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(54) **Carrier, toner and electrophotographic photoreceptor comprising a carbosiloxane dendrimer-functional vinyl type polymer**

(57) A carrier for developing electrostatic latent images has an excellent charging stability, resistance to spenting, and durability and can provide high resolution images over long periods of operation. The carrier achieves these advantageous effects because it contains a pendant carbosiloxane dendrimer-functional vinyl-type polymer. A toner for developing electrostatic images also contains the pendant carbosiloxane dendrimer-functional vinyl-type polymer. The toner has an excellent fluidity, releasability, fixing behavior, resistance to offset, and flexibility and can provide high resolution images. The toner and carrier can be used in various imaging technologies, e.g., electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies. An electrophotographic photoreceptor contains, in at least its surface layer, a binder resin and the pendant carbosiloxane dendrimer-functional vinyl-type polymer.

EP 1 011 033 A2

Description**FIELD OF THE INVENTION**

5 **[0001]** This invention relates to the use of a pendant carbosiloxane dendrimer-functional vinyl-type polymer in electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies. More particularly, this invention relates to a carrier for electrostatic latent image development ("ELID carrier"). More particularly, this invention relates to an ELID carrier that has an excellent charging stability, an excellent resistance to spenting, and an excellent durability. The carbosiloxane dendrimer can also be used in a toner for electrostatic image development
 10 ("toner"). More particularly, this invention relates to a toner that can provide high-resolution images and that has an excellent and balanced fluidity, releasability, fixing behavior, resistance to offset, and flexibility. The carbosiloxane dendrimer can also be used in an electrophotographic photoreceptor. More particularly, this invention relates to an electrophotographic photoreceptor that has an excellent mechanical strength and that can retain its excellent electrophotographic characteristics and excellent resistance to the imaging process over long periods of operation.

15 **[0002]** The ELID carrier, the toner, and the electrophotographic photoreceptor can be used, for example, in electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies.

BACKGROUND OF THE INVENTION

20 **[0003]** One method widely used in electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies to develop the electrostatic latent image comprises bringing the electrostatic latent image already formed on the photoreceptor into proximity with a dry developer to bind toner on the electrostatic latent image, then transferring this toner to the receiving sheet, and finally carrying out a heat fixing operation. Among the dry developers used in this method, two-component developers in particular are frequently used, for example, to produce
 25 full-color copies. Two-component developers are composed of a dispersion of toner (main components = colorant and binder resin) in a carrier (main components = carrier core powder and coating resin). One problem with the two-component developers is that the toner can gradually form an adherent film on the carrier surface due to triboelectrification (generally known as developer spenting), resulting in timewise changes in the charging characteristics of the carrier and a shortening of the service life of the developer.

30 **[0004]** A large number of methods have been proposed to solve this problem. For example, one approach consist of coating the surface of the carrier core powder with a cured release film, e.g., a cured silicone (see Japanese Laid Open (Kokai) Patent Application Numbers Sho 56-106968 (1981), Sho 61-284775 (1986), Hei 2-160259 (1990), Hei 5-88413 (1993), and Hei 9-143429 (1997)). However, these cured films still result in a short developer service life because they have a low flexibility and an inadequate durability.

35 **[0005]** Japanese Laid Open (Kokai) Patent Application Numbers Hei 8-179569 (1996) and Hei 9-114139 (1997) teach coating the surface of the carrier core powder with a thermoplastic resin coating of acrylic resin or styrene resin containing linear siloxane in pendant position. Japanese Laid Open (Kokai) Patent Application Number Hei 8-179566 (1996) teaches coating the surface of the carrier core powder with a thermoplastic resin containing a branched siloxane-grafted polymer. These methods, however, do not provide an unequivocally satisfactory improvement in dura-
 40 bility or inhibition of the timewise changes in carrier charging characteristics.

[0006] An object of this invention is to provide an ELID carrier that has excellent charging stability, excellent resistance to spenting, and excellent durability and that has the ability to produce high resolution images over long periods of operation when used in electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies.

45 **[0007]** Hot roller technology, which is capable of high thermal efficiencies and high-speed fixing, is widely used to fix the toner employed electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies. One problem with hot roller technology has been its pronounced tendency to produce so-called offset images. This occurs when part of the toner image becomes attached during fixing to the surface of the hot roller and is subsequently transferred to the copy paper to produce background staining thereon.

50 **[0008]** A large number of toners have been proposed to solve the offset problem. For example, Japanese Laid Open (Kokai) Patent Application Number Sho 59-197048 (1984) teaches a toner whose main components are colorant and an organic resin-type binder resin that contains straight-chain dimethylpolysiloxane having a viscosity of at least 5,000 centistokes. Japanese Laid Open (Kokai) Patent Application Number Hei 2-3073 (1990) teaches toner whose main components are colorant and an organic resin-type binder resin that contains straight-chain dimethylpolysiloxane
 55 that (i) has a viscosity of 30 to 60,000 centistokes and (ii) contains no more than 3,000 ppm dimethylsiloxane oligomer with a molecular weight less than or equal to 2,000. These toners, however, still suffer from various problems. Thus, their resistance to offset is impaired when they contain small amounts of the dimethylpolysiloxane; but when they contain too much, the dimethylpolysiloxane bleeds onto the surface of the toner and thereby impairs the fluidity and block-

ing characteristics of the toner.

[0009] Japanese Laid Open (Kokai) Patent Application Number Hei 9-269611(1997) teaches toner whose main components are colorant and organic resin-type binder resin comprising a styrene resin that contains the methyldimethoxysilyl group, while Japanese Laid Open (Kokai) Patent Application Number Hei 6-289650 (1994) discloses toner that contains a silicone oil-grafted copolymer.

[0010] These particular toners, however, do not have an unequivocally satisfactory resistance to offset. In addition, within the realm of toners having an improved resistance to offset and improved low-temperature fixing properties, Japanese Laid Open (Kokai) Patent Application Number Hei 7-219272 (1995) teaches toner comprising colorant and organic resin-type binder resin afforded by the addition of a styrene-type starburst dendrimer to organic resin-type binder resin. Since this dendrimer is a non-silicone dendrimer, this toner does not have an altogether satisfactory fluidity and releasability and is difficult to manage during the fixing process.

[0011] It is a further object of this invention to provide toner that can generate high-resolution images and that has an excellent and balanced fluidity, releasability, fixing behavior, resistance to offset, and flexibility.

[0012] Inorganic photoconductive materials such as selenium, cadmium sulfide, and zinc oxide have long been used as the photoconductive material in electrophotographic photoreceptors. Electrophotographic photoreceptors based on organic photoconductive materials, such as polyvinyl carbazole, oxadiazole, and phthalocyanine, are coming into use because they offer advantages such as high productivity and an absence of toxicity. These electrophotographic photoreceptors based on organic photoconductive materials are also known as organic photoconductors or OPCs. One type of OPC that has been developed to practical levels is a photoreceptor consisting of a single photosensitive layer in which a charge-generating substance and charge-transport substance are dispersed in a binder resin. Another type of OPC that has been developed to practical levels is a multilayer photoreceptor in which the photosensitive layer consists of at least 2 layers, i.e., at least a charge-generating layer (CGL) and a charge-transport layer (CTL). The latter, multilayer photoreceptor is in particular very sensitive and hence is in widespread use.

[0013] Unfortunately, when subjected to long-term repetitive use, the surface layers of these electrophotographic photoreceptors suffer from deterioration due the ozone produced during corona charging. This facilitates and supports a decline in sensitivity and a decline in potential. In addition, electrophotographic photoreceptors are easily worn by friction. Consequently, when electrophotographic photoreceptors are subjected to long-term use, paper-derived particulates and toner readily become bound to the surface layer of the photoreceptor, resulting in deterioration of the image.

[0014] A variety of methods have been proposed to solve these problems. For example, one approach has been to disperse a surface modifier, e.g., silicone oil or Teflon[®] powder, in the surface layer of the electrophotographic photoreceptor to impart lubricity and releasability to this surface layer. However, due to their poor compatibility with the coating fluid, these surface modifiers have suffered from such problems as migration to the surface layer, poor dispersibility, reduced transparency, and carrier trapping.

[0015] Japanese Laid Open (Kokai) Patent Application Numbers Sho 62-139557 (1987) and Hei 6-220181(1994) teach the use of a polycarbonate/siloxane block copolymer as the binder resin in the charge-generating layer and/or charge-transport layer. Japanese Laid Open (Kokai) Patent Application Number Sho 62-139557 teaches the admixture of a silicone-based comb-type graft polymer into a polyarylate resin binder and use of this blend in the outermost layer of the photoreceptor. Even these methods, however, are unable to provide entirely satisfactory results upon repetitive use in the areas of surface releasability, wear resistance, and accumulation of residual potential.

[0016] It is a further object of this invention to provide an electrophotographic photoreceptor that over the course of long-term operations evidences an excellent resistance to the imaging process, does not accumulate residual potential, and produces high-quality images.

SUMMARY OF THE INVENTION

[0017] A pendant carbosiloxane dendrimer-functional vinyl-type polymer is used in electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies. The invention further relates to an ELID carrier having an excellent charging stability, excellent resistance to spenting, and excellent durability and that has the ability to produce high resolution images over long periods of operation when used in electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies. The ELID carrier achieves these properties by containing, in at least its surface layer, vinyl-type polymer that contains a pendant carbosiloxane dendrimer structure (hereinafter abbreviated as pendant carbosiloxane dendrimer-functional vinyl-type polymer).

[0018] The invention further relates to a toner that can generate high-resolution images and has an excellent and balanced fluidity, releasability, fixing behavior, resistance to offset, and flexibility. The toner achieves these properties by characteristically containing the pendant carbosiloxane dendrimer-functional vinyl-type polymer.

[0019] The invention further relates to an electrophotographic photoreceptor. The electrophotographic photoreceptor has a surface layer comprising a binder resin and a pendant carbosiloxane dendrimer-functional vinyl-type polymer.

DETAILED DESCRIPTION OF THE INVENTION

[0020] The ELID carrier of this invention contains a pendant carbosiloxane dendrimer-functional vinyl-type polymer in at least the surface layer of the carrier. Any ELID carrier with this structure is wholly encompassed by this invention.

5 The ELID carrier can comprise a carrier core powder for electrostatic latent image development ("carrier core powder") and a pendant carbosiloxane dendrimer-functional vinyl-type polymer with the ELID carrier core powder being coated with the vinyl-type polymer to give a so-called resin-coated carrier. In this case the pendant carbosiloxane dendrimer-functional vinyl-type polymer functions as the coating resin for the carrier core powder.

[0021] The ELID carrier of this invention can also comprise a carrier core powder and a composition comprising a
10 pendant carbosiloxane dendrimer-functional vinyl-type polymer and another organic resin-type coating resin with the carrier core powder being coated with this composition again to give a resin-coated carrier.

[0022] Moreover, the ELID carrier of the present invention can comprise a pendant carbosiloxane dendrimer-functional vinyl-type polymer, an organic resin-type binder resin for electrostatic latent image development ("ELID organic resin-type binder resin"), and a magnetic powder for electrostatic latent image development ("ELID magnetic powder")
15 with said magnetic powder being dispersed in the binder resin composition to give a so-called binder-type carrier.

[0023] The toner of the invention contains the pendant carbosiloxane dendrimer-functional vinyl-type polymer. The type and other properties of this toner are not critical as long as it is toner in which pendant carbosiloxane dendrimer-functional vinyl-type polymer is present.

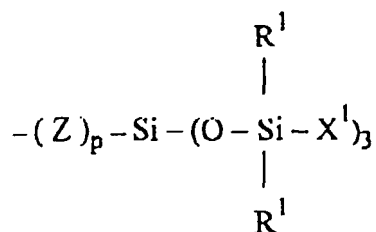
[0024] The toner of the invention comprises the pendant carbosiloxane dendrimer-functional vinyl-type polymer and colorant as known in the art for use in toners. In this case the pendant carbosiloxane dendrimer-functional vinyl-type polymer itself functions as an organic resin-type binder resin. In addition, the toner of the invention can further
20 comprise an organic resin-type binder resin as known in the art for use in toners.

[0025] This invention further relates to an electrophotographic photoreceptor. The electrophotographic photoreceptor contains, at least in its surface layer, the pendant carbosiloxane dendrimer-functional vinyl-type polymer, and any
25 electrophotographic photoreceptor with this structure is wholly encompassed by the present invention. More specifically, the electrophotographic photoreceptor has a photosensitive layer residing on an electrically conductive substrate for electrophotographic photoreceptors and, as desired, can include a nonphotosensitive lower layer, intermediate layer, or surface layer. This photosensitive layer can have a single-layer structure or a multilayer structure that includes a charge-generating layer and a charge-transport layer. The invention can use any of these heretofore known types of
30 electrophotographic photoreceptors.

[0026] For example, the outermost surface layer can comprise the binder resin and the pendant carbosiloxane dendrimer-functional vinyl-type polymer present in a nonphotosensitive surface layer, in a photosensitive layer with a single-layer structure, or in the charge-generating or charge-transport layer of a multilayer photosensitive layer. More particularly, when a photosensitive layer and a nonphotosensitive layer are the constituent components, the outermost surface
35 layer can be the aforesaid nonphotosensitive surface layer or the photosensitive layer. When a multilayer photosensitive layer containing a charge-generating layer and a charge-transport layer is a constituent component, the outermost layer can be the charge-transport layer or the charge-generating layer.

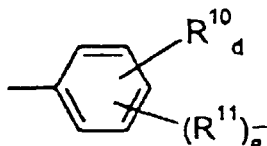
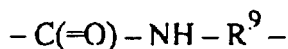
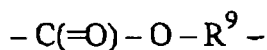
[0027] The ELID carrier, the toner, and the electrophotographic photoreceptor each contain a pendant carbosiloxane dendrimer-functional vinyl-type polymer. The pendant carbosiloxane dendrimer-functional vinyl-type polymer is
40 a vinyl-type polymer that contains a carbosiloxane dendrimer structure in a pendant or side chain position therein. This dendrimer structure refers to a high-molecular-weight group with a predictable and highly branched structure that claborates radially from a single core. An example of carbosiloxane dendrimer having such a structure is the highly branched siloxane-silalkylene copolymer taught in Japanese Patent Application Number Hei 9-171154 (1997).

[0028] The carbosiloxane dendrimer structure in the vinyl-type polymer of the invention preferably is a group with
45 the following general formula.



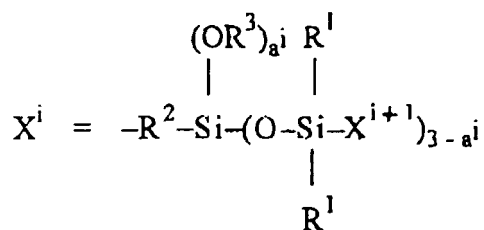
[0029] Z is a divalent organic group, for example, an alkylene group, arylene group, aralkylene group, ester-contain-

ing divalent organic group, ether-containing divalent organic group, ketone-containing divalent organic group, or amide-containing divalent organic group, among which organic groups with the following structures are preferred.



[0030] R^9 represents C_1 to C_{10} alkylene, for example, methylene, ethylene, propylene, and butylene with methylene and propylene being preferred. R^{10} represents C_1 to C_{10} alkyl, for example, methyl, ethyl, propyl, and butyl with methyl being preferred. R^{11} represents C_1 to C_{10} alkylene, for example, methylene, ethylene, propylene, and butylene with ethylene being preferred. The subscript d is an integer from 0 to 4, and the subscript e is 0 or 1. R^1 is C_1 to C_{10} alkyl or aryl.

[0031] The alkyl encompassed by R^1 is exemplified by methyl, ethyl, propyl, butyl, pentyl, isopropyl, isobutyl, cyclopentyl, and cyclohexyl. The aryl encompassed by R^1 is exemplified by phenyl and naphthyl. Methyl and phenyl are preferred for R^1 , and methyl is particularly preferred. X^1 is the silylalkyl group with the following formula at $i = 1$.

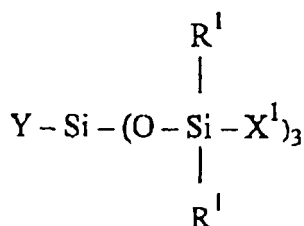


[0032] R^1 is defined as above. R^2 represents C_2 to C_{10} alkylene and is exemplified by straight-chain alkylene such as ethylene, propylene, butylene, and hexylene, and by branched alkylene such as methylmethylene, methylethylene, 1-methylpentylene, and 1,4-dimethylbutylene. Ethylene, methylethylene, hexylene, 1-methylpentylene, and 1,4-dimethylbutylene are preferred for R^2 . R^3 is C_1 to C_{10} alkyl and is exemplified by methyl, ethyl, propyl, butyl, and isopropyl. The subscript i is an integer with a value from 1 to 10 that specifies the generation of said silylalkyl group, and a^i is an integer from 0 to 3.

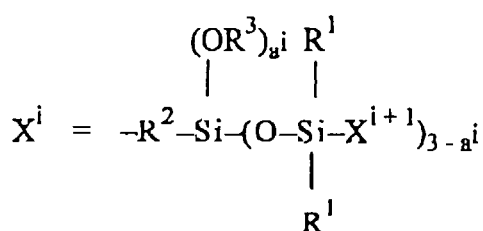
[0033] Preferred for use as the vinyl-type polymer of the invention is a pendant carbosiloxane dendrimer-functional vinyl-type polymer afforded by the polymerization of

(a) 0 to 99.9 weight parts vinyl monomer and

(b) 100 to 0.1 weight parts carbosiloxane dendrimer that contains a radically polymerizable organic group and has the following general formula



[0034] Y is a radically polymerizable organic group. R¹ is C₁ to C₁₀ alkyl or aryl. The alkyl encompassed by R¹ is exemplified by methyl, ethyl, propyl, butyl, pentyl, isopropyl, isobutyl, cyclopentyl, and cyclohexyl. The aryl encompassed by R¹ is exemplified by phenyl and naphthyl. Methyl and phenyl are preferred for R¹, and methyl is particularly preferred. X¹ is the silylalkyl group with the following formula at i = 1.



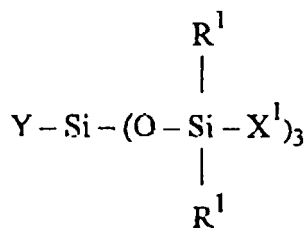
R¹ is defined as above; R² is C₂ to C₁₀ alkylene; R³ is C₁ to C₁₀ alkyl, for example, methyl, ethyl, propyl, and butyl; Xⁱ⁺¹ is selected from the set consisting of the hydrogen atom, C₁ to C₁₀ alkyl, aryl, and the above-defined silylalkyl group; i is an integer with a value from 1 to 10 that specifies the generation of said silylalkyl group; and a is an integer from 0 to 3.

[0035] The vinyl monomer (a) should contain a radically polymerizable vinyl group, but the type and other properties of this monomer are not otherwise critical. This vinyl monomer (a) is exemplified by lower alkyl (meth)acrylates such as methyl (meth)acrylate, ethyl (meth)acrylate, n-propyl (meth)acrylate, and isopropyl (meth)acrylate; glycidyl (meth)acrylate; higher alkyl (meth)acrylates such as n-butyl (meth)acrylate, isobutyl (meth)acrylate, tert-butyl (meth)acrylate, n-hexyl (meth)acrylate, cyclohexyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, octyl (meth)acrylate, lauryl (meth)acrylate, and stearyl (meth)acrylate; the vinyl esters of lower aliphatic acids, such as vinyl acetate and vinyl propionate; the vinyl esters of higher aliphatic acids, such as vinyl butyrate, vinyl caproate, vinyl 2-ethylhexanoate, vinyl laurate, and vinyl stearate; aromatic vinyl monomers such as styrene, vinyltoluene, benzyl (meth)acrylate, phenoxyethyl (meth)acrylate, and vinylpyrrolidone; amide-functional vinyl monomers such as (meth)acrylamide, N-methylol(meth)acrylamide, N-methoxymethyl(meth)acrylamide, isobutoxymethoxy(meth)acrylamide, and N,N-dimethyl(meth)acrylamide; hydroxyl-functional vinyl monomers such as hydroxyethyl (meth)acrylate and hydroxypropyl (meth)acrylate; carboxyl-functional vinyl monomers such as (meth)acrylic acid, itaconic acid, crotonic acid, fumaric acid, and maleic acid; ether linkage-containing vinyl monomers such as tetrahydrofurfuryl (meth)acrylate, butoxyethyl (meth)acrylate, ethoxydiethylene glycol (meth)acrylate, polyethylene glycol (meth)acrylate, polypropylene glycol mono(meth)acrylate, hydroxybutyl vinyl ether, cetyl vinyl ether, and 2-ethylhexyl vinyl ether; unsaturated group-functionalized silicone compounds such as (meth)acryloxypropyltrimethoxysilane, polydimethylsiloxane (branched or straight-chain) bearing a (meth)acryl group at a single terminal, and polydimethylsiloxane bearing a styryl group at a single terminal; butadiene; vinyl chloride; vinylidene chloride; (meth)acrylonitrile; dibutyl fumarate; maleic anhydride; dodecylsuccinic anhydride; (meth)acryl glycidyl ether; the alkali metal salts, ammonium salts, and organic amine salts of radically polymerizable unsaturated carboxylic acids such as (meth)acrylic acid, itaconic acid, crotonic acid, fumaric acid, and maleic acid; radically polymerizable unsaturated monomers that contain a sulfonic acid residue, e.g., styrenesulfonic acid, as well as their alkali metal salts, ammonium salts, and organic amine salts; quaternary ammonium salts that are derived from (meth)acrylic acid, such as 2-hydroxy-3-methacryloxypropyltrimethylammonium chloride; and the methacrylate esters of alcohols that contain a tertiary amine group, such as the diethylamine ester of methacrylic acid, as well as the quaternary ammonium salts thereof.

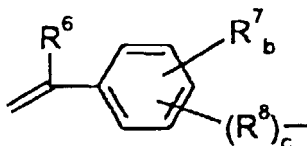
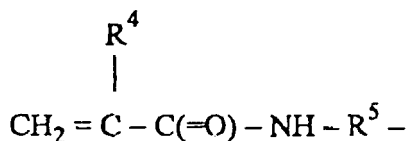
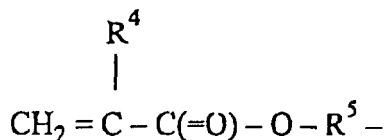
[0036] Also usable are multifunctional vinyl monomers, as exemplified by (meth)acryloyl-functional monomers such as trimethylolpropane tri(meth)acrylate, pentaerythritol tri(meth)acrylate, ethylene glycol di(meth)acrylate, tetracthylene glycol di(meth)acrylate, polyethylene glycol di(meth)acrylate, 1,4-butanediol di(meth)acrylate, 1,6-hexanediol di(meth)acrylate, neopentyl glycol di(meth)acrylate, trimethylolpropane trioxyethyl(meth)acrylate, tris(2-hydroxyethyl)isocyanurate di(meth)acrylate, tris(2-hydroxyethyl)isocyanurate tri(meth)acrylate, the di(meth)acrylates of diols that are the adducts of ethylene oxide or propylene oxide on bisphenol A, the di(meth)acrylates of diols that are the adducts of ethylene oxide or propylene oxide on hydrogenated bisphenol A, and triethylene glycol divinyl ether; divinylbenzene; diallyl phthalate; and also by unsaturated group-functional silicone compounds such as polydimethylsiloxane (branched or straight chain) endblocked at both terminals by the (meth)acryl group and polydimethylsiloxane (branched or straight chain) endblocked at both terminals by the styryl group.

[0037] The vinyl-type polymer used by this invention may be crosslinked or uncrosslinked. Crosslinking can be effected through the use of the above-described multifunctional vinyl monomers during polymerization or copolymerization.

[0038] The carbosiloxane dendrimer (b) is exemplified by compounds with the following general formula.

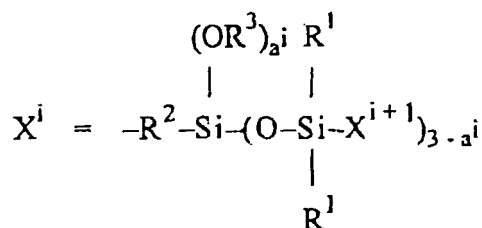


[0039] Y is a radically polymerizable organic group. Generally, Y will be an organic group capable of undergoing radical-mediated addition, while at a more specific level this group can be exemplified by C₂ to C₁₀ alkenyl and by the (meth)acryloxy-functional organic groups, (meth)acrylamide-functional organic groups, and styryl-functional organic groups with the following general formulas.



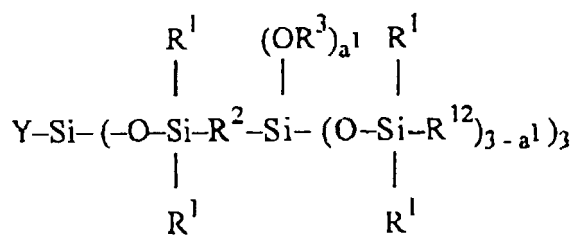
[0040] R⁴ and R⁶ are hydrogen or methyl; R⁵ and R⁸ are C₁ to C₁₀ alkylene; R⁷ is C₁ to C₁₀ alkyl; b is an integer from 0 to 4; and c is 0 or 1. These radically polymerizable organic groups are exemplified by acryloxymethyl, 3-acryloxy-

propyl, methacryloxymethyl, 3-methacryloxypropyl, 4-vinylphenyl, 3-vinylphenyl, 4-(2-propenyl)phenyl, 3-(2-propenyl)phenyl, 2-(4-vinylphenyl)ethyl, 2-(3-vinylphenyl)ethyl, vinyl, allyl, methallyl, and 5-hexenyl. R^1 is C_1 to C_{10} alkyl or aryl. The alkyl encompassed by R^1 is exemplified by methyl, ethyl, propyl, butyl, pentyl, isopropyl, isobutyl, cyclopentyl, and cyclohexyl. The aryl encompassed by R^1 is exemplified by phenyl and naphthyl. Methyl and phenyl are preferred for R^1 , and methyl is particularly preferred. X^1 is the silylalkyl group with the following formula at $i = 1$.



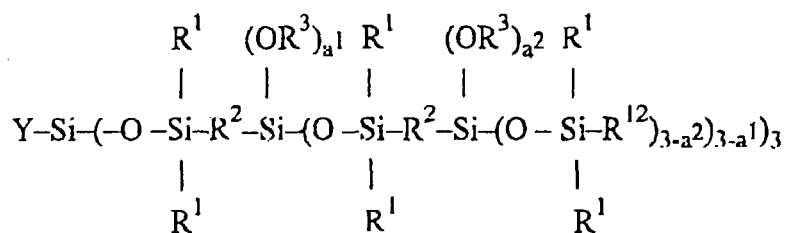
[0041] R^1 is defined as above. R^2 represents C_2 to C_{10} alkylene and is exemplified by straight-chain alkylene such as ethylene, propylene, butylene, and hexylene, and by branched alkylene such as methylmethylene, methylethylene, 1-methylpentylene, and 1,4-dimethylbutylene. Ethylene, methylethylene, hexylene, 1-methylpentylene, and 1,4-dimethylbutylene are preferred for R^2 . R^3 is C_1 to C_{10} alkyl, for example, methyl, ethyl, propyl, butyl, or isopropyl. X^{i+1} is selected from the set consisting of the hydrogen atom, C_1 to C_{10} alkyl, aryl, and the above-defined silylalkyl group. The subscript a^i is an integer from 0 to 3, and i is an integer with a value from 1 to 10 that specifies the generation of said silylalkyl group, i.e., that indicates the number of repetitions of this silylalkyl group.

[0042] The carbosiloxane dendrimer (b) has the following general formula when the number of generations is 1:



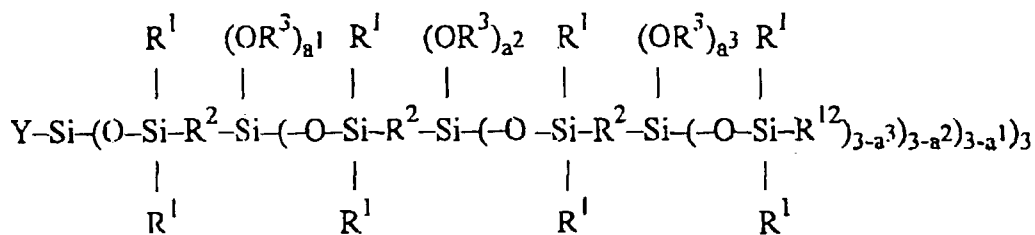
wherein Y , R^1 , R^2 , and R^3 are defined as above; R^{12} is the hydrogen atom or is defined as for R^1 ; a^1 is defined as for a^i ; and the average of the sum of the a^1 values in each molecule is from 0 to 7.

[0043] The carbosiloxane dendrimer (b) has the following general formula when the number of generations is 2:



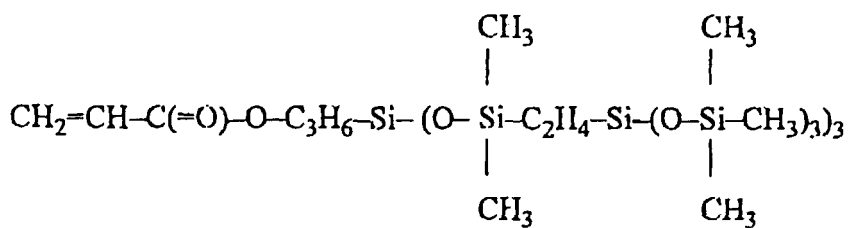
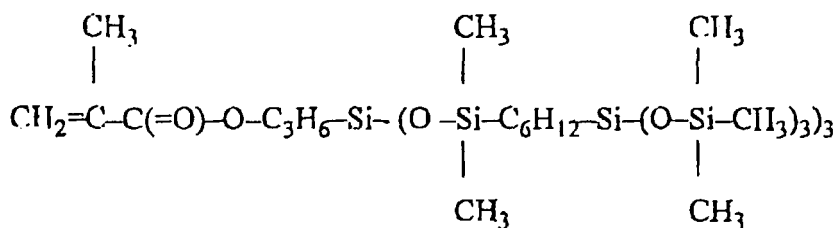
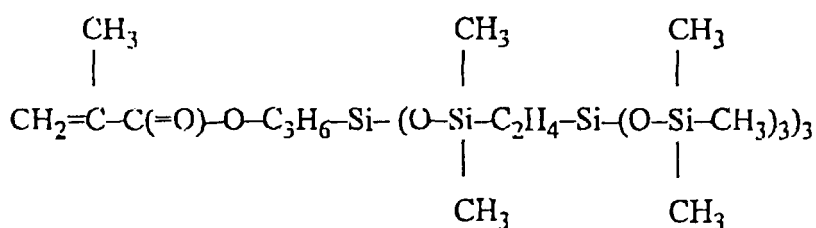
wherein Y , R^1 , R^2 , R^3 , and R^{12} are defined as above; a^1 and a^2 are defined as for a^i ; and the average of the sum of the a^1 and a^2 values in each molecule is from 0 to 25.

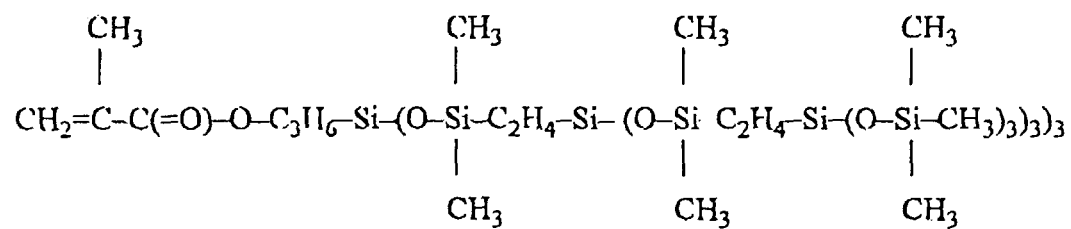
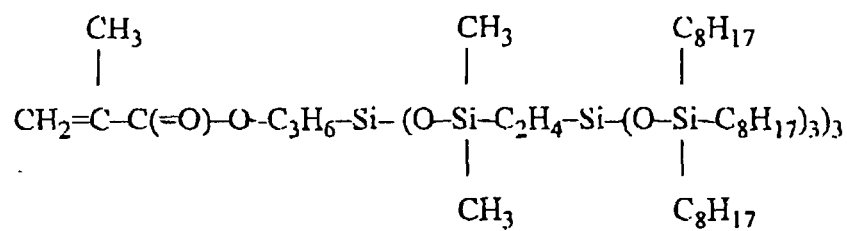
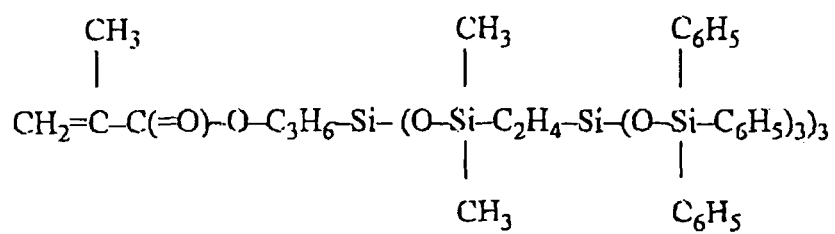
[0044] The carbosiloxane dendrimer (b) has the following general formula when the number of generations is 3:

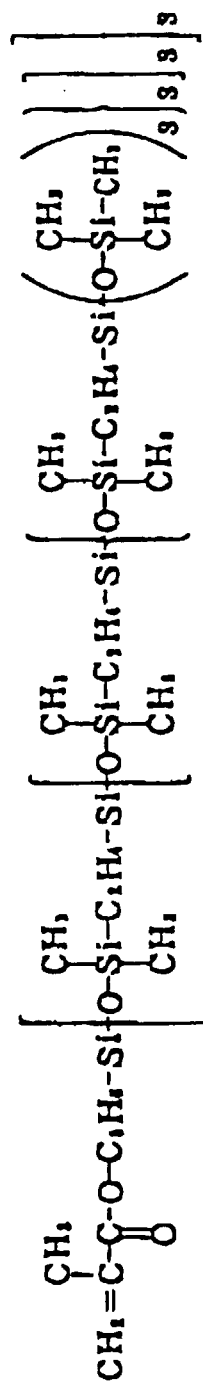


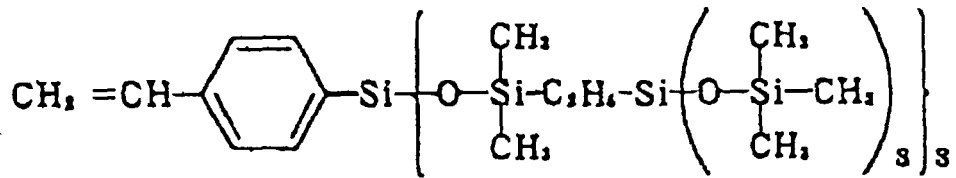
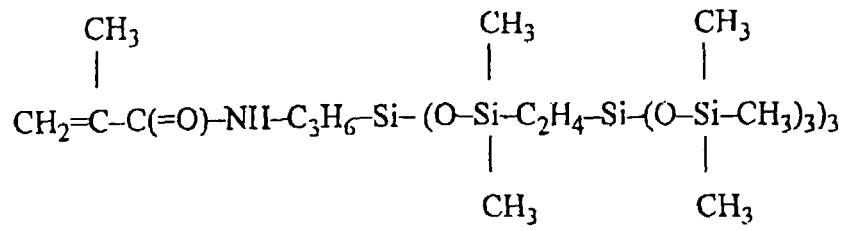
wherein Y, R¹, R², R³, and R¹² are defined as above; a¹, a² and a³ are defined as for aⁱ; and the average of the sum of the a¹, a², and a³ values in each molecule is from 0 to 79.

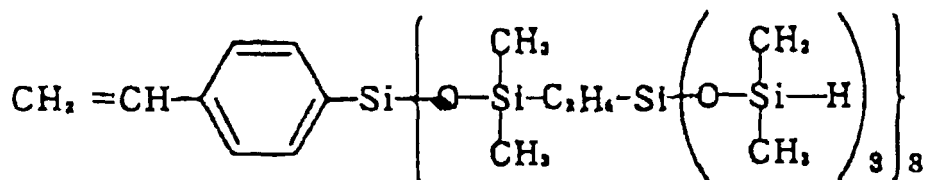
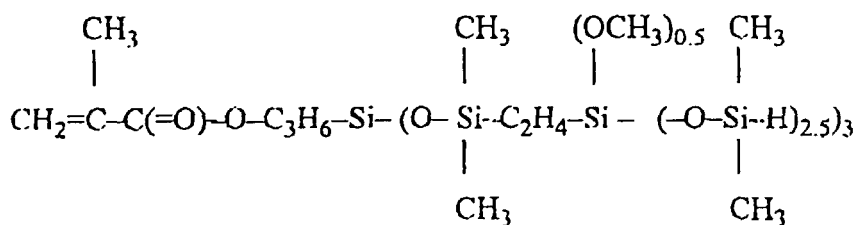
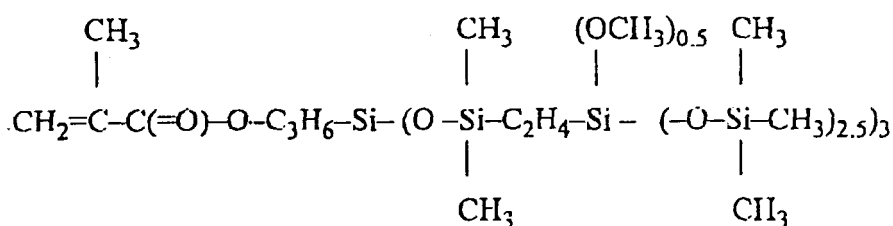
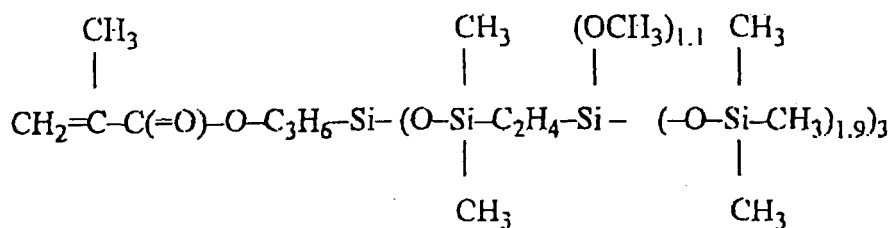
[0045] Carbosiloxane dendrimers with the following average compositional formulas are examples of component (b), i.e., carbosiloxane dendrimer functionalized with a radically polymerizable organic group.



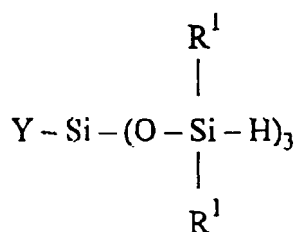








[0046] The carbosiloxane dendrimer described above can be synthesized by the method for synthesizing the branched siloxane-silalkylene copolymer that is described Japanese Patent Application Number Hei 9-171154 (1997). This synthesis can be carried out, for example, by running a hydrosilylation reaction between an alkenyl-functional organosilicon compound and an SiH-functional silicon compound with the following general formula



in which R^1 and Y are defined as above. The silicon compound with this formula is exemplified by 3-methacryloxypro-

pyltris(dimethylsiloxy)silane, 3-acryloxypropyltris(dimethylsiloxy)silane, and 4-vinylphenyltris(dimethylsiloxy)silane. The alkenyl-functional organosilicon compound referenced above is exemplified by vinyltris(trimethylsiloxy)silane, vinyltris(dimethylphenylsiloxy)silane, and 5-hexenyltris(trimethylsiloxy)silane. This hydrosilylation reaction is preferably run in the presence of a transition metal catalyst e.g., chloroplatinic acid or a platinum-vinylsiloxane complex.

[0047] The component (a): component (b) polymerization ratio in the pendant dendrimer-functional vinyl-type polymer used in the present invention should be in the range from 0 : 100 to 99.9 : 0.1 as the component (a) : component (b) weight ratio and is preferably from 1 : 99 to 99 : 1. A component (a) : component (b) ratio of 0 : 100 indicates that the subject polymer may be a homopolymer of component (b).

[0048] The carbosiloxane dendrimer-functional vinyl-type polymer used in this invention is afforded by the copolymerization of the components (a) and (b) or by the polymerization of component (b) alone. This polymerization can be effected by radical polymerization or ionic polymerization with radical polymerization being preferred. While the polymerization technique used for this radical polymerization is not critical, the use of solution polymerization is optimal. This solution polymerization can be run by reacting components (a) and (b) in solvent in the presence of a radical initiator for 3 to 20 hours at a temperature of 50 to 150°C. The solvent used for this solution polymerization is exemplified by aliphatic hydrocarbons such as hexane, octane, decane, and cyclohexane; aromatic hydrocarbons such as benzene, toluene, and xylene; ethers such as diethyl ether, dibutyl ether, tetrahydrofuran, and dioxane; ketones such as acetone, methyl ethyl ketone, methyl isobutyl ketone, and diisobutyl ketone; esters such as methyl acetate, ethyl acetate, butyl acetate, and isobutyl acetate; alcohols such as methanol, ethanol, isopropyl alcohol, and butanol; and organosiloxane oligomers such as octamethylcyclotetrasiloxane, decamethylcyclopentasiloxane, hexamethyldisiloxane, and octamethyltrisiloxane.

[0049] Those compounds generally known in the art for use in radical polymerization can be used as the radical initiator. These are specifically exemplified by azobis compounds such as 2,2'-azobis(isobutyronitrile), 2,2'-azobis(2-methylbutyronitrile), and 2,2'-azobis(2,4-dimethylvaleronitrile), and by organoperoxides such as benzoyl peroxide, lauroyl peroxide, tert-butyl peroxybenzoate, and tert-butyl peroxy-2-ethylhexanoate. This radical initiator can be a single compound or a combination of two or more compounds. The radical initiator is preferably used at from 0.1 to 5 weight parts for each 100 weight parts of the sum of components (a) and (b).

[0050] A chain transfer agent may also be added to the polymerization. This chain transfer agent is specifically exemplified by mercapto compounds such as 2-mercaptoethanol, butyl mercaptan, n-dodecyl mercaptan, 3-mercaptopropyltrimethoxysilane, and mercaptopropyl-functional polydimethylsiloxane, and by halogenated compounds such as methylene chloride, chloroform, carbon tetrachloride, butyl bromide, and 3-chloropropyltrimethoxysilane. 3-mercaptopropyltrimethoxysilane is preferred for use as the chain transfer agent.

[0051] When the pendant carbosiloxane dendrimer-functional vinyl-type polymer is used in an ELID carrier, the chain transfer agent should generally be added at from 0.001 to 10 weight parts per 100 weight parts component (a) plus component (b). When the pendant carbosiloxane dendrimer-functional vinyl-type polymer is used in a toner or an electrophotographic photoreceptor, the chain transfer agent is preferably added at from 0.001 to 15 weight parts, and more preferably at from 0.01 to 10 weight parts, per 100 weight parts component (a) plus component (b).

[0052] Production of the pendant carbosiloxane dendrimer-functional vinyl-type polymer of the invention preferably includes a post-polymerization removal of the residual unreacted vinyl monomer by heating under reduced pressure.

[0053] When the pendant carbosiloxane dendrimer-functional vinyl-type polymer is used in an ELID carrier, the number-average molecular weight of the carbosiloxane dendrimer-functional vinyl-type polymer should generally be from 1,000 to 2,000,000 and is preferably from 1,500 to 1,000,000 and more preferably is from 1,500 to 500,000, based on considerations of mechanical strength, solubility, and electrophotographic characteristics. This polymer can take the form of a liquid, gum, paste, solid, or powder with solid and powder forms being preferred.

[0054] When the composition will be used in a toner or in an electrophotographic photoreceptor, the number-average molecular weight of the pendant carbosiloxane dendrimer-functional vinyl-type polymer used in the present invention is preferably from 1,000 to 2,000,000, more preferably from 1,500 to 1,000,000, and even more preferably from 1,500 to 500,000, based on considerations of ease of blending. This polymer can take the form of a liquid, gum, paste, solid, or powder with solid and powder forms being preferred.

[0055] This invention further relates to an ELID carrier. The ELID carrier comprises the pendant carbosiloxane dendrimer-functional vinyl-type polymer described above and an ELID carrier core powder. The carrier core powder used can be any carrier core powder known in the art for use in carriers for electrostatic latent image development, and its type and other properties are not otherwise critical. This carrier core powder is exemplified by magnetic metals such as iron, nickel, and cobalt and their alloys and mixtures; alloys and mixtures of these magnetic metals with zinc, antimony, aluminum, silicon, lead, tin, bismuth, beryllium, manganese, cerium, tungsten, zirconium, and vanadium; rare earth-containing alloys; ferriferous oxides such as hematite, magnetite, and ferrite and mixtures thereof; and metal oxides such as titanium oxide and magnesium oxide and mixtures thereof.

[0056] The carrier core powder preferably has an average particle size of at least 10 μm in order to inhibit fugitive dispersion and carrier adhesion to the toner and preferably has an average particle size less than 200 micrometers to

avoid impairments in image accuracy by carrier streaks, etc.

[0057] In a first embodiment of the invention, the ELID carrier comprises a carrier core powder and the pendant carbosiloxane dendrimer-functional vinyl-type polymer, wherein said carrier core powder is coated with said pendant carbosiloxane dendrimer-functional vinyl-type polymer. The thickness of the coating layer formed on the surface of the carrier core powder will generally be from 0.1 to 50 micrometers. This ELID carrier can be prepared, for example, by dissolving the pendant carbosiloxane dendrimer-functional vinyl-type polymer in a suitable solvent to give its solvent solution, coating this solvent solution on the surface of the carrier core powder, and drying. Any coating and drying means heretofore known in the art can be used, for example, spray drying, rotational fluidization, and impregnation. The solvent can be, for example, an aliphatic hydrocarbon, aromatic hydrocarbon, ether, ketone, ester, or alcohol.

[0058] In a second embodiment of the invention, the ELID carrier comprises a carrier core powder and a composition comprising the pendant carbosiloxane dendrimer-functional vinyl-type polymer and another organic resin-type coating resin for application in electrostatic latent image development. In this embodiment the carrier core powder is coated with this composition. The organic resin-type coating resin can be any coating resin known in the art for use with ELID carriers, and its type and other properties are not otherwise critical. A variety of resins can be used for this coating resin, for example, styrene resins, acrylic resins, styrene-acrylic resins, epoxy resins, polyolefin resins, vinyl ester resins, and polyester resins. The coating layer formed on the surface of the carrier core powder will generally be from 0.1 to 50 micrometers thick. The ELID carrier in this second embodiment of the invention can be fabricated by the same methods elaborated above for the ELID carrier of the first embodiment of the invention.

[0059] In a third embodiment of the invention, the ELID carrier comprises an ELID magnetic powder and a composition comprising the pendant carbosiloxane dendrimer-functional vinyl-type polymer and an ELID organic resin-type binder resin. In this embodiment the ELID magnetic powder is dispersed in the described composition. The pendant carbosiloxane dendrimer-functional vinyl-type polymer is blended in the subject composition at from 0.1 to 99 weight%.

[0060] The binder resin used in this third embodiment is as described above in the second embodiment of the invention.

[0061] The magnetic powder used in this third embodiment can be the same as the magnetic powders usable for the carrier core powder as described above. While the average particle size of the magnetic powder is not critical, it is preferably from 0.1 to 5 micrometers when one considers the formation of a homogeneous dispersion in the binder. With regard to the blending proportions for the magnetic powder and the composition comprising ELID organic resin-type binder resin and pendant carbosiloxane dendrimer-functional vinyl-type polymer, the magnetic powder is preferably used at from 100 to 900 weight parts per 100 weight parts of the composition.

[0062] The ELID carrier of this invention may further comprise various additives heretofore known for use with ELID carriers insofar as the objects of the invention are not impaired. These additives are exemplified by filler powders such as silica, titanium oxide, zinc carbonate, calcium carbonate, iron oxide, and carbon black; by the esters and metal salts of higher aliphatic acids, such as stearate esters and palmitate esters; and by ester waxes.

[0063] The ELID carrier has an excellent charging stability, an excellent resistance to sparging, and an excellent durability. It can produce high resolution images over long periods of operation when used in, for example, electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies. It will therefore be very useful as an ELID carrier where such features and characteristics are critical.

[0064] This invention further relates to a toner. The toner comprises the pendant carbosiloxane dendrimer-functional vinyl type polymer described above and a colorant.

[0065] The colorant may be any colorant known in the art for use in toners, and its type, properties, etc., are not otherwise critical. This colorant can be an inorganic pigment such as carbon black or iron black or can be an organic pigment, organic dye, or inorganic dye. The colorant is exemplified by the variously produced carbon blacks, e.g., thermal blacks, acetylene blacks, channel blacks, and lamp blacks; oil blacks; grafted carbon blacks as afforded by coating the surface of a carbon black as described above with resin; iron black; chrome yellow; metal chelate dyes; nigrosine dyes; aniline dyes; phthalocyanine blue; Calco oil blue; ultramarine blue; methylene blue; Solvent Blue; Rose Bengal; Permanent Brown; Brilliant Fast Scarlet; Pigment Green; Solvent Red; and rhodamine base.

[0066] The toner comprises the colorant and the pendant carbosiloxane dendrimer-functional vinyl-type polymer. As a general rule, the colorant is preferably admixed in this embodiment at from 0.1 to 20 weight parts, and more preferably at from 0.5 to 10 weight parts, per 100 weight parts of the pendant carbosiloxane dendrimer-functional vinyl-type polymer.

[0067] In an alternative embodiment of the invention, the toner comprises colorant, the pendant carbosiloxane dendrimer-functional vinyl-type polymer, and an organic resin-type binder resin for application in toners. The organic resin-type binder resin used for this toner can be any organic resin-type binder resin known in the art for use in toners for electrostatic image development, and its type, properties, etc., are not otherwise critical.

[0068] The organic resin-type binder resin is exemplified by various resins such as styrene resins, acrylic resins, styrene-acrylic resins, epoxy resins, polypropylene resins, polyethylene resins, vinyl ester resins, and polyester esters.

[0069] When an organic resin-type binder resin is used in the toner of this, it is preferably used as a formulation in

which the pendant carbosiloxane dendrimer-functional vinyl-type polymer has been introduced into the organic resin-type binder resin as described above admixing at least 0.1 weight% of the pendant carbosiloxane dendrimer-functional vinyl-type polymer into the organic resin-type binder resin.

[0070] The toner essentially comprises colorant + the carbosiloxane dendrimer-functional vinyl-type polymer or colorant + the carbosiloxane dendrimer-functional vinyl-type polymer + organic resin-type binder resin, but it may also contain the various additives known for use in toners insofar as the object of the invention is not impaired. These additives are exemplified by various types of silane coupling agents, titanium coupling agents, photosensitizers, the metal salts of higher aliphatic acids, ester waxes, plasticizers, flexibilizers, dyes and pigments, charge-controlling agents, fluidity improvers, magnetic powder, thermoplastic resins, release agents, blocking inhibitors, antistatics, dispersion stabilizers, and agents that improve the cleaning behavior.

[0071] The toner also preferably contains an inorganic micropowder, for example, as a fluidity improver. This inorganic micropowder is exemplified by silica micropowders, alumina, titanium oxide, barium titanate, magnesium titanate, calcium titanate, strontium titanate, zinc oxide, quartz powder, clay, mica, silica ash, diatomaceous earth, chromium oxide, cerium oxide, iron oxide red, antimony trioxide, magnesium oxide, zirconium oxide, barium sulfate, barium carbonate, calcium carbonate, silicon carbide, and silicon nitride. The use of silica micropowder is particularly preferred.

[0072] The toner can be produced by known toner production methods. For example, toner having a desired particle size can be produced by melt-mixing the pendant carbosiloxane dendrimer-functional vinyl-type polymer + colorant — or the vinyl-type polymer + colorant + organic resin-type binder resin or the composition afforded by blending any optional additives into the preceding components — using an extruder, cooling the resulting mixture, grinding the cooled mixture with, for example, a jet mill, and classifying the ground product to give the toner. In addition, toner having a desired particle size can be produced by spraying the melt-mixed mixture afforded by the extruder directly in its molten state using a spray drier or by dispersing this mixture in a fluid.

[0073] The toner can be employed for copying images by using it to develop the electrostatic latent image formed in, for example, an electrophotographic copier, electrostatically transferring the resulting toner image to the copy paper, and fixing the image using a hot roller fixing device.

[0074] The toner has excellent fluidity, releasability, fixing behavior, resistance to offset, and flexibility. Moreover, it can provide high resolution images when applied in any of various imaging technologies, such as electrophotographic technologies, electrostatic recording technologies, and electrostatic printing technologies.

[0075] This invention further relates to an electrophotographic photoreceptor. The electrophotographic photoreceptor has a surface layer comprising a binder resin and a pendant carbosiloxane dendrimer-functional vinyl-type polymer.

[0076] The binder resin used is not critical and may be any binder resin ordinarily used for electrophotographic photoreceptors. The binder resin can be, for example, a thermoplastic resin such as a polystyrene resin, polyvinyl chloride, polyvinyl acetate, vinyl chloride-vinyl acetate copolymer, polyvinyl acetal, alkyd resin, acrylic resin, polyacrylonitrile, polycarbonate, polycarbonate-polydiorganosiloxane block copolymer, polyarylate, polyamide, polyketone, polyacrylamide, butyral resin, or polyester; or a thermosetting resin such as a polyurethane, epoxy resin, or phenolic resin. The binder resin can be a single type of resin or a combination of two or more types of resins. In addition, insofar as the object of the invention is not impaired, the binder resin can contain additives heretofore known for use in electrophotographic photoreceptors, e.g., oxidation inhibitors.

[0077] The blending ratio between the pendant carbosiloxane dendrimer-functional vinyl-type polymer and binder resin used in this electrophotographic photoreceptor is not critical, but the content of the pendant carbosiloxane dendrimer-functional vinyl-type polymer is preferably from 0.01 to 20 weight% and more preferably is from 0.01 to 10 weight%.

[0078] In one embodiment of the invention, the electrophotographic photoreceptor comprises a photosensitive layer having a multilayer structure (charge-generating layer + charge-transport layer), in which the outermost surface layer is the charge-transport layer.

[0079] The electrically conductive substrate used in the electrophotographic photoreceptor can be any electrically conductive substrate known in the art for use in electrophotographic photoreceptors. This substrate is exemplified by the plates, drums, and sheets of metals such as aluminum, brass, copper, nickel, and steel; by the substrates afforded by the execution of a conductivity-imparting treatment on the surface of a plastic sheet, for example, by coating a conductive material (e.g., aluminum, nickel, chromium, palladium, or graphite) on a plastic sheet by vapor deposition, sputtering, or painting; by the substrates afforded by a metal oxide treatment of the surface of a metal drum by electrode oxidation; and by substrates as afforded by the execution of a conductivity-imparting treatment on a substrate such as glass, plastic plate, fabric, or paper.

[0080] An adhesive layer having a barrier function and a bonding function can be provided on the electrically conductive substrate. This adhesive layer is formed for such purposes as improving the adherence of the photosensitive layer, improving the coatability of the photosensitive layer, protecting the substrate, coating defects in the substrate, improving the charge injection characteristics from the substrate, and protecting against electrical breakdown of the photosensitive layer. This layer can be formed by dissolving, for example, polyvinyl alcohol, poly-N-vinylimidazole, pol-

yethylene oxide, ethylcellulose, methylcellulose, ethylene-acrylic acid copolymer, casein, polyamide, a nylon copolymer, glue, or gelatin, in a suitably selected solvent and coating the resulting solution on the substrate.

[0081] The charge-generating layer in a multilayer electrophotographic photoreceptor will contain at least a charge-generating substance. The charge-generating layer can be obtained by forming a layer of a charge-generating substance on the underlying substrate by, for example, vacuum vapor deposition or sputtering, or by forming a layer in which the charge-generating substance is bonded on the underlying substrate using a binder resin. A charge-generating layer that employs binder resin can be formed using the various methods known in the art. Generally, however, the optimal method will be to dissolve or disperse the binder resin and charge-generating substance in a suitable solvent to form a coating solution, applying this coating solution to the substrate that will form the underlying foundation, and drying.

[0082] The various heretofore known charge-generating substances can be used as the charge-generating substance. These are exemplified by a variety of inorganics, for example, selenium, e.g., amorphous selenium and trigonal selenium; alloys of selenium such as selenium-tellurium; selenium-containing compositions and selenium compounds such as As_2Se_3 ; inorganic materials composed of Group II and Group IV elements, e.g., CdS-Se and zinc oxide; oxide semiconductors such as titanium oxide; and silicon materials such as amorphous silicon. The subject charge-generating substances can also be exemplified by a variety of organics, such as metal and nonmetal phthalocyanines, cyanine, anthracene, bisazo compounds, pyrene, perylene, pyrylium salts, thiapyrylium salts, polyvinyl carbazole, and squarylium dyes.

[0083] These charge-generating substances may be used singly or in combinations of two or more. The binder resin in the charge-generating layer can be the same as the binder resins described above. The binder resin may also consist of a single binder resin or a combination of 2 or more binder resins.

[0084] The charge-transport layer can then be elaborated by forming, on the above-described charge-generating layer, a layer in which a charge-transport substance and binder resin are bound with the above-described pendant carbosiloxane dendrimer-functional vinyl-type polymer.

[0085] The various methods known in the art can be used to form this charge-transport layer. Generally, however, this layer will be produced by dissolving or dispersing the charge-transport substance and pendant carbosiloxane dendrimer-functional vinyl-type polymer in a suitable solvent to form a coating solution, applying this coating solution to the substrate that will form the underlying foundation, and drying. The binder resin in the charge-transport layer is exemplified by the same binder resins described above.

[0086] The charge-transport substance is exemplified by the heretofore used electron-transport substances and hole-transport substances. The electron-transport substances are exemplified by electron acceptors such as chloranil, bromanil, 2,3-dichloro-5,6-dicyano-p-benzoquinone, tetracyanoethylene, tetracyanoquinodimethane, 2,4,7-trinitro-9-fluorenone, 2,4,5,7-tetranitro-9-fluorenone, 2,4,7-trinitro-9-dicyanomethylenefluorenone, 2,4,5,7-tetranitroxanthone, 2,4,9-trinitrothioxanthone, and 3,5-dimethyl-3',5'-di-tert-butyl-4,4'-diphenylquinone, and the polymeric forms of these electron acceptors. These electron acceptors can be used individually or as mixtures of two or more electron acceptors.

[0087] The hole-transport substances are exemplified by pyrene; N-ethylcarbazole; N-isopropylcarbazole; N-methyl-N-phenylhydrazino-3-methylidene-9-ethylcarbazole; N,N-diphenylhydrazino-3-methylidene-9-ethylcarbazole; N,N-diphenylhydrazino-3-methylidene-10-ethylphenothiazine; N,N-diphenylhydrazino-3-methylidene-10-ethylphenoxazine; hydrazones such as p-diethylaminobenzaldehyde-N,N-diphenylhydrazone, p-diethylaminobenzaldehyde-N- α -naphthyl-N-phenylhydrazone, p-pyrrolidinobenzaldehyde-N,N-diphenylhydrazone, 1,3,3-trimethylindolenine- ω -aldehyde-N,N-diphenylhydrazone, p-diethylbenzaldehyde-3-methylbenzthiazolinone-2-hydrazine, and 1-phenyl-1,2,3,4-tetrahydroquinone-6-carboxyaldehyde-1',1'-diphenylhydrazone; 2,5-bis(p-diethylaminophenyl)-1,3,4-oxadiazole; pyrazolines such as 1-phenyl-3-(p-diethylaminostyryl)-5-(p-diethylaminophenyl)pyrazoline, 1-(quinolyl(2))-3-(p-diethylaminostyryl)-5-(p-diethylaminophenyl)pyrazoline, 1-(lepidyl(2))-3-(p-diethylaminostyryl)-5-(p-diethylaminophenyl)pyrazoline, 1-(6-methoxypyridyl(2))-3-(p-diethylaminostyryl)-5-(p-diethylaminophenyl)pyrazoline, 1-(pyridyl(5))-3-(p-diethylaminophenyl)pyrazoline, 1-(pyridyl(2))-3-(p-diethylaminostyryl)-5-(p-diethylaminophenyl)pyrazoline, 1-(pyridyl(2))-3-(p-diethylaminostyryl)-4-methyl-5-(p-diethylaminophenyl)pyrazoline, 1-(pyridyl(2))-3-(α -methyl-p-diethylaminostyryl)-5-(p-diethylaminophenyl)pyrazoline, 1-phenyl-3-(p-diethylaminostyryl)-4-methyl-5-(p-diethylaminophenyl)pyrazoline, 1-phenyl-3-(α -benzyl-p-diethylaminostyryl)-5-(p-diethylaminophenyl)pyrazoline, and spiropyrazoline; oxazole compounds such as 2-(p-diethylaminostyryl)- δ -diethylaminobenzoxazole and 2-(p-diethylaminophenyl)-4-(p-dimethylaminophenyl)-5-(2-chlorophenyl)oxazole; thiazole compounds such as 2-(p-diethylaminostyryl)-6-diethylaminobenzthiazole; triarylmethane compounds such as bis(4-diethylamino-2-methylphenyl)phenylmethane; polyarylamines such as 1,1-bis(4-N,N-diethylamino-2-methylphenyl)heptane and 1,1,2,2-tetrakis(4-N,N-dimethylamino-2-methylphenyl)ethane; benzidine compounds such as N,N'-diphenyl-N,N'-bis(methylphenyl)benzidine, N,N'-diphenyl-N,N'-bis(ethylphenyl)benzidine, N,N'-diphenyl-N,N'-bis(propylphenyl)benzidine, N,N'-diphenyl-N,N'-bis(butylphenyl)benzidine, N,N'-diphenyl-N,N'-bis(isopropylphenyl)benzidine, N,N'-diphenyl-N,N'-bis(sec-butylphenyl)benzidine, N,N'-diphenyl-N,N'-bis(tert-butylphenyl)benzidine, and N,N'-diphenyl-N,N'-bis(chlorophenyl)benzidine; butadiene compounds; triphenylamine; poly-N-vinylcarbazole; polyvinylpyrene; polyvinylanthracene; polyvinylacridine; poly-9-vinyl-

phenylanthracene; organopolysilanes; pyrene-formaldehyde resins; and ethylcarbazole-formaldehyde resins. These can be used individually or in combinations of two or more.

[0088] The solvent used for formation of the charge-generating layer and charge-transport layer is exemplified by aromatic hydrocarbons such as benzene, toluene, xylene, and chlorobenzene; ketones such as acetone, methyl ethyl ketone, and cyclohexanone; alcohols such as methanol, ethanol, and isopropanol; esters such as ethyl acetate and ethyl Cellosolve; halogenated hydrocarbons such as carbon tetrachloride, chloroform, dichloromethane, and tetrachloroethane; ethers such as tetrahydrofuran and dioxane; dimethylformamide; dimethyl sulfoxide; and diethylformamide. These solvents can be used individually or as mixtures of two or more solvents.

[0089] The layers can be applied using the various heretofore known coating devices, as exemplified by applicators, spray coaters, bar coaters, tip coaters, roll coaters, dip coaters, and doctor blades.

[0090] In an alternative embodiment of the invention, a monolayer photoreceptor can be prepared. In this case, the photosensitive layer of the electrophotographic photoreceptor contains at least the above-described charge-generating substance and charge-transport substance and also the binder resin and the pendant carbosiloxane dendrimer-functional vinyl-type polymer. The binder resin can be a binder resin as known in the art and is exemplified by the binder resins already described above.

[0091] This photosensitive layer can be formed using various methods known in the art. Generally, however, this layer will be produced, for example, by dissolving or dispersing the charge-generating substance and charge-transport substance in a suitable solvent to form a coating solution, applying this coating solution to the substrate that will form the underlying foundation, and drying.

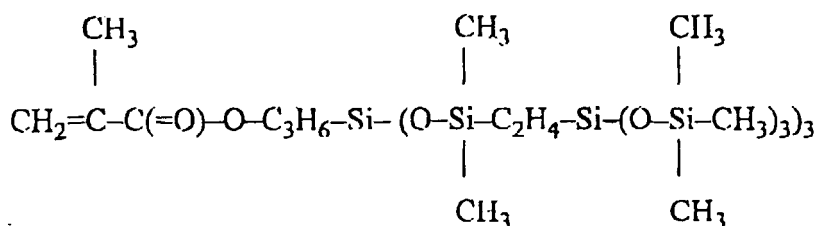
[0092] The electrophotographic photoreceptor has an excellent mechanical strength and the ability to maintain its excellent resistance to the imaging process and its excellent electrophotographic characteristics over long periods of operation. It is therefore well qualified for use in a variety of electrophotographic applications. The electrophotographic photoreceptor evidences an excellent resistance to the imaging process, does not accumulate residual potential, and produces high-quality images and retains these characteristics over the course of long-term operations. The electrophotographic photoreceptor of the present invention achieves this level of performance because it contains, at least in its surface layer, binder resin and the pendant carbosiloxane dendrimer-functional vinyl-type polymer. The following examples are given only for illustrative purposes without limiting the scope

EXAMPLES

[0093] In the examples, values reported for the viscosity were measured at 25°C.

Reference Example 1

[0094] A mixture of 56.0 g styrene, 24.0 g n-butyl acrylate, 20.0 g of the silicone compound (methacryloxy-functional carbosiloxane dendrimer) with the following structure



and 0.3 g radical polymerization initiator (azobisisobutyronitrile) was added dropwise over 2 hours to 150 g toluene at 80°C in a stirrer-equipped flask that had been placed under nitrogen. After the completion of addition the reaction was held at 80°C for an additional 6 hours.

[0095] Part of the toluene was then removed by heating and stirring under an aspirator vacuum. The resulting reaction mixture was introduced into a large excess of methanol. After stirring, the mass was brought to quiescence and the precipitate was isolated. The isolated precipitate was dried in vacuo to yield 92.3 g pendant carbosiloxane dendrimer-functional vinyl-type polymer in the form of a white solid.

Reference Example 2

[0096] A mixture of 49.0 g styrene, 21.0 g n-butyl methacrylate, 30.0 g of the carbosiloxane dendrimer as described

in Reference Example 1, and 0.3 g radical polymerization initiator (azobisisobutyronitrile) was added dropwise over 2 hours to 150 g toluene at 80°C in a stirrer-equipped flask that had been placed under nitrogen. The reaction was held after the completion of addition for an additional 6 hours at 80°C.

[0097] Part of the toluene was then removed by heating and stirring under an aspirator vacuum. The resulting reaction mixture was introduced into a large excess of methanol. After stirring, the mass was brought to quiescence and the precipitate was isolated. The isolated precipitate was dried in vacuo to yield 92.3 g pendant carbosiloxane dendrimer-functional vinyl-type polymer in the form of a white solid.

Example 1

[0098] The vinyl-type polymer synthesized in Reference Example 1 was diluted in methyl ethyl ketone to afford a 3 weight% (solids) resin coating solution. This resin solution was coated using a Spiracoater on a carrier core powder composed of calcined ferrite with an average particle size of 50 micrometers. The resin solution was coated at a rate of 1.5 weight% referred to the carrier core powder. After drying, the carrier core powder was classified using a mesh with a 75 micrometer opening to give a resin-coated carrier. A developer was then prepared by mixing 100 weight parts of this resin-coated carrier with 6 weight parts polyester toner (softening point = 120°C, particle size = 11 micrometers).

[0099] This developer was submitted to copy testing at 25°C and humidity = 50% using an electrophotographic copier. This copy testing consisted of the visual evaluation of image quality after 50,000 copies and 100,000 copies. Image quality was evaluated on the basis of the density in the solid regions of the image and fogging in the background regions of the image.

[0100] The results are in Table 1. The charging level of the carrier itself was also measured, and the results are in Table 2.

Example 2

[0101] The vinyl-type polymer synthesized in Reference Example 2 was diluted in methyl ethyl ketone to afford a 3 weight% (solids) resin coating solution. This resin solution was coated using a Spiracoater on a carrier core powder composed of calcined ferrite with an average particle size of 50 micrometers. The resin solution was coated at a rate of 1.5 weight% referred to the carrier core powder. After drying, the carrier core powder was classified using a mesh with a 75 micrometer opening to give a resin-coated carrier. A developer was then prepared by mixing 100 weight parts of this resin-coated carrier with 6 weight parts polyester toner (softening point = 120°C, particle size = 11 micrometers).

[0102] The characteristics of this developer and the charging level of the carrier itself were measured as in Example 1. The results are in Tables 1 and 2.

Example 3

[0103] The vinyl-type polymer synthesized in Reference Example 2 and styrene-methacrylic resin (100 weight parts per 100 weight parts of the vinyl-type polymer) were diluted in methyl ethyl ketone to afford a 3 weight% (solids) resin coating solution. This resin solution was coated using a Spiracoater on a carrier core powder composed of calcined ferrite with an average particle size of 50 micrometers. The resin solution was coated at a rate of 1.5 weight% referred to the carrier core powder. After drying, the carrier core powder was classified using a mesh with a 75 micrometers opening to give a resin-coated carrier. A developer was then prepared by mixing 100 weight parts of this resin-coated carrier with 6 weight parts polyester toner (softening point = 120°C, particle size = 11 micrometers).

[0104] The characteristics of this developer and the charging level of the carrier itself were measured as in Example 1. The results are in Tables 1 and 2.

Example 4

[0105] 100 weight parts of the vinyl-type polymer synthesized in Reference Example 2, 500 weight parts ferrite powder, 2 weight parts carbon black, and 1.5 weight parts silica were first mixed to homogeneity using a Henschel mixer and were then mixed in a twin-screw mixer. The mixture was thereafter cooled, subjected to a coarse grind with a phaser mill followed by a fine grind with a jet mill, and then classified with an air-stream classifier to give a binder-type carrier consisting of a black powder with an average particle size of 70 micrometers. A developer was then prepared by mixing 100 weight parts of this binder-type carrier with 6 weight parts polyester toner (softening point = 120°C, particle size = 11 micrometers).

[0106] The characteristics of this developer and the charging level of the carrier itself were measured as in Example 1. The results are in Tables 1 and 2.

Table 1

	after 50,000 copies		after 100,000 copies	
	density in solid regions	fogging in background regions	density in solid regions	fogging in background regions
Example 1	excellent	none	excellent	none
Example 2	excellent	none	excellent	none
Example 3	excellent	none	excellent	none
Example 4	excellent	none	excellent	none

Table 2

	After 100,000 copies
Example 1	16.2 $\mu\text{C/g}$
Example 2	16.1 $\mu\text{C/g}$
Example 3	15.8 $\mu\text{C/g}$
Example 4	14.7 $\mu\text{C/g}$

Reference Example 3

[0107] A mixture of 49.0 g styrene, 21.0 g n-butyl methacrylate, 30.0 g of the carbosiloxane dendrimer as described in Reference Example 1, and 0.5 g radical polymerization initiator (azobisisobutyronitrile) was added dropwise over 2 hours to 150 g toluene at 80°C in a stirrer-equipped flask that had been placed under nitrogen. The reaction was held after the completion of addition for an additional 6 hours at 80°C.

[0108] Part of the toluene was then removed by heating and stirring under an aspirator vacuum. The resulting reaction mixture was introduced into a large excess of methanol. After stirring, the mass was brought to quiescence and the precipitate was isolated. The isolated precipitate was dried in vacuo to yield 92.3 g pendant carbosiloxane dendrimer-functional vinyl-type polymer in the form of a white solid.

Example 5

[0109] 100 weight parts of the pendant carbosiloxane dendrimer-functional vinyl-type polymer synthesized in Reference Example 1, 3 weight parts carbon black, and 5 weight parts nigrosine dye were first mixed to homogeneity using a Henschel mixer and were then mixed in a twin-screw mixer. The mixture was thereafter cooled, subjected to a coarse grind with a phaser mill followed by a fine grind with a jet mill, and then classified with an air-stream classifier to give a black powder with an average particle size of 11 micrometers. 100 weight parts of this powder was mixed with 3 weight parts colloidal silica to give a toner. A two-component developer was prepared by mixing 6 weight parts of this toner with 100 weight parts of an iron powder carrier. This developer was submitted to copy testing at 25°C and humidity = 50% using an electrophotographic copier. This copy testing consisted of the visual evaluation of image quality after 50,000 copies and 100,000 copies. Image quality was evaluated on the basis of the density in the solid regions of the image and fogging in the background regions of the image. The results are in Table 3.

Example 6

[0110] 100 weight parts of the pendant carbosiloxane dendrimer-functional vinyl-type polymer synthesized in Reference Example 3, 3 weight parts carbon black, and 5 weight parts nigrosine dye were first mixed to homogeneity using a Henschel mixer and were then mixed in a twin-screw mixer. The mixture was thereafter cooled, subjected to a coarse grind with a phaser mill followed by a fine grind with a jet mill, and then classified with an air-stream classifier to give a black powder with an average particle size of 11 micrometers. 100 weight parts of this powder was mixed with 3 weight

parts colloidal silica to give a toner. A two-component developer was prepared by mixing 6 weight parts of this toner with 100 weight parts of an iron powder carrier. The characteristics of this developer were evaluated as in Example 5, and the results are in Table 3.

5 Example 7

[0111] 40 weight parts of the pendant carbosiloxane dendrimer-functional vinyl-type polymer synthesized in Reference Example 1, 60 weight parts styrene-acrylic resin, 3 weight parts carbon black, and 5 weight parts nigrosine dye were first mixed to homogeneity using a Henschel mixer and were then mixed in a twin-screw mixer. The mixture was thereafter cooled, subjected to a coarse grind with a phaser mill followed by a fine grind with a jet mill, and then classified with an air-stream classifier to give a black powder with an average particle size of 11 micrometers. 100 weight parts of this powder was mixed with 3 weight parts colloidal silica to give a toner. A two-component developer was prepared by mixing 6 weight parts of this toner with 100 weight parts of an iron powder carrier. The characteristics of this developer were evaluated as in Example 5, and the results are in Table 3.

15 Example 8

[0112] 60 weight parts polyester resin, 40 weight parts of the pendant carbosiloxane dendrimer-functional vinyl-type polymer synthesized in Reference Example 3, 3 weight parts carbon black, and 5 weight parts nigrosine dye were first mixed to homogeneity using a Henschel mixer and were then mixed in a twin-screw mixer. The mixture was thereafter cooled, subjected to a coarse grind with a phaser mill followed by a fine grind with a jet mill, and then classified with an air-stream classifier to give a black powder with an average particle size of 11 micrometers, 100 weight parts of this powder was mixed with 3 weight parts colloidal silica to give a toner. A two-component developer was prepared by mixing 6 weight parts of this toner with 100 weight parts of an iron powder carrier. The characteristics of this developer were evaluated as in Example 5, and the results are in Table 3.

Comparative Example 1

[0113] Toner was prepared by the method described in Example 1 in Japanese Laid Open (Kokai) Patent Application Number Hei 9-269611. 6 weight parts of this toner and 100 weight parts iron powder carrier were mixed to give a two-component developer. The characteristics of this developer were evaluated as in Example 5, and the results are in Table 3.

Comparative Example 2

[0114] Toner was prepared by the method described in Example 1 in Japanese Laid Open (Kokai) Patent Application Number Hei 6-289650. 6 weight parts of this toner and 100 weight parts iron powder carrier were mixed to give a two-component developer. The characteristics of this developer were evaluated as in Example 5, and the results are in Table 3.

Comparative Example 3

[0115] Toner was prepared by the method described in Example 1 in Japanese Laid Open (Kokai) Patent Application Number Hei 7-219272. 6 weight parts of this toner and 100 weight parts iron powder carrier were mixed to give a two-component developer. The characteristics of this developer were evaluated as in Example 5, and the results are in Table 3.

Table 3

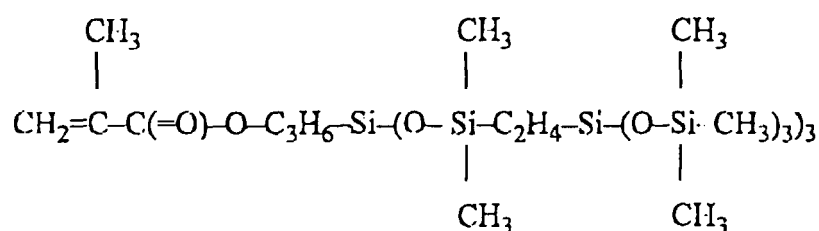
	after 50,000 copies		after 100,000 copies	
	density in solid regions	fogging in background regions	density in solid regions	fogging in background regions
Example 5	excellent	none	excellent	none
Example 6	excellent	none	excellent	none
Example 7	excellent	none	excellent	none

Table 3 (continued)

	after 50,000 copies		after 100,000 copies	
	density in solid regions	fogging in background regions	density in solid regions	fogging in background regions
Example 8	excellent	none	excellent	none
Comp. Ex. 1	excellent	none	low	moderate
Comp. Ex. 2	excellent	none	somewhat low	moderate
Comp. Ex. 3	excellent	none	low	moderate

Reference Example 4

[0116] A mixture of 85.0 g styrene, 24.0 g n-butyl acrylate, 15.0 g of the silicone compound (methacryloxy-functional carbosiloxane dendrimer) with the following structure



and 0.3 g radical polymerization initiator (azobisisobutyronitrile) was added dropwise over 2 hours with stirring to 150 g toluene at 80°C in a stirrer-equipped flask that had been placed under nitrogen. The reaction was held after the completion of addition for an additional 6 hours at 80°C. Part of the toluene was then removed by heating and stirring under an aspirator vacuum.

[0117] The resulting reaction mixture was introduced into a large excess of methanol. After stirring, the mass was brought to quiescence and the precipitate was isolated. The isolated precipitate was dried in vacuo to yield 92.3 g pendant carbosiloxane dendrimer-functional vinyl-type polymer in the form of a white solid.

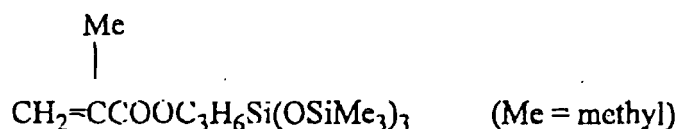
Reference Example 5

[0118] A mixture of 70.0 g styrene, 21.0 g n-butyl methacrylate, 30.0 g of the carbosiloxane dendrimer as described in Reference Example 4, and 0.3 g radical polymerization initiator (azobisisobutyronitrile) was added dropwise over 2 hours with stirring to 150 g toluene at 80°C in a stirrer-equipped flask that had been placed under nitrogen. The reaction was held after the completion of addition for an additional 6 hours at 80°C. Part of the toluene was then removed by heating and stirring the reaction mixture under an aspirator vacuum.

[0119] The resulting reaction mixture was introduced into a large excess of methanol. After stirring, the mass was brought to quiescence and the precipitate was isolated. The isolated precipitate was dried in vacuo to yield 90.0 g pendant carbosiloxane dendrimer-functional vinyl-type polymer in the form of a white solid.

Reference Example 6

[0120] A mixture of 90.0 g styrene, 30.0 g n-butyl acrylate, 10.0 g of the silicone compound with the following structure



and 0.3 g radical polymerization initiator (azobisisobutyronitrile) was added dropwise over 2 hours with stirring to 150 g toluene at 80°C in a stirrer-equipped flask that had been placed under nitrogen. The reaction was held after the completion of addition for an additional 6 hours at 80°C. Part of the toluene was then removed by heating and stirring the reaction mixture under an aspirator vacuum.

- 5 **[0121]** The resulting reaction mixture was introduced into a large excess of methanol. After stirring, the mass was brought to quiescence and the precipitate was isolated. The isolated precipitate was dried in vacuo to yield 91.1 g of a vinyl-type polymer (silicone-based comb-type graft polymer) in the form of a white solid.

Example 9

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[0122] 5 weight parts of the vinyl-type polymer synthesized in Reference Example 4, 50 weight parts polycarbonate resin, and 45 weight parts p-diethylaminobenzaldehyde-N- α -naphthyl-N-phenylhydrazone were dissolved in dichloromethane to prepare a 30 weight% (solids) dichloromethane solution that was used as the coating liquid. This coating liquid was then coated, by an immersion coating method, on an approximately 0.5 micrometer-thick charge-generating layer (based on oxotitanium phthalocyanine) formed on an aluminum electrically conductive substrate. Drying then gave a multilayer electrophotographic photoreceptor provided with a 20 micrometer-thick charge-transport layer.

15

[0123] This electrophotographic photoreceptor was installed in an electrophotographic copier that used a 6 kV corona charger. A charging durability test was then run over 60,000 copies at a temperature of 25°C and a humidity of 50%. Both the VD potential and the VL potential (exposure for 7.5 lux-sec) were measured in order to measure their change over the course of the test. The obtained results are reported in Table 4. The amount of wear in the surface layer of the photoreceptor was also measured after the 60,000-copy durability test.

20

Example 10

25 **[0124]** 5 weight parts of the vinyl-type polymer synthesized in Reference Example 5, 50 weight parts polycarbonate resin, and 45 weight parts p-diethylaminobenzaldehyde-N- α -naphthyl-N-phenylhydrazone were dissolved in dichloromethane to prepare a 30 weight% (solids) dichloromethane solution that was used as the coating liquid. This coating liquid was then coated, by an immersion coating method, on an approximately 0.5 micrometer-thick charge-generating layer (based on oxotitanium phthalocyanine) formed on an aluminum electrically conductive substrate. Drying then gave a multilayer electrophotographic photoreceptor provided with a 20 micrometer-thick charge-transport layer.

30

[0125] The characteristics of this multilayer electrophotographic photoreceptor and the amount of wear in its surface layer were measured as in Example 9, and the results are in Tables 4 and 5.

Example 11

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[0126] 10 weight parts of the vinyl-type polymer synthesized in Reference Example 4, 50 weight parts polycarbonate resin, and 50 weight parts p-diethylaminobenzaldehyde-N- α -naphthyl-N-phenylhydrazone were dissolved in dichloromethane to prepare a 30 weight% (solids) dichloromethane solution that was used as the coating liquid. This coating liquid was then coated, by an immersion coating method, on an approximately 0.5 micrometer-thick charge-generating layer (based on oxotitanium phthalocyanine) formed on an aluminum electrically conductive substrate. Drying then gave a multilayer electrophotographic photoreceptor provided with a 20 micrometer-thick charge-transport layer.

40

[0127] The characteristics of this multilayer electrophotographic photoreceptor and the amount of wear in its surface layer were measured as in Example 9, and the results are in Tables 4 and 5.

45

Comparative Example 3

[0128] 2 weight parts of the vinyl-type polymer synthesized in Reference Example 6, 50 weight parts polyarylate resin, and 48 weight parts p-diethylaminobenzaldehyde-N- α -naphthyl-N-phenylhydrazone were dissolved in dichloromethane to prepare a 30 weight% (solids) dichloromethane solution that was used as the coating liquid. This coating liquid was then coated, by an immersion coating method, on an approximately 0.5 micrometer-thick charge-generating layer (based on oxotitanium phthalocyanine) formed on an aluminum electrically conductive substrate. Drying then gave a multilayer electrophotographic photoreceptor provided with a 20 micrometer-thick charge-transport layer.

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[0129] The characteristics of this multilayer electrophotographic photoreceptor and the amount of wear in its surface layer were measured as in Example 9, and the results are in Tables 4 and 5.

55

Comparative Example 4

[0130] 50 weight parts polycarbonate-polydimethylsiloxane block copolymer and 50 weight parts p-dichthylaminobenzaldehyde-N- α -naphthyl-N-phenylhydrazine were dissolved in dichloromethane to prepare a 30 weight% (solids) dichloromethane solution that was used as the coating liquid. This coating liquid was then coated, by an immersion coating method, on an approximately 0.5 micrometer-thick charge-generating layer (based on oxotitanium phthalocyanine) formed on an aluminum electrically conductive substrate. Drying then gave a multilayer electrophotographic photoreceptor provided with a 20 micrometer-thick charge-transport layer.

[0131] The characteristics of this multilayer electrophotographic photoreceptor and the amount of wear in its surface layer were measured as in Example 9, and the results are in Tables 4 and 5.

Table 4

	initial values		after the 60,000 copy durability challenge	
	VD in volts	VL in volts	VD in volts	VL in volts
Example 9	-730	-200	-690	-280
Example 10	-730	- 200	-690	-270
Example 11	-720	- 200	-690	-270
Comp.Ex.3	-720	-200	-640	-320
Comp.Ex.4	-720	-200	640	-310

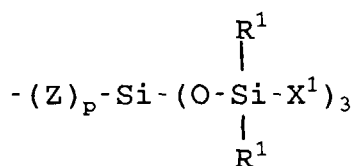
Table 5

	amount of wear in milligrams
Example 9	0.23
Example 10	0.23
Example 11	0.25
Comparative Example 3	0.30
Comparative Example 4	0.31

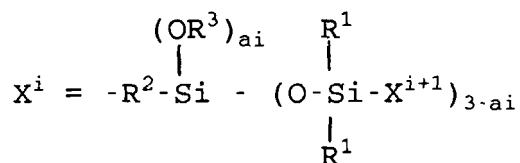
Claims

1. A carrier comprising:

- A) a pendant carbosiloxane dendrimer-functional vinyl-type polymer, and
 B) a carrier core powder; wherein the pendant carbosiloxane dendrimer-functional vinyl-type polymer comprises a carbosiloxane dendrimer structure having the general the formula



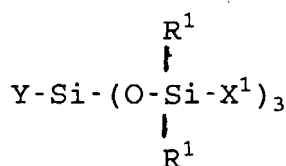
wherein Z is a divalent organic group, p is 0 or 1, R^1 is C_1 to C_{10} alkyl or aryl, and X^1 is a silylalkyl group with the following formula at $i = 1$



wherein R^1 is defined as above; R^2 is C_2 to C_{10} alkylene; R^3 is C_1 to C_{10} alkyl; X^{i+1} is selected from the group consisting of a hydrogen atom, C_1 to C_{10} alkyl, aryl, and the silylalkyl group; i is an integer with a value from 1 to 10; and a^i is an integer from 0 to 3.

2. The carrier of claim 1, wherein component A) has been prepared by polymerization of a composition comprising

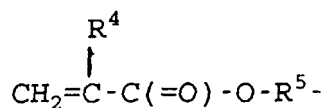
b) a carbosiloxane dendrimer comprising a radically polymerizable organic group and having the general formula



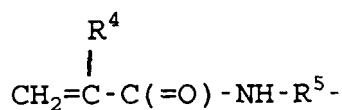
wherein Y is a radically polymerizable organic group, and R^1 and X^1 are as described above.

3. The carrier of Claim 2, wherein the radically polymerizable organic group Y is selected from the group consisting of:

i) acryl- and methacryl-functional organic groups with the general formulas

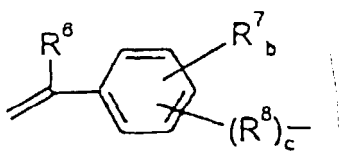


and



wherein R^4 is selected from the group consisting of a hydrogen atom and a methyl group, and R^5 is C_1 to C_{10} alkylene;

ii) a styryl-functional organic groups having the general formula

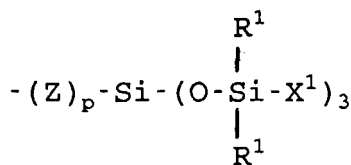


wherein R^6 is selected from the group consisting of a hydrogen atom and a methyl group, R^7 is C_1 to C_{10} alkyl, R^8 is C_1 to C_{10} alkylene, b is an integer from 0 to 4, and c is 0 or 1; and
 iii) C_2 to C_{10} alkenyl.

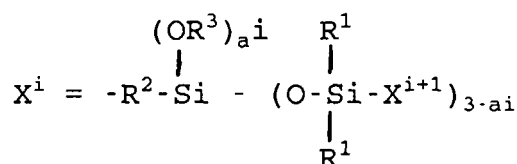
4. The carrier of claims 2-3, wherein the composition further comprises a) a vinyl monomer comprising a radically polymerizable vinyl group.
5. The carrier of claims 1-4, wherein the carrier core powder is coated with a composition comprising the pendant carbosiloxane dendrimer-functional vinyl-type polymer.
6. The carrier of claim 5, wherein the composition further comprises an organic resin-type coating.
7. The carrier of claims 5-6, wherein the composition further comprises a magnetic powder, wherein the magnetic powder is dispersed in said composition.
8. The carrier of claims 5-7, wherein the composition on the carrier core powder has a coating thickness from 0.1 to 50 micrometers.
9. A method for preparing a carrier of claims 1-8, wherein the method comprises:

1) coating a solvent solution on the surface of a carrier core powder, wherein the solvent solution comprises

a) a pendant carbosiloxane dendrimer-functional vinyl-type polymer, wherein the pendant carbosiloxane dendrimer-functional vinyl-type polymer comprises a carbosiloxane dendrimer structure having the following general formula



wherein Z is a divalent organic group, p is 0 or 1, R^1 is C_1 to C_{10} alkyl or aryl, and X^1 is a silylalkyl group with the following formula at $i = 1$

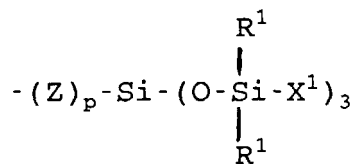


wherein R^1 is defined as above; R^2 is C_2 to C_{10} alkylene; R^3 is C_1 to C_{10} alkyl; X^{i+1} is selected from the group consisting of a hydrogen atom, C_1 to C_{10} alkyl, aryl, and the silylalkyl group; i is an integer with a value from 1 to 10; and a^i is an integer from 0 to 3, and
 b) a solvent; and

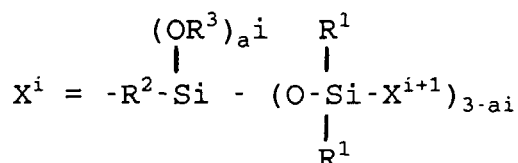
2) drying the product of step 1).

10. The method of claim 9, wherein the solvent is selected from the group consisting of an aliphatic hydrocarbon, aromatic hydrocarbon, ether, ketone, ester, and alcohol.
11. The method of claims 9-10, wherein drying is carried out by a method selected from the group consisting of spray drying, rotational fluidization, and impregnation.
12. A toner comprising:

A) a pendant carbosiloxane dendrimer-functional vinyl-type polymer, wherein the pendant carbosiloxane dendrimer-functional vinyl-type polymer comprises a carbosiloxane dendrimer having a structure with the general formula



wherein Z is a divalent organic group, p is 0 or 1, R¹ is C₁ to C₁₀ alkyl or aryl, and X¹ is a silylalkyl group having the formula at i = 1



wherein R¹ is defined as above; R² is C₂ to C₁₀ alkylene; R³ is C₁ to C₁₀ alkyl; Xⁱ⁺¹ is selected from the group consisting of a hydrogen atom, C₁ to C₁₀ alkyl, aryl, and the silylalkyl group; i is an integer with a value from 1 to 10, and aⁱ is an integer from 0 to 3, and

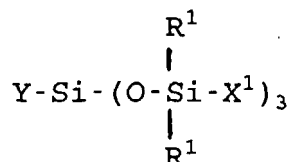
B') a colorant.

13. The toner of claim 12, further comprising an organic resin-type binder resin for use in toners for electro-static image-development.

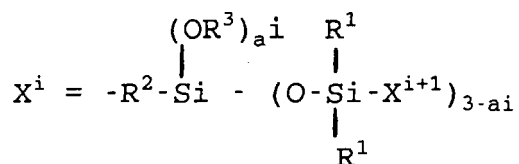
14. The toner of claims 12-13, further comprising additives selected from the group consisting of silane coupling agents, titanium coupling agents, photosensitizers, metal salts of higher aliphatic acids, ester waxes, plasticizer, flexibilizers, dyes and pigments, charge-controlling agents, fluidity improvers, magnetic powder, thermo-plastic resins, release agents, blocking inhibitors, antistatics, dispersion stabilizers, agents that improve cleaning behavior, and an inorganic micropowder.

15. The toner of claim 14, wherein the inorganic micropowder is selected from the group consisting of silica micropowders, alumina, titanium oxide, barium titanate, magnesium titanate, calcium titanate, strontium titanate, zinc oxide, quartz powder, clay, mica, silica ash, diatomaceous earth, chromium oxide, cerium oxide, iron oxide red, antimony trioxide, magnesium oxide, zirconium oxide, barium sulfate, barium carbonate, calcium carbonate, silicon carbide, and silicon nitride.

16. The toner of claims 12-15, wherein A) has been prepared by polymerizing a composition comprising b) a carbosiloxane dendrimer that comprises a radically polymerizable organic group and that has the general formula



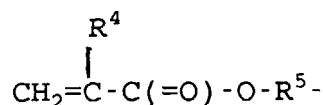
wherein Y is a radically polymerizable organic group, R¹ is C₁ to C₁₀ alkyl or aryl, and X¹ is a silylalkyl group having the formula at i = 1



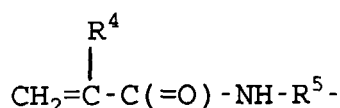
wherein R^1 is defined as above; R^2 is C_2 to C_{10} alkylene; R^3 is C_1 to C_{10} alkyl; x^{i+1} is selected from the group consisting of a hydrogen atom, C_1 to C_{10} alkyl, aryl, and the silylalkyl group; i is an integer with a value from 1 to 10, and a^i is an integer from 0 to 3.

17. The toner of claim 16, wherein Y is selected from the group consisting of:

i) acryl- and methacryl-functional organic groups with the general formulas

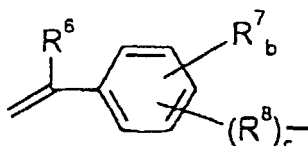


and



wherein R^4 is selected from the group consisting of a hydrogen atom and a methyl group, and R^5 is C_1 to C_{10} alkylene;

ii) styryl-functional organic groups with the general formula



wherein R^6 is selected from the group consisting of a hydrogen atom and a methyl group, R^7 is C_1 to C_{10} alkyl, R^8 is C_1 to C_{10} alkylene, b is an integer from 0 to 4, and c is 0 or 1; and

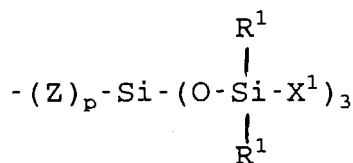
iii) a C_2 to C_{10} alkenyl group.

18. The toner of claims 16-17, wherein the composition further comprises a) a vinyl monomer comprising a radically polymerizable vinyl group.

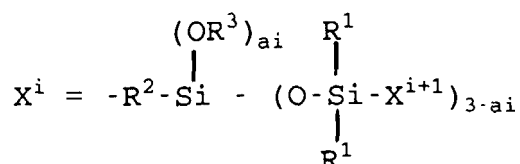
19. A method for preparing a toner according to claims 12-18, wherein the method comprises:

1) melt-mixing a composition comprising

A) a pendant carbosiloxane dendrimer-functional vinyl-type polymer, wherein the pendant carbosiloxane dendrimer-functional vinyl-type polymer comprises a carbosiloxane dendrimer structure having the formula



wherein Z is a divalent organic group, p is 0 or 1, R¹ is C₁ to C₁₀ alkyl or aryl, and X¹ is a silylalkyl group with having the formula at i = 1



wherein R¹ is defined as above; R² is C₂ to C₁₀ alkylene; R³ is C₁ to C₁₀ alkyl; Xⁱ⁺¹ is selected from the group consisting of a hydrogen atom, C₁ to C₁₀ alkyl, aryl, and the silylalkyl group; i is an integer with a value from 1 to 10; and aⁱ is an integer from 0 to 3, and

B') a colorant; and

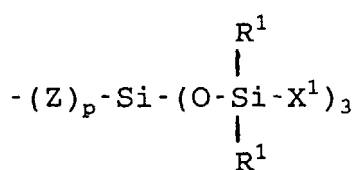
2) forming a toner by a method selected from the group consisting of

- i) spray drying the product of step 1);
- ii) dispersing the product of step 1) in a fluid; and
- iii) cooling the product of step 1), and thereafter grinding the resulting cooled product.

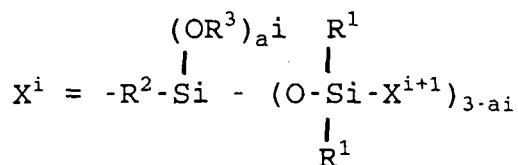
20. An electrophotographic photoreceptor comprising:

- I) an electrically conductive substrate, and
- II) a surface layer coated on the substrate, wherein the surface layer comprises

A) a pendant carbosiloxane dendrimer-functional vinyl-type polymer, wherein the pendant carbosiloxane dendrimer-functional vinyl-type polymer comprises a group having the general formula



wherein Z is a divalent organic group, p is 0 or 1, R¹ is C₁ to C₁₀ alkyl or aryl, and X¹ is a silylalkyl group having the formula at i = 1

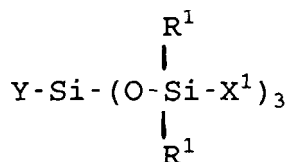


wherein R¹ is defined as above; R² is C₂ to C₁₀ alkylene; R³ is C₁ to C₁₀ alkyl; Xⁱ⁺¹ is selected from the group consisting of a hydrogen atom, C₁ to C₁₀ alkyl, aryl, and the silylalkyl group; i is an integer with a

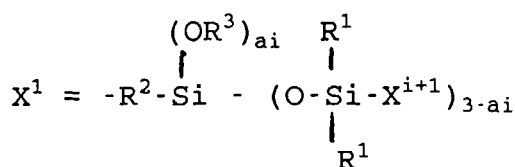
value from 1 to 10; and a^i is an integer from 0 to 3, and B") a binder resin.

21. The electrophotographic photoreceptor of claim 20, wherein component A) has been prepared by the polymerization of a composition comprising:

(b) a carbosiloxane dendrimer comprising a radically polymerizable organic group and having the formula



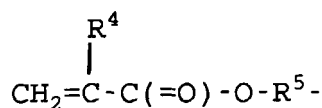
wherein Y is a radically polymerizable organic group, R^1 is C_1 to C_{10} alkyl or aryl, and X^1 is a silylalkyl group with the formula at $i = 1$



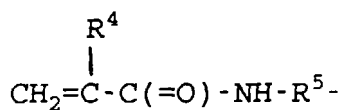
wherein R^1 is defined as above; R^2 is C_2 to C_{10} alkylene; R^3 is C_1 to C_{10} alkyl; X^{i+1} is selected from the group consisting of a hydrogen atom, C_1 to C_{10} alkyl, aryl, and the silylalkyl group; i is an integer with a value from 1 to 10 that specifies the generation of said silylalkyl group; and a^i is an integer from 0 to 3.

22. The electrophotographic photoreceptor of claim 21, wherein Y is selected from the group consisting of:

i) acryl- and methacryl-functional organic groups with the general formulas

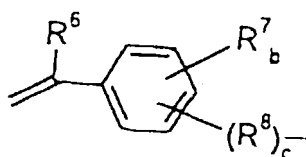


and



wherein R^4 is selected from the group consisting of a hydrogen atom and a methyl group, and R^5 is C_1 to C_{10} alkylene;

ii) styryl-functional organic groups having the formula



wherein R^6 is selected from the group consisting of a hydrogen atom and a methyl group, R^7 is C_1 to C_{10} alkyl,

R^8 is C_1 to C_{10} alkylene, b is an integer from 0 to 4, and c is 0 or 1; and
 iii) a C_2 to C_{10} alkenyl group.

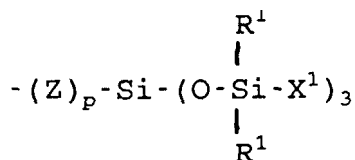
23. The electrophotographic photoreceptor of claims 21-22, wherein the composition further comprises a) a vinyl monomer.
24. The electrophotographic photoreceptor of claims 20-23, wherein the electrically conductive substrate is selected from the group consisting of:
- i) plates, drums, and sheets of metals selected from the group consisting of aluminum, brass, copper, nickel, and steel;
 - ii) substrates afforded by a method selected from the group consisting of executing a conductivity-imparting treatment on the surface of a plastic sheet by a method selected from the group consisting of vapor deposition, sputtering, and painting; a metal oxide treatment of a surface of a metal drum by electrode oxidation; and executing a conductivity-imparting treatment on a substrate selected from the group consisting of glass, plastic plate, fabric, and paper.
25. The electrophotographic photoreceptor of claims 20-24, wherein the binder resin is selected from the group consisting of a thermoplastic resin selected from the group consisting of a polystyrene resin, polyvinyl chloride, polyvinyl acetate, vinyl chloride-vinyl acetate copolymer, polyvinyl acetal, alkyd resin, acrylic resin, polyacrylonitrile, polycarbonate, polycarbonate-poly-diorganosiloxane block copolymer, polyarylate, polyamide, polyketone, polyacrylamide, butyral resin, and polyester; a thermosetting resin selected from the group consisting of a polyurethane, epoxy resin, or phenolic resin; and a combination of two or more types of resins.
26. The electrophotographic photoreceptor of claims 20-25, wherein the surface layer is selected from the group consisting of a nonphotosensitive layer, a photosensitive layer with a single layer structure, and a photosensitive layer with a multi-layer structure.
27. The electrophotographic photoreceptor of claim 26, wherein the photosensitive layer has a multi-layer structure comprising a charge generating layer and a charge transport layer.
28. The electrophotographic photoreceptor of claim 27, wherein the charge generating layer comprises a charge generating substance selected from the group consisting of alloys of selenium, selenium-containing composition, and selenium compounds, inorganic materials comprising Group II and Group IV elements, oxide semiconductors, silicon materials, and organics selected from the group consisting of metal and nonmetal phthalocyanines, cyanine, anthracene, bisazo compounds, pyrene, perylene, pyrylium salts, thiapyrylium salts, polyvinyl carbazole, and squarylium dyes, and combinations of two or more of these charge generating substances; and wherein the charge transport layer comprises a charge transport substance selected from the group consisting of electron-transport substances and hole-transport substances.
29. The electrophotographic photoreceptor of claim 28, wherein the electron-transport substances are electron acceptors selected from the group consisting of chloranil, bromanil, 2,3-dichloro-5,6-dicyano-p-benzoquinone, tetracyanoethylene, tetracyanoquinodimethane, 2,4,7-trinitro-9-fluorenone, 2,4,5,7-tetranitro-9-fluorenone, 2,4,7-trinitro-9-dicyanomethylenefluorenone, 2,4,5,7-tetranitroxanthone, 2,4,9-trinitrothioxanthone, and 3,5-dimethyl-3',5'-di-tert-butyl-4,4'-diphenylquinone, polymeric forms of these electron acceptors, and mixtures of two or more electron acceptors; and wherein the hole-transport substances are selected from the group consisting of: N-ethylcarbazole, N-isopropylcarbazole, N-methyl-N-phenylhydrazino-3-methylidene-9-ethyl-carbazole, N,N-diphenylhydrazino-3-methylidene-9-ethyl-carbazole, N,N-diphenylhydrazino-3-methylidene-10-ethyl-phenothiazine, N,N-diphenylhydrazino-3-methylidene-10-ethylphenoxazine, hydrazones, 2,5-bis(p-diethylamino-phenyl)-1,3,4-oxadiazole, pyrazolines, oxazole compounds, thiazole compounds, triarylmethane compounds, polyarylamines, benzidine compounds, butadiene compounds, triphenylamine, poly-N-vinylcarbazole, polyvinylpyrene, polyvinylanthracene, polyvinylacridine, poly-9-vinyl-phenylanthracene, organopolysilanes, pyrene-formaldehyde resins, ethylcarbazole-formaldehyde resins, and combinations of two or more.
30. The electrophotographic photoreceptor of claims 20-29, the electrophotographic photoreceptor is a multi-layer photoreceptor, further comprising an adhesive layer between the substrate and the surface layer, wherein the adhesive layer comprises a material selected from the group consisting of a polyvinyl alcohol, poly-N-vinylimidazole, polyethylene oxide, ethylcellulose, methylcellulose, ethylene-acrylic acid copolymer, casein, polyamide, a nylon copoly-

mer, glue, and gelatin.

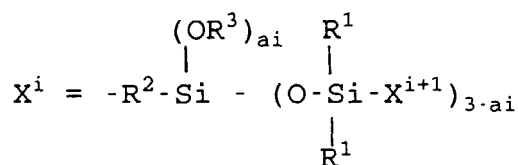
31. A method for preparing an electrophotographic photoreceptor according to claims 20-30, wherein the method comprises:

1) applying to an electrically conductive substrate, a solvent solution comprising

A) a pendant carbosiloxane dendrimer-functional vinyl-type polymer, wherein the pendant carbosiloxane dendrimer-functional vinyl type polymer comprises a group having the general formula



wherein Z is a divalent organic group, p is 0 or 1, R¹ is C₁ to C₁₀ alkyl or aryl, and X¹ is a silylalkyl group having the formula at i = 1



wherein R¹ is defined as above; R² is C₂ to C₁₀ alkylene; R³ is C₁ to C₁₀ alkyl; Xⁱ⁺¹ is selected from the group consisting of a hydrogen atom, C₁ to C₁₀ alkyl, aryl, and the silylalkyl group; i is an integer with a value from 1 to 10; and aⁱ is an integer from 0 to 3, and

iii) a solvent; and
B") a binder resin; and

2) drying.

32. The method of claim 31, wherein the solvent solution further comprises

C) a charge-transport substance, and
D) a charge generating substance.

33. The method of claims 31-32, wherein the electrophotographic photoreceptor comprises a photosensitive layer having a multilayer structure comprising:

a) a charge transport layer comprising a charge-transport substance, and
b) a charge generating layer comprising a charge generating substance.

34. The method of claim 33, wherein the charge transport layer is an outermost surface layer and wherein the charge transport layer further comprises A) the pendant carbosiloxane dendrimer-functional vinyl-type polymer and B") the binder resin.