorbing agents (E) and a dye and/or pigment component (F) comprised in any one of a transparent silicone film-forming composition described in items 1 to 5 in another vessel, mixing immediately before use thereof with a reaction product (A) of alkoxysilane having an epoxy group (a) and alkoxysilane having an amino group with active hydrogen (b) using it as a liquid mixture, and applying to a pretreated surface of transparent substrate followed by curing.

The present invention will be further described in the following examples.

EXAMPLES

Reference Example 1

(1) γ -Glycidoxypropyltrimethoxysilane in an amount of 85 g, 80 g of γ -amino-propyltriethoxysilane and 50 g of methyltrimethoxysilane were mixed, stirred for one hour and then allowed to stand in a constant temperature room at 25 °C for fourteen days for aging to yield a reaction product.

(2) In 20 g of propylene glycol monoethyl ether acetate, 5 g of 2,4-dihydroxybenzophenone was dissolved.

(3) In 10 g of dipropylene glycolmonomethyl ether acetate, 0.2 g of boron trifluoride piperidine was dissolved.

(4) In 5 g of propylene glycol monoethyl ether acetate, 0.5 g of ITO having particle size of 25 nm (Indium TinOxide; available from Fuji Titanium Co., Ltd.) is dispersed.

(5) Each liquid obtained in steps (3) and (4) were mixed with a solution of step (2) and then homogeneously mixed with 20 g of a solution obtained in the step (1) to form a transparent silicone film-forming composition (I).

Control Example 1

A control sample (I') of transparent silicone film-forming composition was prepared in a similar manner as described in Example 1 except that a dispersion of step (2) was not added.

Reference Example 2

(6) γ -Glycidoxypropyltrimethoxysilane in an amount of 85 g, 80 g of γ -amino-propyltriethoxysilane and 50 g of methyltrimethoxysilane were mixed, and stirred aged similarly as described in the step (1) above to yield a reaction product.

(7) A solution similar to the step (2) but excluded 2,4-dihydroxybenzophenone (2') and that of step (3) were prepared in a similar manner as described in Example 1, while each liquid of steps (3) and (4) were mixed with the solution of step (2') and then homogeneously mixed with 20 g of the product of step (6) to form a transparent silicone film-forming composition (II).

Control Example 2

A control sample (II') of transparent silicone film-forming composition was prepared in a similar manner as described in Example 2 except that a dispersion of step (2) was not added.

Reference Example 3

(8) γ -Glycidoxypolytrimethoxysilane in an amount of 85 g, 80 g of γ -aminopropyltriethoxysilane and 50 g of methyltrimethoxysilane were mixed, and stirred aged similarly as described in the step (1) above to yield a reaction product.

(9) In 20 g of propylene glycol monoethyl ether acetate, 5 g of 2,2,4,4-tetrahydroxybenzophenone was dissolved.

(10) Each liquid obtained in steps (3) and (4) were mixed with a solution of step (9) and then homogeneously mixed with 20 g of a solution obtained in the step (8) to form a transparent silicone film-forming composition (III).

Control Example 3

A control sample (III') of transparent silicone film-forming composition was prepared in a similar manner as described in Example 3 except that a dispersion of step (2) was not added.

Example 1

(11) To 55 g of γ -Glycidoxypolytrimethoxysilane and 35 g of γ -aminopropyltriethoxysilane, 23 g of methyltrimethoxysilane was mixed, stirred for one hour and then allowed to stand in a constant temperature room at 25 °C for fourteen days for aging to yield a reaction product. Further, the thus yielded product was mixed with 0.92 g of methoxysilane and allowed to stand in the constant temperature room at 25 °C for three days.

(12) In 20 g of propylene glycol monoethyl ether acetate, 0.05 g of 2,4-dihydroxybenzophenone was dissolved.

(13) In 10 g of dipropylene glycolmonomethyl ether acetate, 0.2 g of boron trifluoride piperidine was dissolved.

(14) In 5 g of propylene glycol monoethyl ether acetate, 0.5 g of ITO having particle size of 30 nm (Indium TinOxide; available from Fuji Titanium Co., Ltd.) is dispersed.

(15) Each liquid obtained in steps (13) and (14) were mixed with a solution of step (12) and then homogeneously mixed with 20 g of a solution obtained in the step (11) to form a transparent silicone film-forming composition (IV).

Control Example 4

A control sample (IV') of transparent silicone film-forming composition was prepared in a similar manner as described in Example 4 except that a dispersion of step

(14) was not added.

4 August 2004

Example 2

(16) To 53 g of γ -Glycidoxypropyltrimethoxysilane and 29 g of γ -amino-propyltriethoxysilane, 19 g of methyltrimethoxysilane was mixed, stirred for one hour and then allowed to stand in a constant temperature room at 25 °C for fourteen days for aging to yield a reaction product. Further, the thus yielded product was mixed with 0.72 g of methoxysilane and allowed to stand in the constant temperature room at 25 °C for three days.

(17) In 20 g of propylene glycol monoethyl ether acetate, 0.05 g of 2,4-dihydroxybenzophenone was dissolved.

(18) In 10 g of dipropylene glycolmonomethyl ether acetate, 0.2 g of boron trifluoride piperidine was dissolved.

(19) Each liquid obtained in steps (18) and (14) were mixed with a solution of step (17) and then homogeneously mixed with 20 g of a solution obtained in the step (16) to form a transparent silicone film-forming composition (V).

Control Example 5

A control sample (V') of transparent silicone film-forming composition was prepared in a similar manner as described in Example 5 except that a dispersion of step (14) was not added.

Example 3

(19) To 40 g of γ -Glycidoxypropyltrimethoxysilane and 70 g of γ -amino-propyltriethoxysilane, 20 g of methyltrimethoxysilane was mixed, stirred for one hour and then allowed to stand in a constant temperature room at 25 °C for fourteen days for aging to yield a reaction product, which was subsequently mixed with 0.92 g of glycidisilane and allowed to stand in the constant temperature room at 25 °C for three days.

(20) In 20 g of propylene glycol monoethyl ether acetate, 0.05 g of 2,4-dihydroxybenzophenone, 0.01 g of nickel dibutyldithiocarbamate and 0.03 g of 2,6-di-tert-butyl-4-methylphenol were dissolved.

(21) In 10 g of a mixed solution containing 2 g of N-methyl-2-pyrrolidone and 8 g of dipropylene glycol monomethyl ether propanol, 0.2 g of boron trifluoride piperidine was dissolved.

(22) Each liquid obtained in steps (21) and (14) were mixed with a solution of step (20) and then homogeneously mixed with Perylene Black pigment and a solution obtained in the step (19) in an amount of 20 g to form a transparent silicone film-forming composition (VI).

Control Example 6

A control sample (VI') of transparent silicone film-forming composition was prepared in a similar manner as described in Example 5 except that a dispersion of step (14) was not added.

Composition of these products will be shown in detail in Table 1 below.

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Table 1

	Component (A)	(B)	(C)	(D)	(E)	(F)
Reference Example 1	(a) 85g (b) 15g	BF ₃	ITO 1	PGMA DPMP	DHB	-
Control 1	ditto	ditto	-	ditto	ditto	-
Reference Example 2	(a) 65g (b) 35g	BF ₃	ITO 1	PGMA DPMP	-	-
Control 2	ditto	ditto	-	ditto	-	-
Reference Example 3	(a) 75g (b) 25g	BF ₃	ITO 1	PGMA DPMP	THB	-
Control 3	ditto	ditto	-	ditto	ditto	-
Example 1	(a) 65g (b) 35g (c) 23g (d) 0.92g (e) -	BF ₃	ITO 2	PGMA DPMP	DHB	-
Control 4	ditto	ditto	-	ditto	ditto	-
Example 2	(a) 53g (b) 29g (c) 18g (d) 0.72g (e) -	BF ₃	ITO 2	PGMA DPMP	DHB	D1
Control 5	ditto	ditto	-	ditto	ditto	ditto
Example 3	(a) 40g (b) 70g (c) 20g (d) - (e) 0.92g	BF ₃	ITO 2	PGMA DPMP NMP	DHB TBF P 1	P 1
Control 6	ditto	ditto	-	ditto	ditto	ditto

(a) γ - Glycidoxypropyltrimethoxysilane

(b) γ - aminopropyltriethoxysilane

(c) trimethoxymethylsilane

(d) methoxysilane

(e) glycidysilane

ITO 1: ITO dispersion having average particle size of 25nm (available from Fuji Titanium Co., Ltd)

ITO 2: ITO dispersion having average particle size of 30nm (available from Fuji Titanium Co., Ltd)

DPMP: dipropylene glycol monomethyl ether propanol

PGMA: propylene glycol monoethyl ether acetate

NMP: N-methyl-2-pyrrolidone

DHB: 2,4-dihydroxybenzophenone

10 THB: 2,2,4,4-tetrahydroxybenzophenone

TBF: 2,6-di-tert-butyl-4-methylphenol

D1: C.I. Direct Blue 77

P1: C.I. Perylene Black pigment

15 Reference Examples 4 to 7

ITO dispersion obtained in the step (4) above was added to various commercial transparent film-forming compositions to form reference compositions.

Reference Example 4

20 The finely ground ITO dispersion was added to a commercial acrylic paint in the same ratio as Example 1 (mass ratio to solid component).

Reference Example 5

The finely ground ITO dispersion was added to a commercial polycarbonate paint in the same ratio as Example 1 (mass ratio to solid component).

Reference Example 6

25 The finely ground ITO dispersion was added to a commercial polyvinyl acetate paint in the same ratio as Example 1 (mass ratio to solid component).

Reference Example 7

The finely ground ITO dispersion was added to a commercial cellulose lacquer in the same ratio as Example 1 (mass ratio to solid component).

30 Using transparent silicone film-forming compositions prepared in Examples, Control Examples and Reference Examples, application on a glass substrate and curing of

the thus formed films will be detailed in the following.

Oil Film Removal Process

An oil film cleaning compound is spread on an abrasive sponge containing a small amount of water to scour all over the surface of glass substrate. The glass is wiped with
5 water and sponge thoroughly to confirm that the oil film is completely removed. As the oil film still leaves on the glass if water drops do not appear thereon, the above mentioned procedure should be repeated using the oil film cleaning compound until the glass surface gets wet all over. Water and the compound are then wiped off completely, while the glass surface is further cleaned with non-woven fabric of several folds and isopropyl alcohol to
10 remove oil.

Application Process of Transparent Silicone Film-forming Compositions

4 August 2004

To a tray having volume of 150 ml (50 mm/W x 150 mm/L x 20 mm/D), about 30 ml of a solution of transparent silicone film-forming compositions prepared as examples is poured and soaked into only an oblique section of melamine foam sponge.

While holding the sponge tight, the thus soaked solution is applied to the glass substrate slowly from the right or left top to the bottom in the direction of gravity to foam a belt-like coat. After the sponge has reached the bottom, a similar procedure is repeated from the top to the bottom in the direction of gravity, thereby about one third to one forth of each coat being overlapped, until the glass substrate is coated homogeneously as a whole.

Drying Process

After the application is completed, the coated glass substrate is kept in a suitable space without influence of moisture and dust to proceed air-drying. In general, the coated film is dried to the touch, a situation in which the coated surface does not stick to fingers, within about ten minutes in summer and about 30 minutes in winter (dry to the touch). The coated film is dried up almost completely after allowing to stand for about 24 hours so that the film formed on the glass substrate such as window is not scratched through taking care thereof with soft cloth.

Film properties of various transparent silicone film-forming compositions prepared as examples were evaluated in a manner as will be described bellow.

Dry to the Touch Time

Dry to the touch time was determined according to a method based on JIS K 5400 at 10-minutes intervals at 25°C in summer and 10°C in winter, respectively.

Condition of coated films at the time of 72 hours after application was evaluated as in the following.

Transparency

The coated film was visually evaluated based on JIS K 5400.

Non-uniformity of Coating

The coated film was visually evaluated based on JIS K 5400.

Hardness of Film

Hardness of film was evaluated according to the pencil scratch test based on JIS K 5400.

Transparent silicone film-forming compositions prepared as examples were applied on glass test pieces (70 mm in width x 110 mm in length x 5 mm in thickness) and dried in a similar manner as described above. Ultraviolet transmission of each glass test pieces was determined as in the following after air-dried for 24 hours.

Ultraviolet Transmission

Each test piece was evaluated by determining the ultraviolet transmission at wave

4 August 2004

length of 345 nm by means of a spectrophotometer. The ultraviolet transmission was further determined at the time of 192 hours after the test pieces were kept in an accelerated light resistance testing device specified by JIS B 7754.

Infrared Transmission

The infrared transmission was determined according to a method based on ISO 9050 by means of a spectrophotometer (Shimazu Double Chronometer9).

With regard to Examples, Control Examples and Reference Examples, curing properties of each composition will be shown in Table 2 below.

Table 2

	drying time (hr) season	surface hardness	transmissi on UV (%)	transmissi on IR (%)	hardness after 2 hours	hardness after 72 hours
Ref. Ex. 1	summer 0.5	HB	0	60	3H	7H
	winter 1	HB	0	61	3H	7H
Cont. 1	summer 0.5	B	0	89	5H	6H
	winter 1	B	0	88	4H	6H
Ref. Ex. 2	summer 0.5	2H	33	58	4H	8H
	winter 1	2H	33	59	4H	8H
Cont. 2	summer 0.5	H	82	89	4H	6H
	winter 1	H	82	89	4H	5H
Ref. Ex. 3	summer 0.5	H	0	58	4H	6H
	winter 1	H	0	58	4H	6H
Cont. 3	summer 0.5	HB	0	87	2H	5H
	winter 1	HB	0	89	2H	4H
Ex. 1	summer 0.5	3H	0	57	6H	≥9H
	winter 1	3H	0	58	6H	≥9H
Cont. 4	summer 0.5	2H	0	89	6H	9H
	winter 1	2B	0	88	6H	9H
Ex. 2	summer 0.5	2H	0	56	5H	9H
	winter 1	2H	0	56	5H	9H
Cont. 5	summer 0.5	H	0	77	2H	6H
	winter 1	H	0	76	2H	5H
Ex. 3	summer 0.5	2H	0	3	5H	6H
	winter 1	2H	0	10	4H	6H
Cont. 6	summer 0.5	H	0	25	3H	6H
	winter 1	H	0	28	2H	5H
Ref. 4	summer 1	2H	-	-	3H	3H
Ref. 5	summer 1	4H	-	-	4H	4H
Ref. 6	summer 1	H	-	-	2H	2H
Ref. 7	summer 1	2H	-	-	2H	2H

UV and IR transmission were determined according to ISO 9050 by means of a spectrophotometer (Shimazu Double Chromometer).

- 5 Tables 1 and 2 show that the present invention provides a transparent silicone film-forming composition which does not cause insufficient coating- and color uniformity, and is curable at room temperature within a short period of time, thereby forming an attractive and weather resistant film having film hardness of 6H to 9H or more after the film is cured acceleratingly under a condition of ordinary environment, i.e., at normal temperatures in
- 10 the air. Further, the composition of the present invention comprising an infrared absorbing

4 August 2004

- 17A -

agent other than essential components makes it possible to control thermal emission and dew condensation in the room in winter time when such a composition is applied to windows, because the film absorbs infrared light and keeps heat therein.

What is claimed is:

1. A transparent silicone film-forming composition comprising a reaction product (A) prepared by reacting alkoxysilane having an epoxy group (a), alkoxysilane having an amino group with active hydrogen (b), and alkoxysilane (c) in a mass ratio of 3 to 7:4 to 8:1 to 5, followed by further adding thereto monoalkoxysilane (d) and/or glycidysilane (e) in a mass ratio of 0.1% to 20% to the alkoxysilane (c), an acid catalyst (B), a finely ground ITO cocatalyst (C) and at least one solvent (D) selected from organic solvents.
2. A transparent silicone film-forming composition as claimed in claim 1 in which alkoxysilane having an amino group with active hydrogen (b) is γ -aminopropyltriethoxysilane.
3. A transparent silicone film-forming composition as claimed in either one of claims 1 and 2 further comprising one or more components (E) selected from ultraviolet absorbing agents, infrared screening- and infrared absorbing agents and/or dye and/or pigment (F).
4. A transparent silicone film-forming composition as claimed in any one of claims 1 to 3 comprising one or more kinds of solvent selected from alcoholic-, ketone type-, and ether type solvents, and solvents having two or more functional groups is used as the organic solvent (D).
5. A transparent silicone film-forming composition as claimed in any one of claims 1 to 4 comprising one or more kinds of organic acid compounds selected from salicylic acid, fumaric acid, crotonic acid, succinic acid and tartaric acid, or an organophosphorous compound, or photo-stabilising agent as a stabilizing agent (G).
6. A method for curing a transparent silicone film-forming composition comprising curing a film-forming component of a transparent silicone film-forming composition as claimed in any one of claims 1 to 5 using an acid catalyst and a finely ground ITO cocatalyst as a curing catalyst.
7. A method for curing a transparent silicone film-forming composition comprising separating and keeping an acid catalyst (B), a finely ground ITO cocatalyst (C), at least one solvent (D) selected from organic solvents, one or more compounds

8. selected from ultraviolet absorbing agents, infrared screening- and infrared absorbing agents (E) and a dye and/or pigment component (F) comprised in any one of a transparent silicone film-forming composition claimed in claims 1 to 7 in another vessel mixing immediately before use thereof with a reaction product (A)
- 5 of alkoxysilane having an epoxy group (a) and alkoxysilane having an amino group with active hydrogen (b) using it as a liquid mixture, and applying to a pretreated surface of transparent substrate followed by curing.