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(54) Image bearing member, and process cartridge and image forming apparatus using the same

(57) An image bearing member including a substrate, a photosensitive layer overlying the substrate, a surface layer overlying the photosensitive layer. The surface layer is formed by applying to the photosensitive layer a liquid composition containing a monomer having at least three radical polymerizable groups without a charge transport structure, a monomer having a radical polymerizable functional group with a charge transport structure and a photo-radical polymerization initiator containing a titanocene derivative and curing the liquid composition with irradiation of light, The monomer having a radical polymerizable functional group with a charge transport structure has an optical absorption spectrum such that an absorption end wavelength thereof is at least. 40 nm shorter than an absorption end wavelength of the titanocene derivative,

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an image bearing member, and a process cartridge and an image forming apparatus using the same.

Discussion of the Background

[0002] In recent years, organic image bearing members have been widely used in an image forming apparatus.. Organic image bearing members have advantages over inorganic image bearing members in terms of development of materials suitable for light ranging from optical light to infrared light emitted from various kinds of light sources, selection of materials free from environment, contamination, low manufacturing cost, etc. However, organic image bearing members have drawbacks, for example, their weakphysical strength and chemical strength, meaning organic image bearing members are easily a braded or flawed for repetitive use over a long period of time..

[0003] Typically, an image forming apparatus based on electrophotographic technology integrally includes an image bearing member, a charging device for charging the image bearing member, a latent electrostatic image forming unit for forming a latent electrostatic image on the surface of the image bearing member charged by the charging device, a developing device for developing the latent electrostatic image with toner, and a transferring device for transferring the toner image to a transferring medium and an optional cleaning device for cleaning the surface of the image bearing member to remove remaining toner thereon. A cleaning device is adoped in most image forming apparatuses because the remaining toner causes deterioration of image quality. Such a cleaning device used brushes, magnetic brushes, blades or the like. Polyester fibers, acrylic fibers are used for brushes and these fibers are optimized in light of, for example, shape (e.g., a loop shape or a lissotrichic shape), hardness and thickness. However, with regard to brush cleaning, it is difficult to sufficiently remove remaining toner because fine toner particles may slip between fibers. It is also difficult to sufficiently remove remaining toner by a method of using a magnetic brush in which remaining toner is electrostatically removed by application of voltage in electric fields. This is because, for example, toner scattered by the electrostatic force may be re-attracted to an image bearing member. Thus, blade-cleaning, which uses an elastic blade, is predominantly used in consideration of removability of remaining toner, cost, and size reduction in toner particle diameters. Inblade cleaning, a blade and toner are abrasively pressed against the surface of an image bearing member. Resultantly, the surface of an image bearing member tends to be mechanically abraded or flawed.

[0004] Due to the structural properties of the devices described above, the surface of an image bearing member directly receives external physical forces. Therefore, an image bearing member has been required to have a durability against such forces.

[0005] To these problems, there have been reported a large number of study examples of enhancing the hardness of an image bearing member. When a magnetic brush type is used as a charging device, magnetic particles are involuntarily transferred to an image bearing member and strongly pressed against the surface thereof by the transferring device and/or the cleaning device. This causes flaws on the surface of an image bearing member. Unexamined published Japanese Patent Applications Nos. (hereinafter referred to as JOP) 2001-125286, and 2001-324857 describe a technology of enhancing the hardness of the surface of an image bearing member not to cause such flaws. JOP 2003-98708 describes a technology of enhancing the hardness of the surface of an image bearing member to restrain the abrasion thereof when a blade cleaning system is employed.

[0006] Containing a cross-linking material, for example, a thermosetting resin or a UV curable resin, in the surface layer of an image bearing member is proposed as a specific measurement for the above-mentioned enhancement of the hardness thereof. For example, JOPs H05-181299, 2002-6526 and 2002-82465 describe a method in which abrasion resistance and flaw resistance of an image bearing member surface layer are improved by using a thermosetting resin as a binder component of the surface layer.. Further, JOPs 2000-284514, 2000-284515 and 2001-194813 describe a method of improving abrasion resistance and flaw resistance of an image bearing member surface layer by using a siloxane resin having a cross-linking structure as a charge transport material, Furthermore, Japanese Patent Nos, (herein after referred to as JP) 3194392 and 3286704 describes a method in which a monomer having a carbon-carbon double bond, a charge transport material having a carbon-carbon double bond, and a binder resin to improve abrasion resistance and flaw resistance of an image bearing member surface layer.

[0007] In these cross-linking materials, molecules are cross-linked to each other to thereby form a strong layer.. These cross-linking materials are characteristic in that these materials can have different characteristics for the same material when the cross-linking conditions (for example, in the case of a thermosetting resin, temperature condition and humidity condition; in the case of a photo-curable resin, wavelength of light, illuminance, exposure, temperature condition and humidity condition) are changed.

[0008] In comparison with thermosetting resins, photo-curable resins are relatively versatile and unique. For example, photo-curable resins are extremely quickly cured or can form a layer having locally different characteristics by locally changing light irradiation conditions. Such photo-curable resins are practically used in other industries, for example, for an adhesive tape having locally different tackiness or etchingprocess used for microscopic processing. However, to obtain desired properties, it is preferred to set up and control detailed manufacturing conditions. When a photo-curable resin is used for a laminate structure which deteriorates upon irradiation of light, it is preferred to reduce impact on the laminate structure by the selection of an emission wavelength of a light source for curing the resin, its corresponding initiator and light irradiation conditions, for example, illuminance and exposure.

[0009] When a photo-curable material is applied to the surface layer of an image bearing member to obtain desired characteristics, for example, hardness, to elongate the life of an image bearing member, abrasion and flaws of the surface layer can be restrained for an extended period of time with suitable processing conditions, for example, layer forming conditions and cross-linking conditions.

[0010] Characteristics preferred for an image bearing member in addition to the mechanical strength mentioned above are, for example, electric conductivity upon irradiation of light. This applies to the case in which a surface layer is formed as in the present invention. When a surface layer is formed on an image bearing member, it is desired to add a charge transport material beforehand other than a photo-curable material. Basically, the charge transport material added to obtain desired electric characteristics does not necessarily have a polymerizable functional group therein. However, when a charge transport material having no polymerizable functional group is added in a binder having a polymerizable functional group, the charge transport material is not involved in the cross-linking. This results in a reduction in the average cross-linking molecular weight in appearance. Consequently, sufficient mechanical durability is not obtained. Taking account of these, it is preferred to use a charge transport material having a polymerizable functional group for a photo-cross-linkable surface layer to obtain desired mechanical durability and electric characteristics.

[0011] However, it is known that well-known materials having excellent charge transportability, for example, triarylamine, have light absorption property in wavelengths ranging from ultraviolet rays to visible light having a short wavelength. In addition, a material, for example, an acrylic acid ester, in which a conjugate bond is introduced into a charge transport material to improve the charge transportability, has a tendency that the absorption wavelength is furthermore shifted to the long wavelength side.

[0012] When a charge transport material having such light absorption property is used in the surface layer of an image bearing member which is cured by light irradiation, initiators functioning as a trigger of radical polymerization are carefully selected.

[0013] Photo-radical polymerization initiators have each own light absorption properties inherent to each material and are excited upon absorption of light in the light absorption wavelength range. In the excited state, a radical serving as a trigger of initiation of polymerization is generated. To cure a photo-curable material quickly and steadily, it is preferred to have a good combination of the wavelength of light used for irradiating a curable film and the absorption property of a photo-polymerization initiator to efficiently generate radicals. When a curable film is thick, a light wavelength and an initiator are selected taking into consideration the light absorption by the curable film itself. When a curable film contains a material that absorbs a large amount of light, it is desired to select irradiation light and an initiator in consideration of the light absorption property thereof.

[0014] From these viewpoints, when a charge transport material having the above-mentioned light absorption property is used for a photo-curable surface layer in combination with a typical photo-polymerization initiator having a light absorption wavelength around 360 nm, the efficiency of radical generation inside the film decreases. This causes problems such that desired film physical property is difficult to obtain or a laminate structure (e.g., a charge generating layer and a charge transport layer) deteriorates due to excessive irradiation for a photo-cross-linkable surface layer.

[0015] For example, JOP 2004-258344 describes a technology in which abrasion resistance is improved by using a penta- or higher functional acryl monomer and mono-functional acrylic donor to form a curable film while maintaining surface smoothness and electric property. However, the absorption property of the charge transport structure is extremely strong. Thus, irradiation light does not reach sufficiently the inside of the curable layer when the curable film is thickened. Resultantly, the radical generation efficiency decreases so that the inside of the layer tends not to be sufficiently cured. Consequently, such a layer does not have a good abrasion resistance.

[0016] JOP 2004-258344, etc., also describes a technique using a photo-polymerization initiator having a morphorino group and a dialkylamino group to improve abrasion resistance and flaw resistance of a photo curable surface layer. When these photo-polymerization initiators are used, a photo curable surface layer is quickly cured and a smooth surface layer is obtained. However, tertiary amine structures substituted by dialkyl groups remain in the surface layer and causes charge trap. This raises the residual voltage during repetitive use.

[0017] Using an image bearing member having a good mechanical strength represented by, for example, hardness or elastic power of the surface thereof, is effective to restrain abrasion or flaws that may occur during the repetitive use. To enhance these properties, various methods and materials have been developed. To boost the mechanical strength, cross-linkable materials, in which molecules are bonded to each other, are known. In addition, cross-linkable materials can have a variety of characteristics depending on the selection of functional group structure, molecular structure, the number of functional groups, etc. This is an advantage in light of molecule designing because electric properties of an image bearing member can be taken into consideration in addition to desired mechanical strength. Therefore, these materials are thought to be suitable for an image beraing member.

[0018] Cross-linkable materials are typified into heat cross-linkable materials, photo-cross-linkable materials, and ionizable radiation cross-linkable materials. Heat cross-linkable materials have a characteristic that inter-molecular cross-linking is gradually conducted under room temperature or high-temperature conditions. Heat cross-linkable materials are easily cross-linked by heat after layer forming so that a simple manufacturing facility can be used. In addition, heat cross-linkable materials have a small impact on human body and environments and thus are widely used for industrial purposes. However, heat cross-linkable materials take a long time to cure and are readily affected by manufacturing environments. During this relatively long curing time, a heat cross-linkable material should be heated and thus low molecular additives are transferred between layers, which may cause a problem.

[0019] Photo cross-linkable materials and ionizable radiation cross-linkable materials are readily cross-linked upon irradiation of light or ionizing radiation, meaning that a highly cross-linked film (layer) is instantly formed. Thus, different from heat cross-linkable materials, photo cross-linkable materials and ionizable radiation cross-linkable materials are hardly dependent on manufacturing environments, and interlayer transition of low-molecular materials therein rarely occurs. In addition, photo cross-linkable materials can be manufactured by an uncomplicated apparatus and have small impact on human body. Thus, photo cross-linkable materials are widely used in industries. In contrast, ionizable radiation cross-linkable materials are typically manufactured by a complicated and expensive manufacturing facility and have an adverse impact on a human body. Currently, ionizable radiation cross-linkable materials are not practically applied in many industrial cases.

[0020] Therefore, it is effective to use a photo cross-linkable material for a surface layer of an image bearing member in light of mechanical strength. To satisfy the electric properties, which are the most important factor for an image bearing member, a charge transport material is contained in the surface layer thereof. Specific examples of materials having excellent charge transport property include triarylamine based materials. Such materials tend to absorb light having a relatively long wavelength. When such a material is contained in a photo cross-linkable material as in the present invention, irradiation light does not sufficiently reach the inside of a layer at the time of curing. That is, the cured status may be different depending on the depth from the surface (i.e., the surface and the inside). A light source typically used for curing a photo cross-linkable material emits light having a high energy in the ultraviolet range. As in the case mentioned above in which a charge transport material absorbing light having a relatively long wavelength is contained in a surface layer of an image bearingmember, a combination of the prescription and curing conditions of materials is carefully determined.

[0021] An image bearing member is centered in the image forming process and receives mechanical and/or electrical hazards at the time of, for example, charging or toner cleaning.. Naturally, the surface of an image bearing member gradually is worn down with use. In the case of when the cured condition differs depending on the depth of the surface layer, an image bearing member may not be able to maintain a desired durability when the inside of the layer is exposed by abrasion. To maintain a desired durability for a long period of time, it is preferred to minimize the difference in cured status between the surface and the inside of a layer. When a photo cross-linkable material having such a light absorption property as described in the present invention is contained in a surface layer, one of the methods for uniformly curing a surface layer is to excessively irradiate the surface layer with light. However, when an image bearing member has a laminate structure, there may be an adverse impact on layers different from the surface layer. The image bearing member described in the present invention has a widely used layer structure. Since such a structure contains a charge generating material and a charge transport material, which tend to deteriorate upon application of light, this curing method is not suitable for the image bearing member of the present invention.. There is another method in which the temperature during cross-linking is set relatively high. When this method is used, the control margin is narrow. Thus, material variations from lot to lot and impurities in a material have an impact. This results in difficulty in forming a stably cross-linked film (layer). In addition, the surface layer is insufficiently cross-linked in some cases so that desired surface physical properties may not be obtained. Furthermore, this method accelerates the interlayer transition of low molecular components, for example, additives, which has an adverse impact on various kinds of properties of a surface layer, when the temperature condition is set to be in a high temperature range. Thus, obtained products do not realize or reflect the full potentials of the materials and may not satisfy the specification required as a product.

SUMMARY OF THE INVENTION

[0022] Because of these reasons, the present inventors recognize that a need exists for an image bearing member having excellent durability for abrasion, flaws, etc., and excellent surface smoothness to elongate the operation life of the image bearing member and a process cartridge and an image forming apparatus using the image bearing member.

[0023] Accordingly, an object of the present invention is to provide an image bearing member having excellent durability for abrasion, flaws, etc., and excellent surface smoothness to elongate the operation life of the image bearing member, and a process cartridge and an image forming apparatus using the image bearing member.

[0024] Briefly this object and other objects of the present invention as hereinafter described will become more readily apparent and can be attained, either individually or in combination thereof, by an image bearing member including a substrate, a photosensitive layer overlying the substrate, a surface layer overlying the photosensitive layer. The surface layer is formed by applying to the photosensitive layer a liquid composition containing a monomer having at least three radical polymerizable groups without a charge transport structure, a monomer having a radical polymerizable functional group with a charge transport structure and a photo-radical polymerization initiator containing a titanocene derivative and curing the liquid composition with irradiation of light. The monomer having a radical polymerizable functional group with a charge transport structure has an optical absorption spectrum such that an absorption end wavelength thereof is at least 40 nm shorter than an absorption end wavelength of the titanocene derivative.

[0025] It is preferred that, in the image bearingmembermentioend above, the absorption end wavelength in an optical absorption spectrum of the monomer having a radical polymerizable functional group with a charge transport structure is at least 370 nm.

[0026] It is still further preferred that, in the image bearing member mentioned above, the absorption end wavelength in an optical absorption spectrum of the monomer having a radical polymerizable functional group with a charge transport structure is at least 400 nm.

[0027] It is still further preferred that, in the image bearing member mentioned above, the monomer having a radical polymerizable functional group with a charge transport structure has one radical polymerizable functional group.

[0028] It is still further preferred that, in the image bearing member mentioned above, a light source having a maximum peak wavelength in a wavelength range of not shorter than 400 nm is used for the irradiation of light.

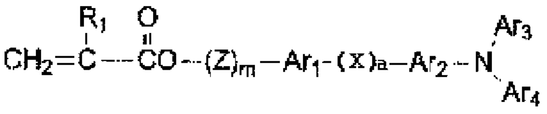
[0029] It is still further preferred that, in the image bearing member mentioned above, the radical polymerizble functional group of the monomer having a radical polymerizable functional group with a charge transport structure is at least one of an acryloyloxy group and a methacryloyloxy group.

[0030] It is still further preferred that, in the image bearing member mentioned above, the radical polymerizable functional groups of the monomer having at least three radical polymerizable functional groups without a charge transport structure are at least one of an acryloyloxy group and a methacryloyloxy group.

[0031] It is still further preferred that, in the image bearing member mentioned above, the ratio (M/F) of the molecular weight (M) of the monomer having at least three radical polymerizable functional groups without a charge transport structure to the number of functional groups (F) thereof is not greater than 250.

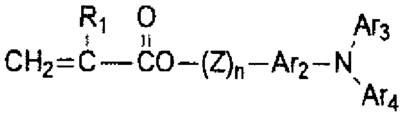
[0032] It is still further preferred that, in the image bearing member mentioned above, the charge transport portion of the monomer having a radical polymerizable functional group with a charge transport structure has a triarylamine structure.

It is still further preferred that, in the image bearing member mentioned above, the monomer having a radical polymerizable functional group with a charge transport structure is at least one of the following monomers represented by chemical formulae (1) and (2),



$$CH_2=\overset{R_1}{\overset{|}{C}}-\overset{O}{\overset{\|}{C}}O-(Z)_m-Ar_1-(X)_a-Ar_2-N\begin{matrix}Ar_3\\ Ar_4\end{matrix}$$

Chemical formula (1)

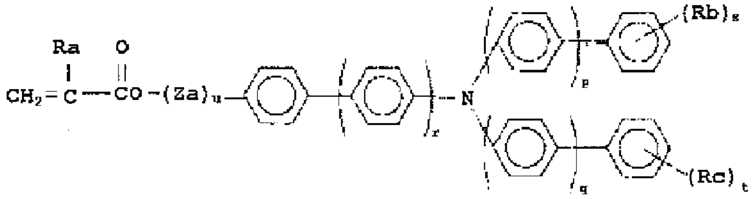


$$CH_2=\overset{R_1}{\overset{|}{C}}-\overset{O}{\overset{\|}{C}}O-(Z)_n-Ar_2-N\begin{matrix}Ar_3\\ Ar_4\end{matrix}$$

Chemical formula (2)

[0033] In the chemical formulae (1) and (2), R_1 represents hydrogen atom, a halogen atom, a substituted or non-substituted alkyl group, a substituted or non-substituted aralkyl group, an aryl group, cyano group, nitro group or a substituted or non-substituted alkoxy group, or-$COOR_7$ (R_7 represents hydrogen atom, a substituted or non-substituted alkyl group, a substituted or non-substituted aralkyl group, or a substituted or non-substituted aryl group); a halogenated carbonyl group or $CONR_8R_9$ (R_8 and R_9 independently represent hydrogen atom, a halogen atom, a substituted or non-substituted alkyl group, a substituted or non-substituted aralkyl group, or a substituted or non-substituted aryl group); Ar_1 and Ar_2 independently represent a substituted or unsubstituted arylene group; Ar_3 and Ar_4 independently represent a substituted or unsubstituted aryl group; X represents a substituted or non-substituted alkylene group, a substituted or non-substituted cycloalkylene group, a substituted or non-substituted alkylene ether divalent group, oxygen atom, sulfur atom, or vinylene group; Z represents a substituted or non-substituted alkylene group, a substituted or non-substituted alkylene ether divalent group or an alkyleneoxy carbonyl divalent group; a represents 0 or 1 and m and n independently represent 0 or an integer of from 1 to 3.

[0034] It is still further preferred that, in the image bearing member mentioned above, the monomer having a radical polymerizable functional group with a charge transport structure is the following monomer represented by the following chemical formula (3),

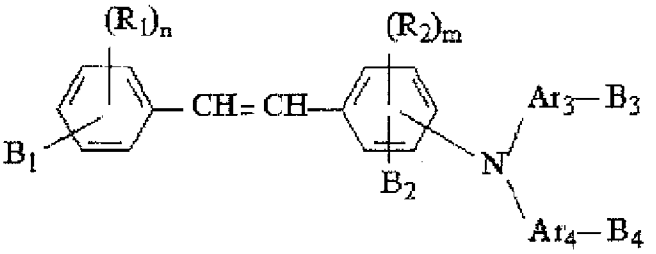


Chemical formula (3)

[0035] In the chemical formula (3), u, r, p, q represent 0 or 1, s and t independently represent 0 or an integer of from 1 to 3, Ra represents hydrogen atom or methyl group, each of Rb and Rc independently represents an alkyl group having 1 to 6 carbon atoms, and Za represents methylene group, ethylene group, $-CH_2CH_2O-$, $-CHCH_3CH_2O-$, or $-C_6H_5CH_2CH_2-$.

[0036] It is still further preferred that, in the image bearing member mentioned above, the monomer having a radical polymerizable functional group with a charge transport structure is an acrylic acid ester compound represented by the following chemical formula (4) : B_1-Ar_1-CH=CH--Ar_2-B_2. In the chermical formula (4), Ar_1 represents a monovalent or divalent group having a substituted or non-substituted aromatic hydrocarbon skeleton; Ar_2 represents a monovalent or divalent group having an aromatic hydrocarbon skeleton having at least one tertiary amino group, or a monovalent or divalent group having a heterocyclic compound having at least one tertiary amino group; and at least one of B_1 and B_2 is present and independently represents an acryloyloxy group, a methacryloyloxy group, vinyl group, an alkyl group having an acryloyloxy group, a methacryloyloxy group or vinyl group, or an alkoxy group having an acryloyloxy group, a methacryloyloxy group or vinyl group.

[0037] It is still further preferred that, in the image bearing member mentioned above, the monomer having a radical polymerizable functional group with a charge transport structure is represented by the following chemical formula (5):



Chemical formula (5)

[0038] In the chermical formual (5), R_1 and R_2 independently represent a substituted or non-substituted alkyl group, a substituted or non-substituted alkoxy group, or a halogen atom and n represents 0 or an integer of from 1 to 5 and m represents 0 or an integer of from 1 to 4; Ar_3 and Ar_4 independently represent a substituted or non-substituted aryl group or arylene group, or a substituted or non-substituted benzyl group; and B_1, B_2, B_3, and B_4 are the same as defined for B_1 and B_2 in Chemical formula (4) and only one or two of B_1, B_2, B_3 and B_4 simultaneously exist in the monomer.

[0039] It is still further preferred that, in the image bearing member mentioned above, the titanocene derivative is bis (cyclopentadienyl) -bis (2,6-difluoro-3-(pyrrole-1-yl) phenyl) titanium.

[0040] It is still further preferred that, in the image bearing member mentioned above,

[0041] It is still further preferred that, in the image bearing member mentioned above, the photosensitive layer includes a charge generating layer and a charge transport layer overlying the charge generating layer.

[0042] As another aspect of the present invention, an image forming method is provided which includes charging the image bearing member mentioned above, forming a latent electrostatic image on a surface of the image bearing member, developing the latent electrostatic image with a toner to visualize the latent electrostatic image, transferring the visualized image to a recording medium, fixing the transferred image on the recording medium, and cleaning the surface of the image bearing member,

[0043] As another aspect of the present invention, a process cartridge is provided which includes the image bearing member mentioend above, an optional charging device for charging the surface of the image bearing member, an optional irradiating device for irradiating the surface of the image bearingmember to forma latent electrostatic image thereon, an optional developing device for developing the latent electrostatic image formed on the image bearing member with a toner, and an optional transferring unit for transferring the visible image to a recording medium and an optional cleaning unit for cleaning the surface of the image bearing member. The process cartridge is detachably attached to the main body of an image forming apparatus

[0044] As another aspect of the present invention, an image forming apparatus is provided which includes the process cartridge and a fixing device for fixing the image on the recording medium..

[0045] These and other obj ects, features and advantages of the present invention will become apparent upon consideration of the following description of the preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] Various other objects, features and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood from the detailed description when considered in connection with the accompanying drawings in which like reference characters designate like corresponding parts throughout and wherein:

Fig. 1 is a diagram illustrating an example of the image forming apparatus to which the present invention is applied;
Fig. 2 is a diagram illustrating an image formation process;
Fig. 3 is light emission wavelength characteristics of the UV lamp system for use in Example 1 described later; and
Fig. 4 is a light emission wavelength characteristics of the lamp for use in Example 10 described later.

DETAILED DESCRIPTION OF THE INVENTION

[0047] The present invention will be described below in detail with reference to several embodiments and accompanying drawings.

[0048] The image bearing member of the present invention has a laminate structure having at least a photosensitive layer and a surface layer on a substrate in this order. The photosensitive layer can adopt a single layered or multi-layered (laminate) structure as long as the photosensitive layer has a charge generating function and a charge transport function. When a multi-layered structure is adopted, a function separated laminate structure is typically used.. In this structure, there are a charge generating layer, which has a charge generating function, and a charge transport layer, which has a charge transport function. In the case of a function separated laminate structure, there is no specific limit to the order of a charge generating layer and a charge transport layer on a substrate. When a charge generating layer is provided on the surface side, the charge generating layer can easily deteriorate due to acid gasses or the like produced by a charging device, etc. In addition, it is difficult to apply a charge generating layer on a charge transport layer without corroding the charge transport layer. Thus, a charge generating layer is accumulated on the substrate side in most cases.

[0049] When forming a surface layer of the image bearing member of the present invention, a monomer having at least three radical polymerizable functional groups without a charge transport structure is used. Thus, a three-dimensional mesh structure is developed so that a hard surface layer having a high cross-linking property can be obtained. Consequently, the image bearingmember has a high abrasion resistance.. In contrast, when only a monomer having one or two radical polymerizable functional groups is used, the density of the cross-linking bond in a cross-linked surface layer is thin and the abrasion resistance thereof is not significantly improved. When a non-cross-linked surface layer is used and contains a large amount of high molecular materials, the development of a three-dimensional mesh structure is inhibited and/or the density of cross-linking network is thin. Thus, the abrasion resistance is relatively insufficient in comparison with that in the present invention. Furthermore, high molecular materials contained in a surface layer and cured product generated by a reaction between amonomer having a radical polymerizable functional group with a charge transport structure and a monomer having a radical polymerizable functional group with no charge transport structure has a poor compatibility. This causes phase separation of the materials so that the surface smoothness is low and local abrasion and flaws easily occur. In the surface layer in the present invention, a monomer having a radical polymerizable functional group with a charge transport structure is contained in addition to a monomer having at least radical polymerizable functinal groups having no charge transport structure. The monomer having a radical polymerizable functional group with a charge transport structure is incorporated in a cross-linking bond when the monomer having at least three radical polymerizable functional groups without a charge transport structure is cured. In contrast, when a low molecular charge transport material having no functional group is contained in a cross-linked surface layer, the low molecular charge transport material is precipitated or white clouded due to the low compatibility. This reduces the mechanical strength of the cross-linked surface layer.

[0050] In the present invention, when the monomer having at least three radical polymerizable functional groups without a charge transport structure and the monomer having a radical polymerizable functional group with a charge transport structure are cured with light, a titanocene derivative is used as a polymerization initiator. By the titanocene derivative, the surface layer is sufficiently cured from the surface to the inside of the surface layer so that the surface layer can maintain an excellent durability for a long period of time. In addition, it is possible to provide a smooth surfaced image bearing member which can maintain the voltage at irradiated portions low for a long period of time. In the present invention, a monomer having a radical polymerizable functional group with a charge transport structure is contained as a component and the portion of the charge transport structure typically absorbs light having a relatively long wavelength when forming a surface layer. When a typical photo-radical initiator is used, the amount of generated radical is reduced due to this absorption. Thus, irradiation time is elongated or the energy of the irradiation light is set to be high. This has an adverse impact and the charge transport structure in a surface layer or a photosensitive layer is dissembled, which causes deterioration of characteristics. To increase the amount of generated radical, it is possible to increase the content of photo-polymerization initiator. However, this results in the reduction of the actual content of monomers having a radical polymerizable functional group and charge transport compounds in a cross-linked surface layer. Consequently, this invites a low abrasion resistance property or a rise in the residual voltage, or the photo-polymerization initiator in an excessive amount causes a termination reaction in the radical polymerization. To the contrary, most of the titanocene derivatives absorb light having a wavelength not shorter than 400 nm in the optical light range. That is, radicals can be efficiently generated by irradiation light having a wavelength range out of the range for a monomer having a radical polymerizable functional group with a charge transport structure. Thus, it is possible to obtain a uniform cured layer regardless of the depth thereof. Namely, concave and convex portions ascribable to the difference in the hardness or volume contraction between cured portions and non-cured portions are not formed so that a cross-linking layer having an excellent smoothness can be obtained. The deterioration (e.g., the rise in the residual voltage) of the electric characteristics does not occur because there is no tertiary amino group, for example, dialkylamino group or morphorino group, which is used as a structure for sensitizing radical generation of a photo-polymerization initiator, and excessive irradiation or illuminance is not used for charge transport materials in a surface layer and/or a photosensitive layer.

[0051] The absorption end wavelength of the charge transport material and the photo-radical polymerization initiator defined in the present invention is a value equivalent to the wavelength conversion of transition energy of HOMO-LUMO specific to each material. Namely, in a range around the light absorption end on the long wavelength side, it is considered that the following relationship is satisfied:

$$\alpha h\nu = B(h\nu - E_0)^2,$$

in the relationship, α represents an absorption coefficient, hν represents a light energy (h is Plank's constant, and ν is wavenumber), E_0 represents band gap energy and B is a constant number.

[0052] Specifically, the absorption spectrum is measured, based on the absorption spectrum value, the value hν is plotted for the value obtained from $(\alpha h\nu)^{0.5}$; the value of hν obtained by extrapolating the straight line at α being equal to zero is the transition energy E_0; and the value in wavelength conversion: $\lambda_0 = hc/E_0$ (c represents light speed) is the absorption endwavelength for use in the present invention.

[0053] With regard to the calculation of the absorption end wavelength according to the calculation stated above, it is necessary to obtain a relationship between the absorbance relative to the wavelength (absorption properties) for each material. There is no specific limit to the measurement method of light absorption properties. For a target material that has excessively small light absorption (for example, in the case where the content of a charge transport material is low relative to the bulk thereof), it is extremely difficult to calculate λ_0. Therefore, a material that has an absorbance of from 1 to less than 3 around the light absorption end on the long wavelength side is preferred.

[0054] Any known titanocene derivatives can be used. For example, JOPs S59-152396, S61-151197, S63-41484, H02-249 and H02-4705 describe such titanocene derivatives. Specific examples thereof include bis(cyclopentadienyl)-dichloro-tatanium, bis(cyclopentadienyl)-di-phenyl-titanium, bis (cyclopentadienyl) -bis (2, 3, 4, 5, 6-pentafluorophenyl) titanium, bis(cyclopentadienyl)-bis(2,6 difluorophenyl) titanium, bis(methylcyclopentadienyl)-bis(2,3,4,5,6- pentafluorophenyl) titanium, bis(methylcyclopentadienyl)-bis(2,6 difluorophenyl) titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-(2-(1-pil-1-yl)ethyl) phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3((1-pil-1-yl) methylphenyl) titanium, bis (methylcyclopentadienyl)-bis[2,6-difluoro-3-((1-pil-1-yl)methyl)phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-

3-((2,5-dimethyl-1-pil-1-y 1)methyl)phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-((3-trimethylsilyl-2,5-dimethyl-1-pil-1-yl)met hyl)phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-((2,5- bis(moiphorinomethyl)-1-pil-l-yl) methyl) phenyl] titanium, bis(cyclopentadienyl)-bis [2,6-difluoro-4-((2,5-dimethyl-l-pil-l-yl)methyl)phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-methyl-4-(2-(1-pil-1-yl)ethyl)phenyl]titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-(1-methyl-2-(1-pil-1-yl)ethyl)phenyl]titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-(6-(9-carbazole-9-yl)hexyl)phenyl]titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-(3-(4,5,6,7-tetrahydro-2-methyl-1-indle-1-yl)propyl)phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-((acetylamino)methyl)phenyl] titanium, bis(cyclopentadiehyl)-bis[2,6-difluoro-3-(2-(propionylamino)ethyl)phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-(4-(pivaloylamino)butyl) phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-(2-(2,2-dimehylpentanoyl amino) ethyl)phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-(3-(benzoylamino)propyl) phenyl] titanium, bis(cyclopentadienyl)-bis[2,6-difluoro-3-(2-(N-allylmethyl sulfonylamino)ethyl)phenyl] titanium, and bis(cyclopentadienyl)-bis(2,6-difluoro-3-(pyrrole-1-yl) phenyl)titanium. These can be used alone or in combination.

[0055] A commonly used photo-radical polymerization initiator can be used in combination with the titanocene derivatives mentioned above. There is no specific limit to such a photo-radial polymerization initiator used in combination with the titanocene derivatives in the present invention as long as the photo-radial polymerization initiator generates radical upon irradiation of light. Specific examples thereof include acetophenone or ketal photo-polymerization initiators, for example, diethoxyacetophenone, 2,2-dimethoxy-1,2-diphenylethane-1-on, 1-hydroxy-cyclohexyl-phenyl-ketone, 4-(2-hydroxyethoxy)phenyl-(2-hydroxy-2-propyl)ketone, 2-benzyl-2-dimethylamino-1-(4-morphorinophenyl)butanone-1,2-hydro xy-2-methyl-1-phenylpropane-1-on, 2-methyl-2-morphorino(4-methylthiophenyl)propane-1-on, and 1-phenyl-1,2-propanedione-2-(o-ethoxycarbonyl)oxime; benzoin ether photo-polymerization initiators, for example, benzoin, benzoinmethyl ether, benzoin ethyl ether, benzoin isobutyl ether, and benzoin isopropyl ether; benzophenone photo-polymerization initiators, for example, benzophenone, 4-hydroxybenzophenon, methyl o-benzoyl benzoate, 2-benzoylnaphthalene, 4-benzoylbiphenyl, 4-benzoylphenyl ether, acrylated benzophenone, and 1,4-benzoylbenzene; thioxanthone photo-polymerization initiators, for example, 2-isopropyl thioxanthone, 2-chlorothioxanthone, 2,4-dimethylthioxanthone, 2,4-diethylthioxanthone, and 2-4-dichlorothioxanthone; and other photo-polymerization initiators, for example, ethyl anthraquinone, 2,4,6-trimethyl benzoyl phenylphosphine oxide, 2,4,6-trimethylbenzoyl phenylethoxyphosphine oxide, bis (2,4,6-trimethylbenzoyl)phenylphosphine oxide, bis(2,4-dimethoxybenzoyl)-2,4,4-trimethylpentylphosphine oxide, methyphenyl glyoxyester, 9,10-phenanthrene, acridine compounds, triazine compounds, and imidazole compounds. These photo-radial polymerization initiators can be used singularly or in combination and can be used with the titanocene derivatives.

[0056] In addition, a compound having a photo-polymerization accelerating effect can be used alone or in combination with the photo-polymerization initiators. Specific examples of the compound include triethanol amine, methyldiethanole amine, 4-dimethylamino ethyl benzoate, 4-dimethylamino isoamyl benzoate, ethyl benzoate (2-dimethylamino) and 4,4'-dimethylaminobenzophenone. The content of the titanocene derivative and the polymerization initiator is 0.5 to 40 parts by weight, and preferably 1 to 20 parts by weight relative to 100 parts by weight of total radical polymerizable components contained in a surface layer.

[0057] The monomer having at least three radical polymerizable functional groups without a charge transport structure used in the present invention represents a monomer having at least three radical polymerizable functional groups which does not have a positive hole transport structure, for example, triarylamine, hydrazone, pyrazoline or carbazole, or which does not have an electron transport structure, for example, electron-sucking aromatic ring having condensed polycyclic quinone, diphenoquinone, cyano group, or nitro group. Any radical polymerizable functional group having a carbon-carbon double bond and conducting radical polymerization reaction can be used.

[0058] Specific examples of these radical polymerizable functional groups include 1-ethylene substituted functional groups, and 1,1-substituted ethylene functional groups as follows:

[0059] Specific examples of the 1-substituted ethylene functional group include functional groups represented by the following chemical formula (i):

$$CH_2 = CH - X_1, \qquad \text{Chemical formula (i)}$$

in the chemical formula (i), X_1 represents a substituted or non-substituted arylene group, for example, phenylene group, or naphthylene group, a substituted or non-substituted alkenylene group, CO group, COO group, CON(R_{10}) group (R_{10} represents a hydrogen atom, an alkyl group, for example, methyl group or ethyl group, or an aralkyl group, for example, benzyl group, naphthylmethyl group or phenethyl group, or an aryl group, for example, phenyl group or naphthyl group), or an S group.

[0060] Specific examples of these substituent groups include vinyl group, styryl group, 2-methyl-1,3-butadienyl group, vinylcarbonyl group, acryloyloxy group, acryloylamide group, and vinylthioether group.

[0061] Examples of the 1,1-substituted ethylene functional group include functional groups represented by the following chemical formula (ii):

$CH_2 = C(Y)-X_2$ Chemical formula (ii)

[0062] In the chemical formula (ii), Y represents a substituted or non-substituted alkyl group, a substituted or non-substituted aralkyl group, a substituted or non-substituted aryl group, for example, phenyl group and naphthyl group, ahalogenatom, or an alkoxy group, for example, cyano group, nitro group, methoxy group or ethoxy group, $COOR_{11}$ (R_{11} represents a hydrogen atom, a substituted or non-substituted alkyl group, for example, methyl group or ethyl group; a substituted or non-substituted aralkyl group, for example, benzyl group or phenethyl group, or a substituted or non-substituted aryl group, for example, phenyl group or naphthyl group), or $CONR_{12}R_{13}$ (R_{12} and R_{13} independently represent a hydrogen atom, a substituted or non-substituted alkyl group, for example, methyl group or ethyl group, a substituted or non-substituted aralkyl group, for example, benzyl group, naphthylmethyl group or phenethyl group, or a substituted or non-substituted aryl group, for example, phenyl group or naphthyl group. X_2 represents the same substituent group as X_1, a single bond or an alkylene group.. At least either of Y and X_2 is an oxycarbonyl group, cyano group, an alkenylene group or an aromatic zing.

[0063] Specific examples of these substituent groups include α-acryloyloxy chloride group, methacryloyloxy group, α-cyanoethylene group, α-cyanoacryloyloxy group, α-cyanophenylene group, and methacryloylamino group.

[0064] Examples of substituent groups that are furthermore substituted in the substituent group of X_1, X_2, or Y include an alkyl group for example, a halogen atom, nitro group, cyano group, methyl group or ethyl group; an alkoxy group, for example, methoxy group, and ethoxy group; an aryloxy group, for example, phenoxy group; an aryl group, for example, phenyl group and naphthyl group; and an aralkyl group, for example, benzyl group and phenethyl group.

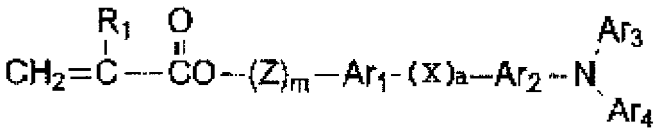
[0065] Among these radical polymerizable functional groups, acryloyloxy group, and methacryloyloxy group are particularly effective, and a compound having three or more acryloyloxy groups can be obtained by conducting, for example, an ester reaction or an ester exchange reaction of a compound having 3 or more hydroxyl groups in the molecule, an acrylic acid (salt), an acrylic acid halide, and an acrylic acid ester. A compound having 3 or more methacryloyl groups can also be obtained in the same manner. The radical polymerizable functional groups in the monomer having 3 or more radical polymerizable functional groups may be the same or different from each other.

[0066] Specific examples of the monomer having at least three radical polymerizable functional groups without a charge transport structure include the following compounds but not limited thereto.

[0067] Specific examples of the monomer having at least three radical polymerizable functional groups for use in the present invention include trimethylolpropane triacrylate (TMPTA), trimethylolpropane trimethacrylate, trimethylolpropane alkylene-modified triacrylate, trimethylol propane ethylene oxy-modified (EO-modified) triacrylate, trimethylolpropane propyleneoxy-modified (PO-modified) triacrylate, trimethylolpropane caprolactone-modified triacrylate, trimethylolpropane alkylene-modified trimethacrylate, pentaerythritol triacrylate, pentaerythritol tetraacrylate (PETTA), glycerol triacrylate, glycerol epichlorohydrine-modified (ECH-modified) triacrylate, glycerol EO-modified triacrylate, glycerol PO-modified triacrylate, tris(acryloxyethyl)isocyanurate, dipentaerythritol hexaacrylate (DPHA), dipentaerythritol caprolactone-modified hexaacrylate, dipentaerythritol hydroxypentaacrylate, alkylated dipentaerythritol pentaacrylate, alkylated dipentaerythritol tetraacrylate, alkylated dipentaerythritol triacrylate, dimethylolpropane tetraacrylate (DTMPTA), pentaerythritol ethoxytetraacrylate, phosphoric acid EO-modified triacrylate, and 2,2,5,5-tetrahydroxymethyl cyclopentanone tetraacrylate. These can be used alone or in combination.

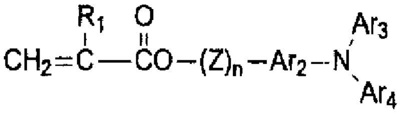
[0068] With regard to the monomer having at least three radical polymerizable functional groups without a charge transport structure for use in the present invention, the ratio of molecular weight relative to the number of functional groups (molecular weight/the number of functional group) in the monomer is preferably from 250 or less to form a dense cross-linking bond in the cross-linked surface layer. When the ratio is excessively great, the cross-linked surface layer is soft, and the abrasion resistance is degraded in some degree. Thus, it is not suitable to single out a compound having an extremely long modified group for use among the monomers having a modified group, for example, EO, PO, and caprolactone. The content of the monomer having at least three radical polymerizable functional groups without a charge transport structure contained in the surface layer in the solid content of the liquid composition is adjusted such that the component ratio thereof is from 20 to 80 % by weight, and preferably from 30 to 70 % by weight based on the total amount of the cross-linked surface layer. When the content of the monomer component is too small, the three dimensionally cross-linked bonding density of the cross-linked surface layer tends to be low. Also the abrasion resistance is not significantly improvement in comparison with the case where a typical thermoplastic binder resin is used. When the content of the monomer is too great, the content of the charge transport compound tends to decrease, which causes degradation of electric properties. It is difficult to jump to any conclusion but considering a good combination of the abrasion resistance and the electric characteristics, the content of the monomer preferably ranges from 30 to 70 % by weight.

[0069] The monomer having at least three radical polymerizable functional groups without a charge transport structure for use in the present invention represents a radical polymerizable functional compound having, for example, a positive hole transport structure, for example, triarylamine, hydrazone, pyrazoline, and carbazole, and an electron-transport structure, for example, electron-sucking aromatic ring having condensed polycyclic quinone, diphenoquinone, cyano group, and nitro group. Specific examples of the monomers having radical a polymerizable functional group include the monomers having radical polymerizable functional groups described above. Acryloyloxy groups and methacryloyloxy groups are particularly preferred. The number of radical polymerizable functional groups per molecule may be one or more. Since it is easy to restrain the internal stress of the cross-linked surface layer to obtain a smooth surface and to maintain good electric characteristics, the number of the radical polymerizable functional groups is preferably one. In the present invention, a titanocene derivative is used as photo-polymerization initiator and a light energy emission wavelength is selected to form a smooth and uniform cross-linked surface layer. Therefore, even when a charge transport compound has two or more radical polymerizable functional groups, a cross-linked surface layer having highly cross-linked density can be formed without distortion inside the cross-linked layer. Therefore, it is possible to provide an image bearing member which has a good resistance to abrasion and damage and maintains electric characteristics for a long period of use. With regard to the charge transport structure of the monomer having a radical polymerizable functional group with a charge transport structure, the triarylamine structures are preferred in terms of the mobility property. Among these, when a compound represented by the following chemical formula (1) or (2) is used, electric properties, for example, sensitivity and residual potential, can be efficiently maintained.



$$CH_2=\overset{R_1}{\overset{|}{C}}-\overset{O}{\overset{\|}{C}}O-(Z)_m-Ar_1-(X)_a-Ar_2-N\begin{matrix}Ar_3\\Ar_4\end{matrix}$$

Chemical formula (1)



$$CH_2=\overset{R_1}{\overset{|}{C}}-\overset{O}{\overset{\|}{C}}O-(Z)_n-Ar_2-N\begin{matrix}Ar_3\\Ar_4\end{matrix}$$

Chemical formula (2)

[0070] In the chemical formulae (1) and (2), R_1 represents hydrogen atom, a halogen atom, an alkyl group, an aralky group, an aryl group, a cyano group, a nitro group, an alkoxy group, -$COOR_7$, wherein R_7 represents hydrogen atom, a substituted or non-substituted alkyl group, a substituted or non-substituted aralkyl group or a substituted or non-substituted aryl group, a halogenated carbonyl group or $CONR_8R_9$, wherein R_8 and R_9 independently represent hydrogen atom, a halogen atom, a substituted or non-substituted alkyl group, a substituted or non-substituted aralkyl group or a substituted or non-substituted aryl group, Ar_1 and Ar_2 independently represent a substituted or unsubstituted arylene group, Ar_3 and Ar_4 independently represent a substituted or unsubstituted aryl group, X represents a substituted or non-substituted alkylene group, a substituted or non-substituted cycloalkylene group, a substituted or non-substituted alkylene ether group, oxygen atom, sulfur atom or vinylene group, Z represents a substituted or non-substituted alkylene group, a substituted or non-substituted alkylene ether divalent group or an alkyleneoxy carbonyl divalent group, a represents 0 or 1 and and m and n represent 0 or an integer of from 1 to 3.

[0071] Materials having a triarylamine structure as described above are extremely excellent in charge transportability. Also, such materials have a light absorption end on a relatively long wavelength (specifically, 300 nm or more) side and thus, when such a material is contained in a photo-cross-linkable surface layer, cross-linking may be inhibited by light absorption. When the titanocene derivative described in the present invention is used, a cross-linked film (layer) having a cured state from the surface to the inside of the layer is obtained in comparison with another typical photo radical polymerization initiator. However, the titanocene derivative is not effective to any of the monomers having radical polymerizable functional groups with a charge transport structure but to only a monomer having a radical polymerizable functional group with a charge transport structure having the absorption end wavelength in the light absorption spectrum 40 nm or more, preferably 60 nm or more, shorter than the absorption end wavelength of the titanocene derivative. When the absorption end wavelength of a monomer having a radical polymerizable functional group with a charge transport structure minus the absorption end wavelength of a titanocene derivative is, for example, 40 nm or less, almost all absorption wavelengths of the titanocene derivative correspond with those of the monomer having a radical polymerizable functional group with a charge transport structure. This may result in a decrease of the radical generation efficiency, which leads to bad cross-linking.

[0072] When the titanocene derivative described in the present invention is used with a compound having a light absorption end wavelength of 370 nm or longer to form a surface layer, it is found that the titanocene derivative is advantageous over other photo-radial polymerizable initiators.

[0073] In the chemical formulae (1) and (2), in the substituent group of R_1, specific examples of the alkyl groups include methyl group, ethyl group, propyl group, and butyl group; specific examples of the aryl groups include phenyl group and naphthyl group; specific examples of the aralkyl groups include benzyl group, phenethyl group and naphthylmethyl group; specific examples of the alkoxy group include methoxy group, ethoxy group, and propoxy group. These groups can be substituted by a halogen atom; nitro group; cyano group; an alkyl group, for example, methyl group and ethyl group; an alkoxy group, for example, methoxy group and ethoxy group; an aryloxy group, for example, phenoxy group; an aryl group, for example, phenyl group and naphthyl group; or an aralkyl group, for example, phenethyl group,

[0074] Among the substituent groups of R_1, hydrogen atom, and methyl group are particularly preferred.

[0075] substituted or unsubstituted Ar_3 and Ar_4 are aryl groups, and specific examples thereof include condensed polycyclic hydrocarbon groups, non-condensed cyclic hydrocarbon groups, and heterocyclic groups.

[0076] Preferred specific examples of the condensed polycyclic hydrocarbon group include groups in which the number of the carbon atoms forming a ring is 18 or less. Specific examples thereof include pentanyl group, indenyl group, naphthyl group, azulenyl group, heptalenyl group, biphenylenyl group, as (asym)- indacenyl group, s(sym)-indacenyl group, fluorenyl group, acenaphthylenyl group, pleiadenyl group, acenaphtenyl group, phenalenyl group, phenanthryl group, anthryl group, fluoranthenyl group, acephenantolylenyl group, aceanthrylenyl group, triphenylel group, pyrenyl group, chrysenyl group and naphthacenyl group.

[0077] Specific examples of the uncondensed cyclic hydrocarbon groups include, but are not limited to, monovalent groups derived frombenzene, diphenyl ether, polyethylene diphenyl ether, diphenyl thioether, diphenyl sulfone, biphenyl, polyphenyl, diphenyl alkane, diphenyl alkene, diphenyl alkyne, triphenylmethane, distyrylbenzene, 1,1-diphenyl cycloalkane, polyphenyl alkane, and polyphenyl alkene. In addition, monovalent groups derived from polycyclic hydrocarbons such as 9,9-diphenyl fluorene can also be used.

[0078] Specific examples of the heterocyclic groups include, but are not limited to, monovalent groups derived from carbazole, dibenzofuran, dibenzothiophene, oxadiazole, thiazole, etc.

[0079] The aryl groups represented by Ar_3 and Ar_4 may have the following substituent groups.

(1) A halogen atom, cyano group, nitro group, etc.

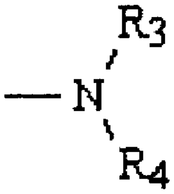
(2) A straight-chain or branched-chain alkyl group having 1 to 12 carbon atoms, more preferably 1 to 8 carbon atoms, and much more preferably 1 to 4 carbon atoms, which may substituted with fluorine atom; hydroxyl group; cyano group; an alkoxy group having 1 to 4 carbon atoms; or a phenyl group substituted with a halogen atom, an alkyl group having 1 to 4 carbon atoms, or an alkoxy group having 1 to 4 carbon atoms. Specific examples of the alkyl groups include, but are not limited to, methyl group, ethyl group, n-butyl group, i-propyl group, t-butyl group, s-butyl group, n-propyl group, trifluoromethyl group, 2-hydroxyethyl group, 2-ethoxyethyl group, 2-cyanoethyl group, 2-methoxyethyl group, benzyl group, 4-chlorobenzyl group, 4-methylbenzyl group, and 4-phenylbenzyl group..

(3) An alkoxy group ($-OR_2$, wherein R_2 represents an alkyl group defined in the paragraph (2)). Specific examples of the alkoxy groups include, but are not limited to, methoxy group, ethoxy group, n-propoxy group, i-propoxy group, t-butoxy group, n-butoxy group, s-butoxy group, i-butoxy group, 2-hydroxyethoxy group, benzyloxy group, and trifluoromethoxy group.

(4) An aryloxy group. Specific examples of the aryl groups include, but are not limited to, phenyl group and naphthyl group. The aryloxy group can be substituted with an alkoxy group having 1 to 4 carbon atoms, an alkyl group having 1 to 4 carbon atoms, or a halogen atom. Specific examples of the aryloxy groups include, but are not limited to, phenoxy group, 1-naphthyloxy group, 2-naphthyloxy group, 4-methoxyphenoxy group, and 4-methylphenoxy group.

(5) An alkylmercapto group or an arylmercapto group. Specific examples of these groups include, but are not limited to, methylthio group, ethylthio group, phenylthio group, and p-methylphenylthio group.

(6) A substituent group represented by the following chemical formula:



$$-N(R_3)(R_4)$$

wherein each of R_3 and R_4 independently represents a hydrogen atom, an alkyl group defined in the paragraph (2), or an aryl group (e.g., phenyl group, biphenyl group, naphthyl group) which can be substituted with an alkoxy group having 1 to 4 carbon atoms, an alkyl group having 1 to 4 carbon atoms, or a halogen atom; and wherein R_3 and R_4 optionally share bond connectivity to form a ring. Specific examples of the substituent groups mentioned above include, but are not limited to, amino group, diethylamino group, N-methyl-N-phenylamino group, N,N-diphenylamino group, N,N-di(tolyl)amino group, dibenzylamino group, piperidino group, morpholino group, and pyrrolidino group.

(7) An alkylenedioxy group and an alkylenedithio group such as methylenedioxy group and methylenedithio group.

(8) A substituted or unsubstituted styryl group, a substituted or unsubstituted β-phenyl styryl group, diphenyl aminophenyl group, dinitrile aminophenyl group, etc.

[0080] Specific examples of the arylene groups represented by Ar_9 and Ar_{10} include, but are not limited to, divalent groups derived from the aryl groups represented by Ar_{11} and Ar_{12}.

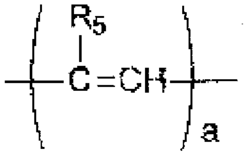
[0081] X represents a single bond, a substituted or unsubstituted alkylene group, a substituted or unsubstituted cycloalkylene group, a substituted or unsubstituted alkylene ether group, an oxygen atom, a sulfur atom, or a vinylene group.

[0082] The substituted or unsubstituted alkylene group is a straight-chained or branched-chain alkylene group having 1 to 12 carbon atoms, preferably 1 to 8 carbon atoms, and more preferably 1 to 4 carbon atoms. These alkylene groups may have a fluorine atom, a hydroxyl group, a cyano group, an alkoxy group having 1 to 4 carbon atoms, a phenyl group, or a phenyl group substituted with a halogen atom, an alkyl group having 1 to 4 carbon atoms, or an alkoxy group having 1 to 4 carbon atoms. Specific examples of the substituted or unsubstitutedalkylene groups include, but are not limited to, methylene group, ethylene group, n-butylene group, i-propylene group, t-butylene group, s-butylene group, n-propylene group, trifluoromethylene group, 2-hydroxyethylene group, 2-ethoxyethylene group, 2-cyanoethylene group, 2-mehoxyethylene group, benzylidene group, phenylethylene group, 4-chlorophenylethylene group, 4-methylphenylethylene group, and 4-biphenylethylene group.

[0083] The substituted or non-substituted cycloalkylene group is a cyclic alkylene group having 5 to 7 carbon atoms which may have a fluorine atom, a hydroxyl group, an alkyl group having 1 to 4 carbon atoms, or an alkoxy group having 1 to 4 carbon atoms. Specific examples of the substituted or non-substituted cycloalkylene groups include, but are not limited to, cyclohexylidene group, cyclohexylene group, and 3,3-dimethylcyclohexylidene group.

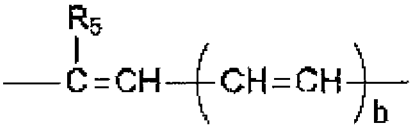
[0084] Specific examples of the substituted or non-substituted alkylene ether divalent groups include, but are not limited to, an alkyleneoxy divalent group (e.g., ethyleneoxy group, propyleneoxy group); an alkylenedioxy divalent group derived from ethylene glycol, propylene glycol, etc.; and di- or poly- (oxyalkylene)oxy group derived from diethylene glycol, tetraethylene glycol, tripropylene glycol, etc. The alkylene group of the alkylene ether divalent group may have a substituent group, for example, a hydroxyl group, a methyl group, and an ethyl group.

[0085] Specific examples of the vinylene groups include, but are not limited to, the following substituent groups:



$$-\left(\overset{R_5}{\overset{|}{C}}=CH\right)_a-$$

or



$$-\overset{R_5}{\overset{|}{C}}=CH-\left(CH=CH\right)_b-$$

[0086] R_5 represents a hydrogen atom, an alkyl group (same as defined in the paragraph (2)), or an aryl group (same aryl groups as represented by Ar_3 and Ar_4); a represents an integer of 1 or 2; and b represents an integer of from 1 to 3.

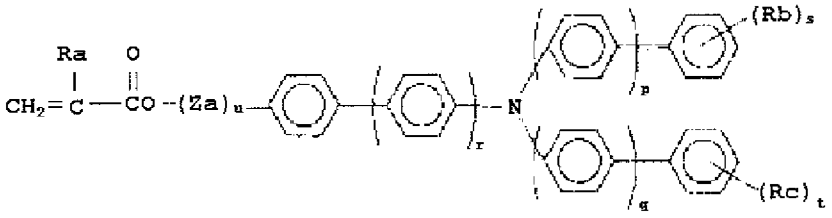
[0087] Z represents a substituted or unsubstituted alkylene group, a substituted or non-substituted alkylene ether divalent group, or an alkyleneoxycarbonyl divalent group.

[0088] Examples of the substituted or non-substituted alkylene group include the same alkylene groups as those described in the X.

[0089] Examples of the substituted or non-substituted alkylene ether divalent group include the same alkylene ether divalent groups as those described in the X.

[0090] Examples of the alkyleneoxycarbonyl divalent group include caprolactone-modified divalent groups.

[0091] As the monomers having a radical polymerizable functional group with a charge transport structure for use in the present invention, compounds represented by the following chemical formula (3) are preferably used.



Chemical formula (3)

[0092] In the chemical formula (3), u, r, p, q represent 0 or 1, s and t independently represent 0 or an integer of from 1 to 3, Ra represents hydrogen atom or methyl group, each of Rb and Rc independently represents an alkyl group having 1 to 6 carbon atoms, and Za represents methylene group, ethylene group, $-CH_2CH_2O-$, $-CHCH_3CH_2O-$, or $-C_6H_5CH_2CH_2-$.

[0093] Among the compounds represented by chemical structure illustrated above, the compounds having a methyl group or an ethyl group as each of Rb and Rc are preferred.

[0094] The radical polymeric compound for use in the present invention having a functional group with a charge transport structure represented by the chemical formulae (1), (2) and especially (3) is polymerized in such a manner that the double linkage of C and C is open to both ends. Therefore, the radical polymeric compound is not present at the end but in the chained polymer. In a polymer in which a cross linking chain is formed with a radical polymeric monomer having at least 3 functional groups, the radical polymeric compound is present in the main chains of the polymer and in a cross linking chain. There are two kinds of cross linking chains. One is referred to as inter-molecule cross linking, in which the cross linking chain is formed between a polymer and another polymer. The other is referred to as internal cross linking, in which the cross linking chain is formed between a portion in the main chain present in a polymer formed in a folded state and another portion deriving from the monomer which is polymerized at a position remote from that portion in the main chain. Whether the radical polymeric monomer having at least 3 functional groups is present in a main chain or in a cross linking chain, the triaryl amine structure suspending from the chain portion has at least three aryl groups disposed in the radial directions from the nitrogen atom therein. Such a triaryl amine structure is bulky and does not directly bind with the chain portion but suspends from the chain portion via a carbonyl group, etc. That is, the triaryl amine structure is stereoscopically fixed in the polymer in a flexible state. Therefore, these triaryl amine structures can be adjacent to each other with a moderate space in a polymer. Therefore, the structural distortion in a molecule is slight. In addition, when the structure is used in the surface layer of an image bearing member, it can be deduced that the internal molecular structure can have a structure in which there are relatively few disconnections in the charge transport route.

[0095] Further, to improve the abrasion resistance in the present invention, a charge transport compound having two or more radical polymerizable functional groups can be preferably used, In typical techniques, when a charge transport compound having two or more radical polymerizable functional group is used, bulky charge transport structures are fixed in plural bonds in a cross-linking bond, which leads to distortions inside the cross-linked film (layer). This increases internal stress, which may cause cracks and film exfoliation. In contrast, in the present invention, a titanocene derivative is used as a photo- polymerization initiator. Therefore, a surface layer is cured instantly to the inside thereof without causing distortion in the inside thereof while achieving a uniformly cross-linked surface layer. A cross-linked surface layer having higher cross-linking densities with high durability is thus obtained. Since there is no distortion in the inside of the cross-linked layer, it is possible to stably keep intermediate structures (cation radical) during charge transport. Consequently, the sensitivity degradation and the residual potential rise caused by charge trap hardly occur. Also, the electric characteristics are stably maintained over a long period of time.

[0096] Hereinafter, specific examples of the monomer having a radical polymerizable functional group with a charge transport structure having a triarylamine structure as a charge transport structure will be described. However, the radial polymerizable monomer is not limited to the compounds having these structures.

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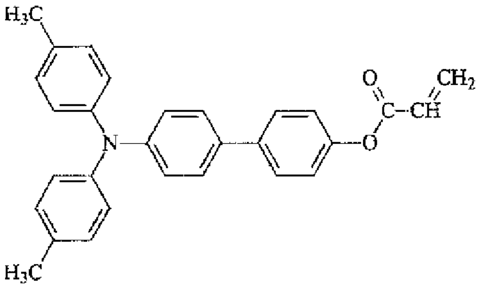

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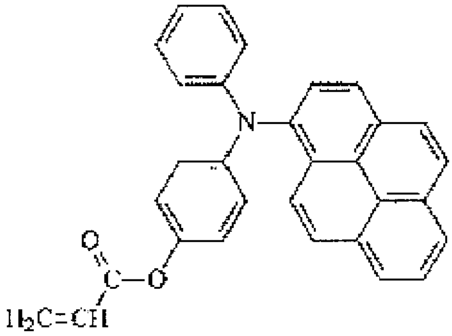

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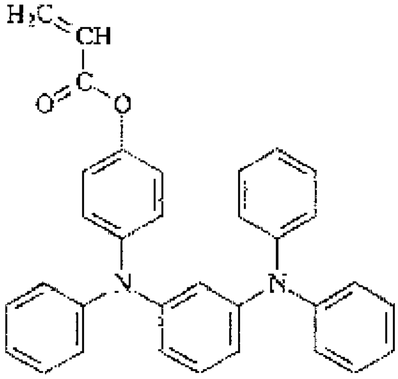

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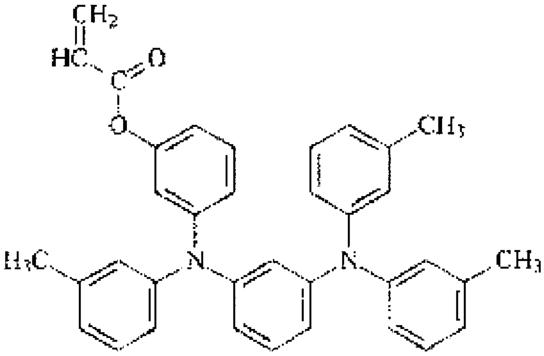

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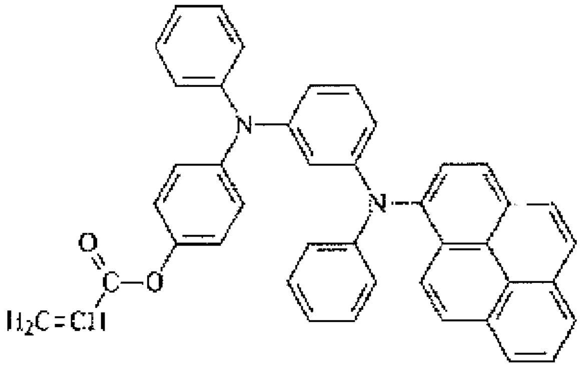

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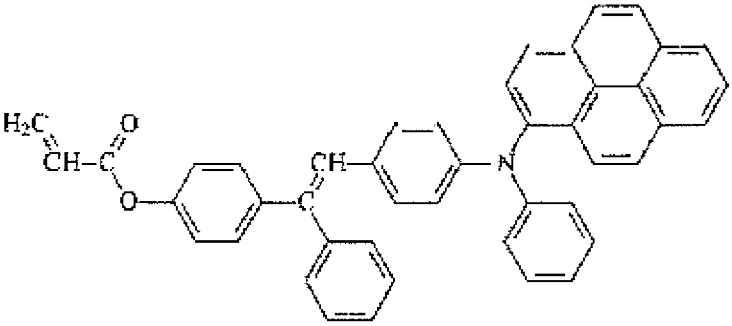

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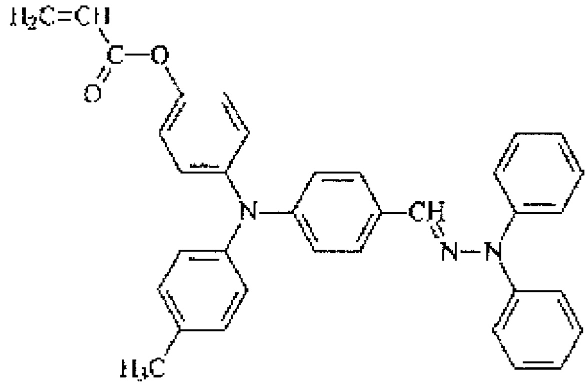

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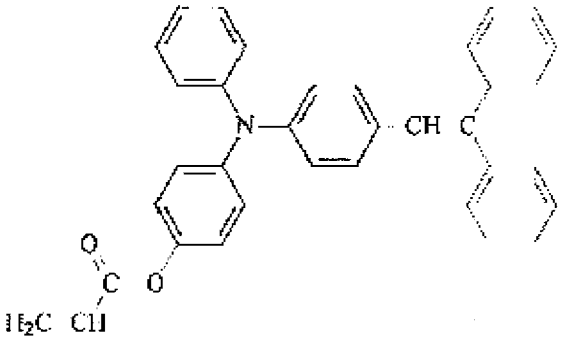

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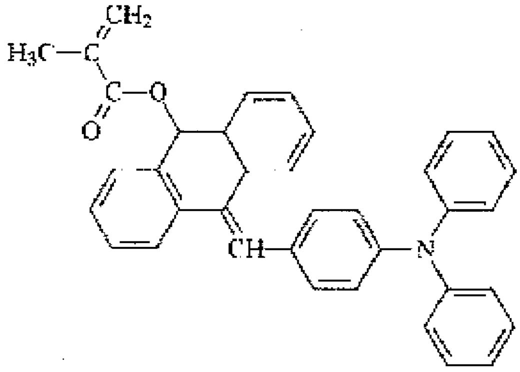

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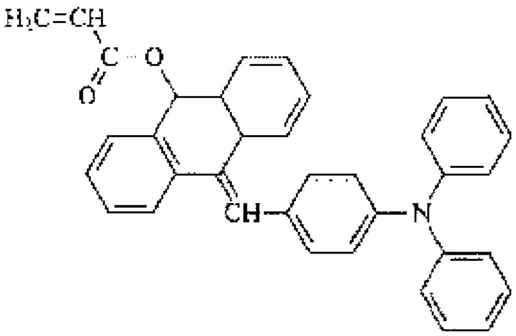

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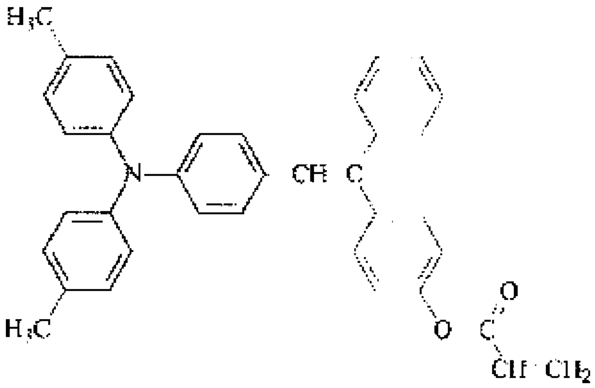

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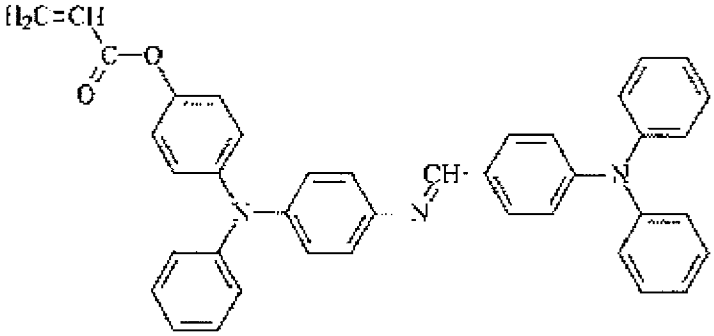

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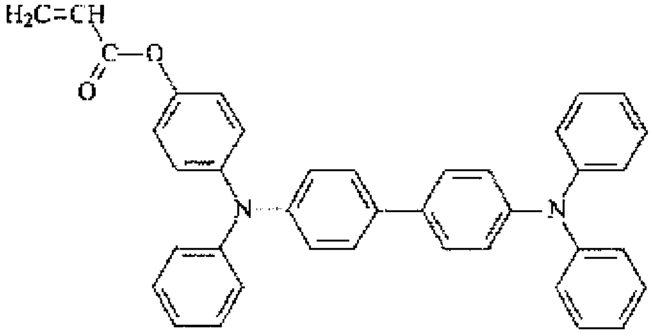

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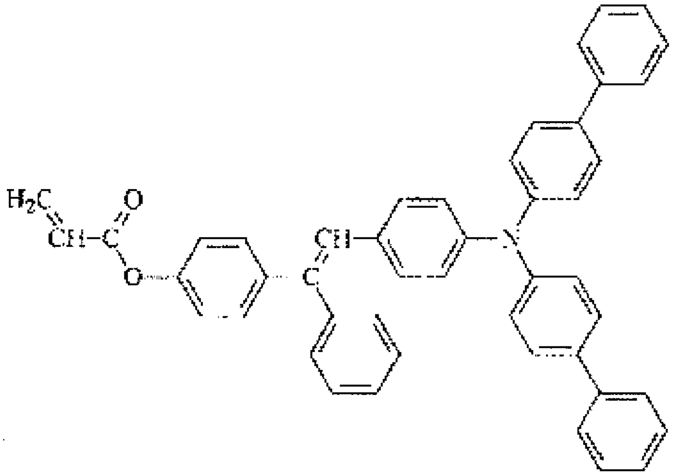

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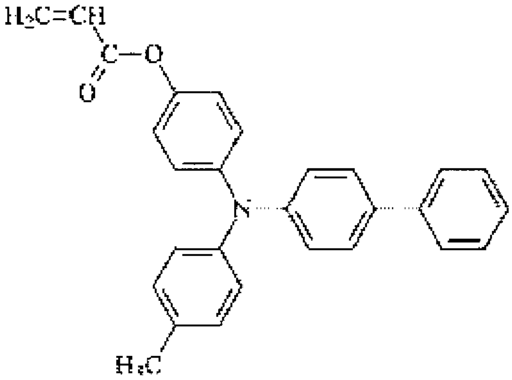

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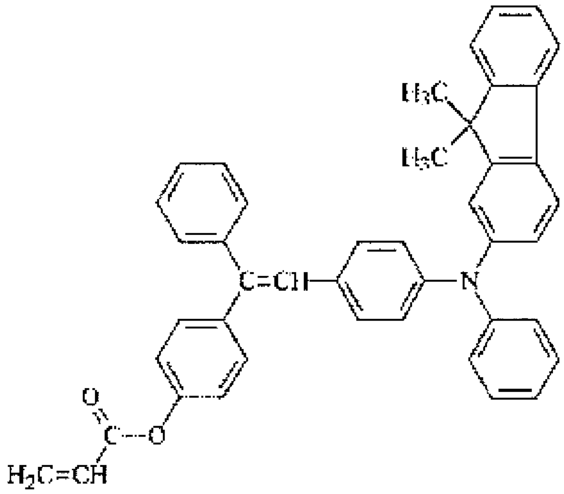

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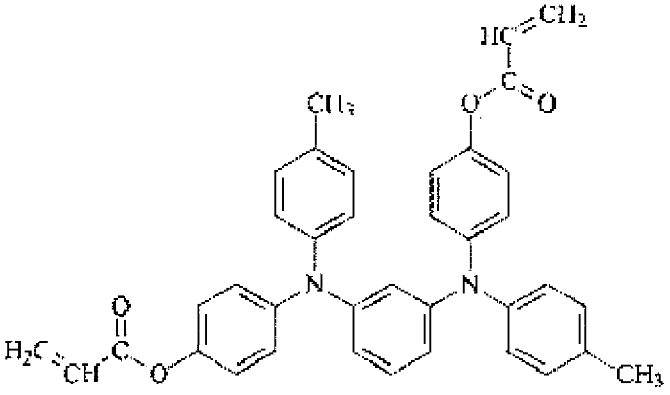

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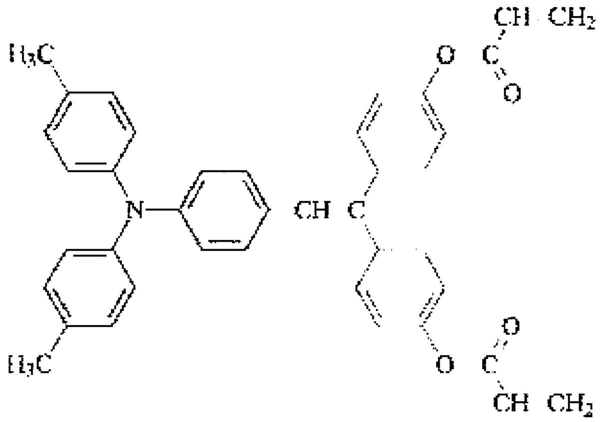

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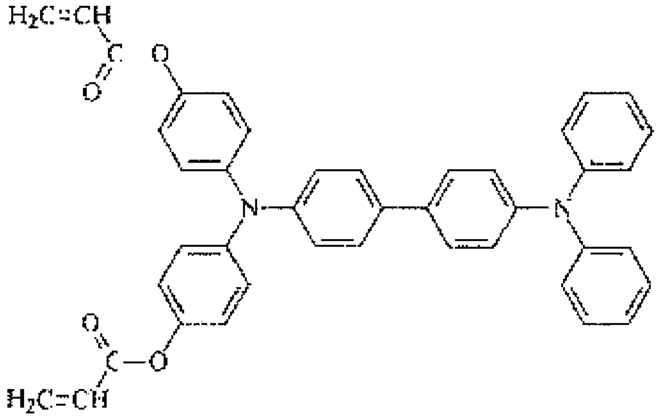

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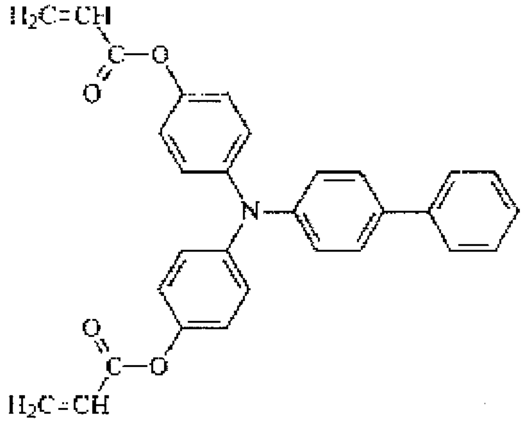
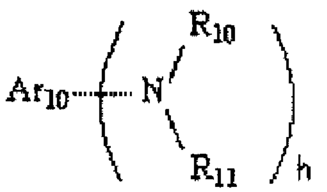


[0097] In the present invention, a specific acryl ester compound illustrated in the following chemical formula (4) can also be preferably used as a monomer having a radical polymerizable functional group with a charge transport structure.

B_1-Ar_1-CH=CH-Ar_2-B_2 Chemical formula (4)

[0098] In the chemical formula (4), Ar_1 represents a monovalent group or a divalent group having a substituted or non-substituted aromatic hydrocarbon skeleton. Specific examples of the aromatic hydrocarbon include benzene, naphthalene, phenanthrene, biphenyl, and 1,2,3,4-tetrahydronaphthalene. Specific examples of the substituent group include an alkyl group having 1 to 12 carbon atoms, an alkoxy group having 1 to 12 carbon atoms, benzyl group, and a halogen atom. The alkyl groups and the alkoxy groups may further have a halogen atom and/or phenyl group as a substituent group.

[0099] Ar_2 represents a monovalent group or a divalent group having an aromatic hydrocarbon skeleton or a heterocyclic skeleton having at least one tertiary amino group. The aromatic hydrocarbon skeleton having at least one tertiary amino group is represented by the following Chemical formula (8)

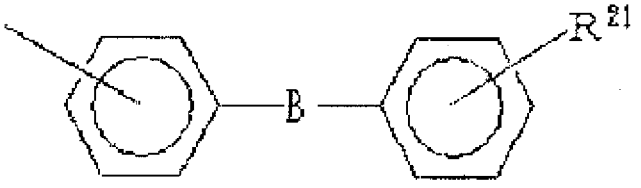


$$Ar_{10}\left(N\begin{matrix}R_{10}\\R_{11}\end{matrix}\right)_h$$

Chemical formula (8)

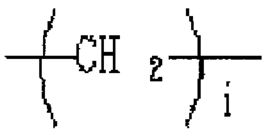
[0100] In the chemical formula (8), R_{10} and R_{11} independently represent an acyl group, a substituted or non-substituted alkyl group, or a substituted or non-substituted aryl group. A-r_{10} represents an aryl group, and h is an integer of 1 to 3.

[0101] Specific examples of the acyl group of R_{10} and R_{11} include acetyl group, propionyl group, and benzoyl group. The substituted or non-substituted alkyl group of R10 and R11 are the same as the alkyl groups described for the substituent group of Ar_1. The substituted or non-substituted aryl group of R_{10} and R_{11} include a phenyl group, a naphthyl group, a biphenyl group, a terphenylyl group, a pyrenyl group, a fluorenyl group, 9, 9-dimethyl-2-fluorenyl group, an azurenyl group, an anthryl group, a triphenylenyl group, chrysenyl groups and groups represented by the following chemical formula (9):

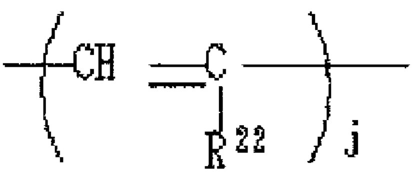


Chemical formula (9)

[0102] In the chemical formula (9), B is -O-, -S-, -SO-, -SO_2-, -CO-, or a divalent group represented by the following chemical formulae:



$$-\left(CH_2\right)_i-$$



$$-\left(CH=\underset{R^{22}}{C}\right)_j-$$

[0103] In the formulae illustrated above, R_{21} represents hydrogen atom, a substituted or non-substituted alkyl group defined for Ar_1, an alkoxy group, a halogen atom, a substituted or non-substituted aryl group defined for R_{10}, an amino group, nitro group, or cyano group; R_{22} represents a hydrogen atom, a substituted or non-substituted alkyl group defined for Ar_1, or a substituted or non-substituted aryl group defined for R_{10}; i is an integer of from 1 to 12; and j is an integer of from 1 to 3.

[0104] Specific examples of the alkoxy group of R21 include methoxy group, ethoxy group, n-propoxy group, 1-propoxy group, n-butoxy group, i-butoxy group, s-butoxy group, t-butoxy group, 2-hydroxyethoxy group, 2-cyanoethocy group, benzyloxy group, 4-methylbenzyloxy group, and trifluoromethoxy group.

[0105] Specific examples of the halogen atom of R_{21} include fluorine atom, chlorine atom, bromine atom, and iodine atom.

[0106] Specific examples of the amino group of R_{21} include diphenylamino group, ditolylamino group, dibenzylamino group, and 4-methylbenzyl group.

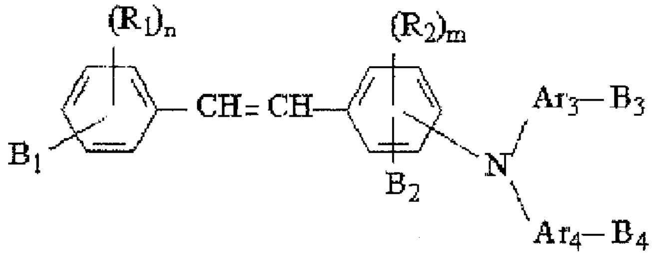
[0107] Specific examples of the aryl group of Ar_{10} include phenyl group, naphthyl group, biphenylyl group, terphenylyl group, pyrenyl group, fluorenyl group, 9,9-dimethyl-2-fluorenyl group, azurenyl group, anthryl group, triphenylenyl group, and chrysenyl group.

[0108] Ar_{10}, R_{10}, and R_{11} may contain an alkyl group, an alkoxy group, and halogen atom defined in the substituent group for Ar_1.

[0109] Specific examples of the heterocyclic skeleton having a tertiary amino group include heterocyclic compounds having an amine structure, for example, pyrrole, pyrazole, imidazole, triazole, dioxazole, indole, isoindole, benzimidazole, benzotriazole, benzoisoxazine, carbazole and pheoxazine. Each of these heterocyclic compounds may contain an alkyl group, an alkoxy group, and a halogen atom defined for the substitutent group of Ar_1.

[0110] B_1 and B_2 independently represent an acryloyloxy group, a methacryloyloxy group, vinyl group, an alkyl group having an acryloyloxy group, a methacryloyloxy group or a vinyl group, or an alkoxy group having an acryloyloxy group, a methacryloyloxy group or a vinyl group. The alkyl group and the alkoxy group are those described in the Ar_1. B_1 and B_2 are not present simultaneously.

[0111] Specific examples of more preferred structure for the acrylic acid ester compound of the chemical formula (4) include the compounds represented by the following chemical formula (5) .



Chemical formula (5)

[0112] In the chemical formula (5), R_1 and R_2 respectively represent a substituted or non-substituted alkyl group, a substituted or non-substituted alkoxy group, Or a halogen atom; Ar_3 and Ar_4 independently represent a substituted or non-substituted aryl group or arylene group, or a substituted or non-substituted benzyl group. The alkyl group, the alkoxy group, and the halogen atom include those described for the Ar_1.

[0113] The aryl group is the same as those defined for the R_{10} and R_{11}. The arylene group is a divalent group derived from the aryl group.

[0114] B_1, B_2, B_3, and B_4 in the chemical formula 5 are the same as those defined for B_1, B_2, and only one of B_1 to B_4 exists, i.e., B_1, B_2, B_3 and B_4 do not coexist. n is 0 or an integer of from 1 to 5, and m represents 0 or an integer of from 1 to 4.

[0115] The specific acrylic ester compound has a tertiary amine compound having a developed stilbene conjugate structure. This developed conj ugate system contributes to great improvement in the electric charge infusion property at the interface of a cross-linked layer. Further, when the compound is fixed in cross-linking bond, the intermolecular interaction is hardly inhibited and the electric charge mobility is excellent.. The specific acrylic acid ester has one highly radical-polymerized acryloyloxy group or methacryloyloxy group per molecule and is immediately gelatinized during radical polymerization without excessive distortion, Double bonds in the stilbene structural portion in a molecule are partially taken in the polymerization. The polymerizability of the bond is lower than those of an acryloyloxy group or a methacryloyloxy group. Therefore, the time lag occurs in the cross-linking reaction, meaning that the distortion in the compound is not maximized. Furthermore, since double bonds in the molecules are used in cross-linking, the number of cross-linking reactions per molecule increases, resulting in increase in the density of cross-linking. Thus, the abrasion resistance is improved. In addition, the polymerization degree of this double bond can be adjusted depending on the cross-linking conditions, meaning an optimal cross-linking film can be prepared. Such a double bond, which partially forms the radical polymerization, is characteristic to the specific acrylic acid ester compound and does not occur in an α-phenylstilbene structure.

[0116] As another characteristic of the acrylic acid ester compound, the acrylic acid ester compound tend to shift the light absorption end to longer wavelengths in comparison with other compounds because of the developed conjugate system. In most case of triarylamine materials as described in the chemical formula (6), the light absorption end thereof exceeds 400 nm. When a triarylamine material is used in a cross-linked surface layer, the cross-linked status tends to be different between the surface and the inside of the layer due to the light absorption. When the titanocene derivative described in the present invention is used, the light absorption end thereof is on a longer wavelength side than those of the acrylic acid ester compound in most cases. Thus it is easy to obtain a layer uniformly cured over the entire layer.

[0117] As described above, by using a monomer having a radical polymerizable functional group with a charge transport structure illustrated in the chemical formula (4), in particular, the chemical formula (5), in combination with the titanocene derivative described in the present invention, it is possible to forma filmhaving an extremely highcross-linkingdensity-withoutcracking. Therefore, it is possible to provide an image bearing member having excellent characteristics which has hardly been abraded or flawed over a long period of time, resulting in reduction of image deficiency.

[0118] Hereinafter, specific examples of the monomer having a radical polymerizable functional group with a charge transport structure represented by the chemical formula (4) will be illustrated below, however, the monomer having a radical polymerizable functional group with a charge transport structure is not limited thereto.

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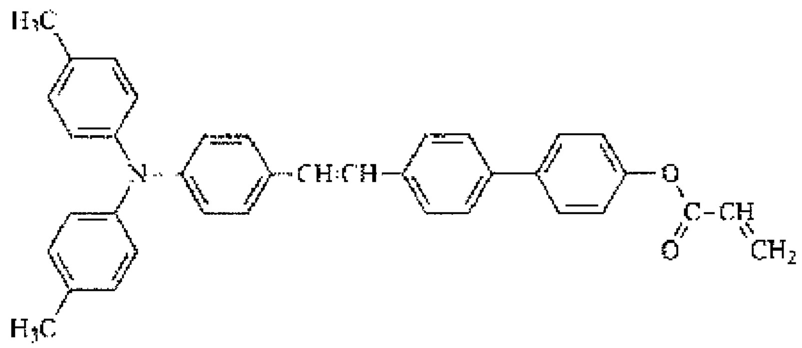

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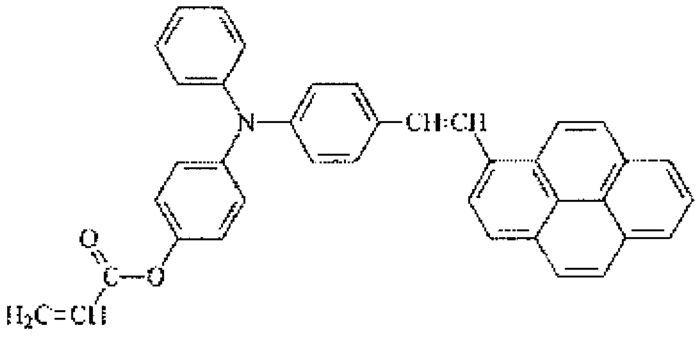

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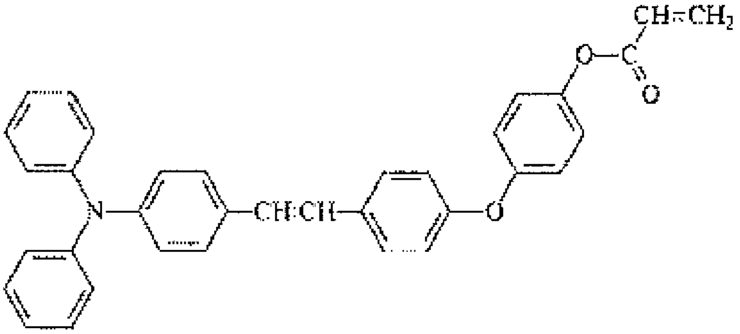

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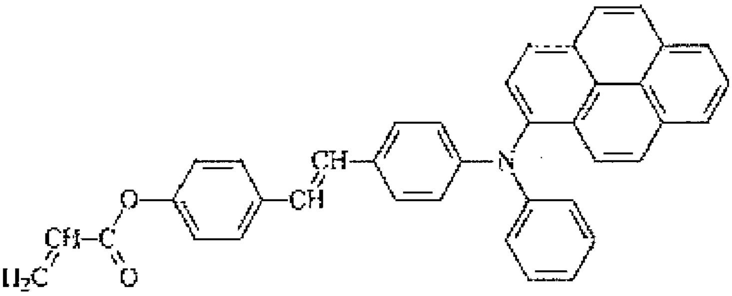

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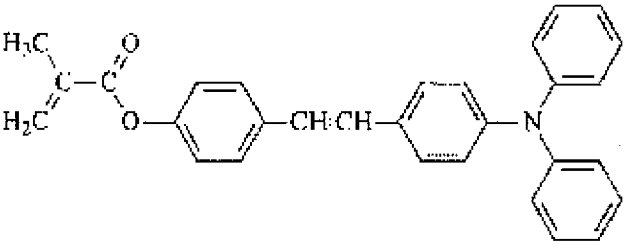

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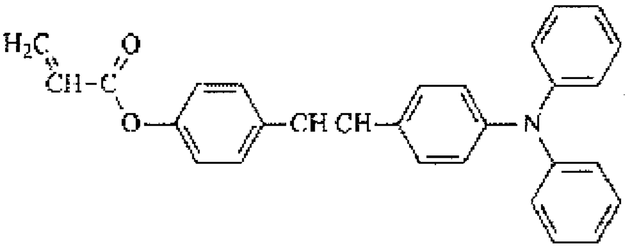

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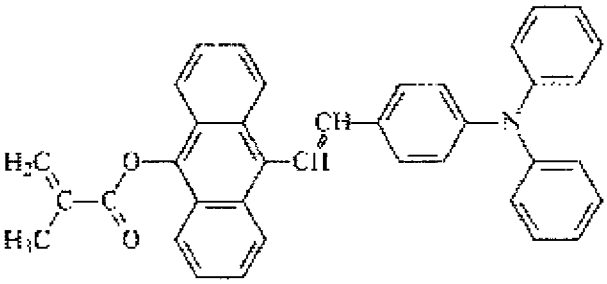

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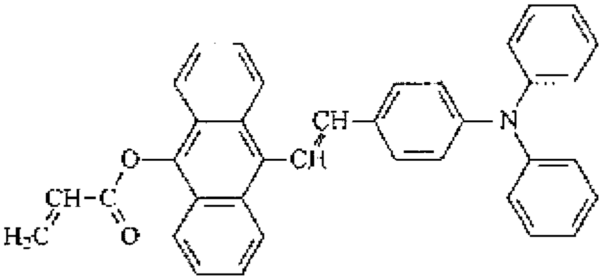

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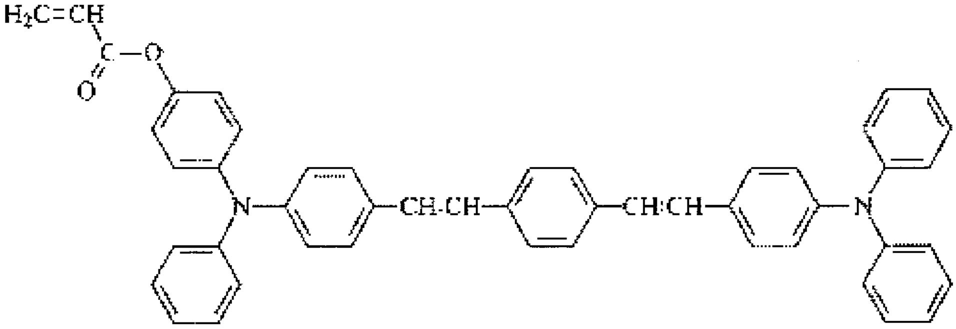

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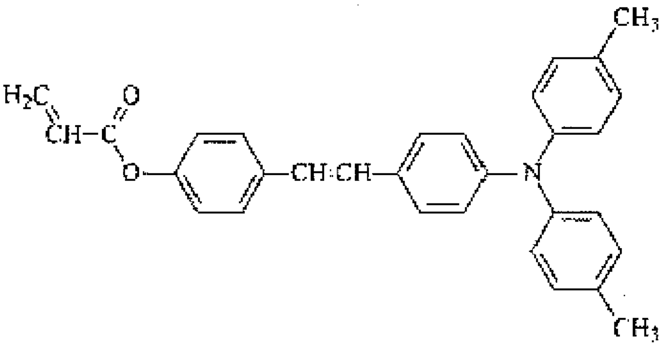

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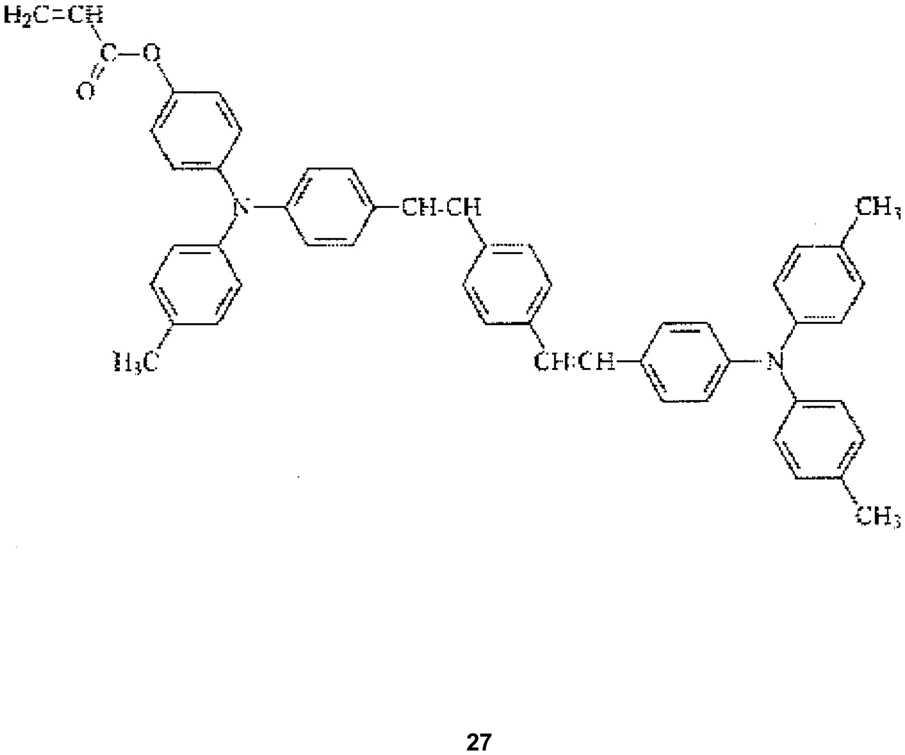

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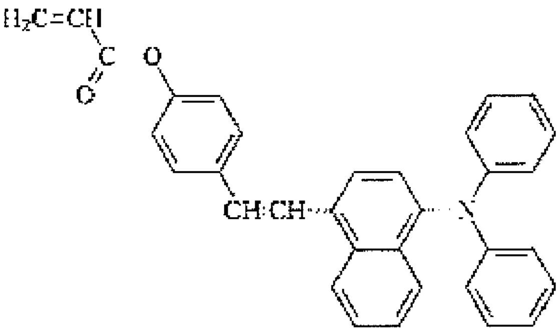

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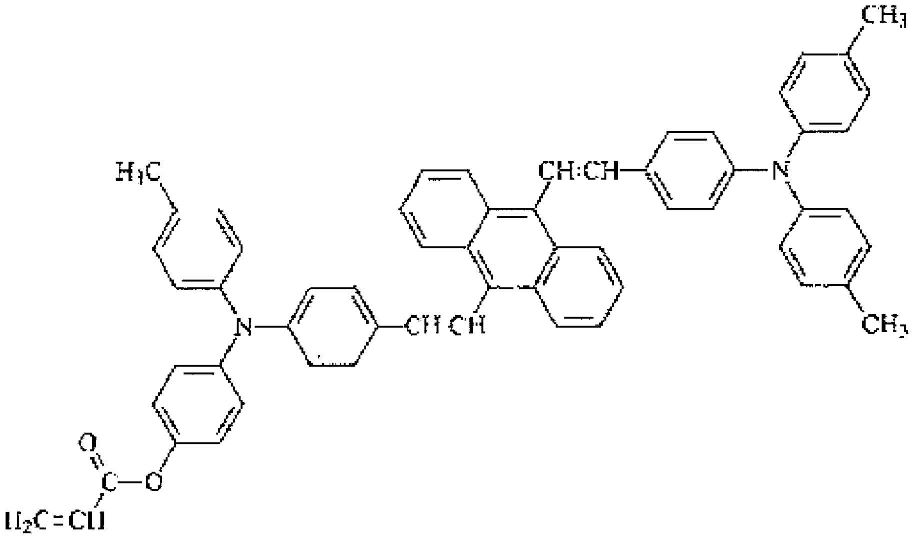

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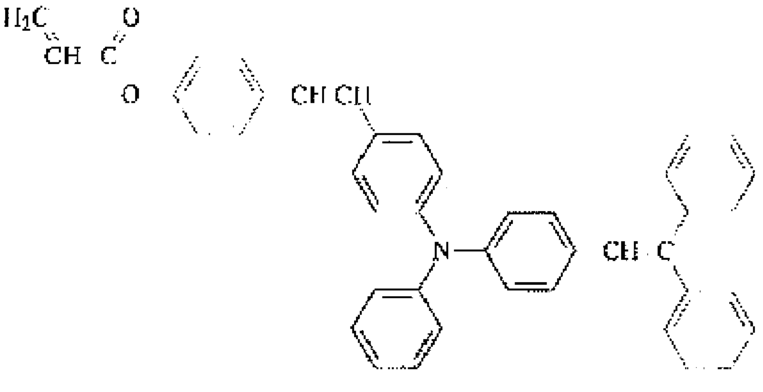

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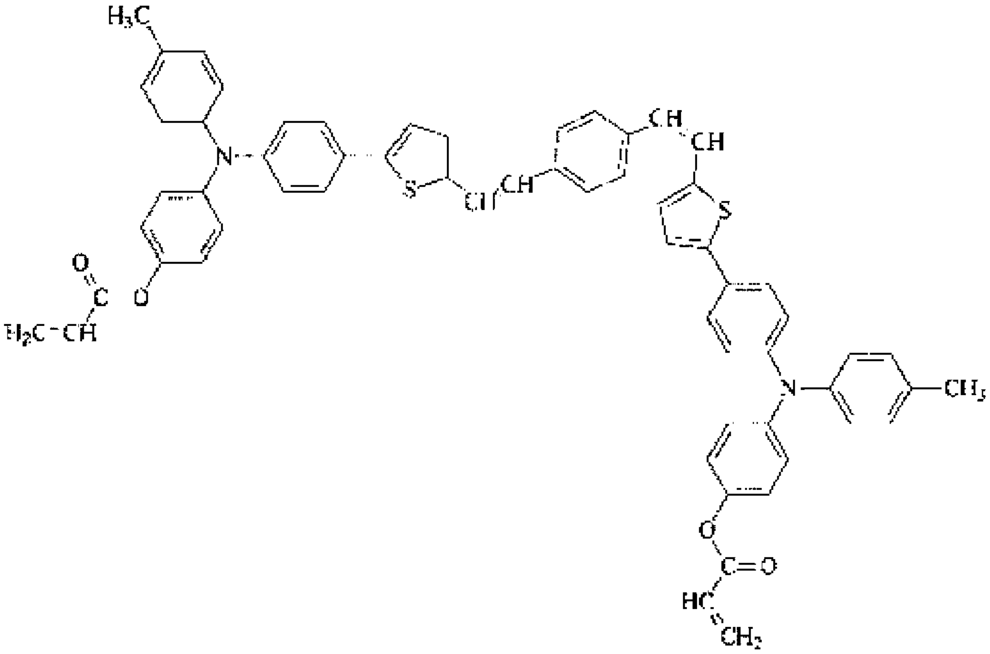
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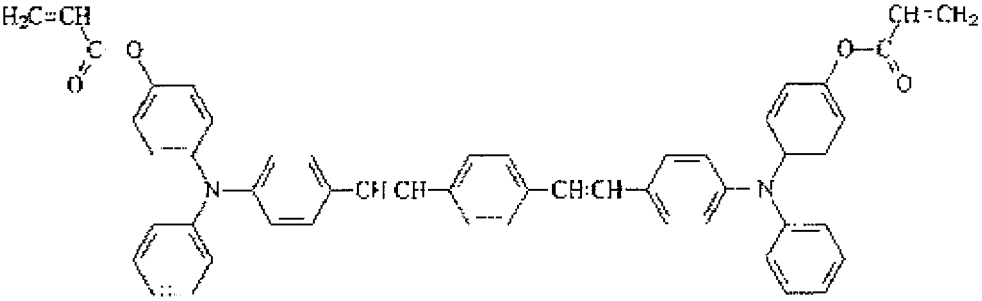
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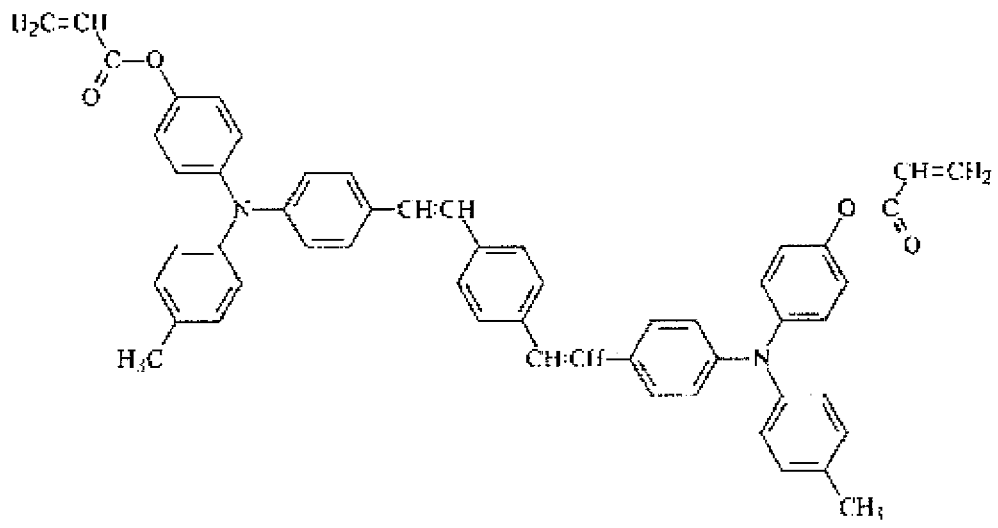

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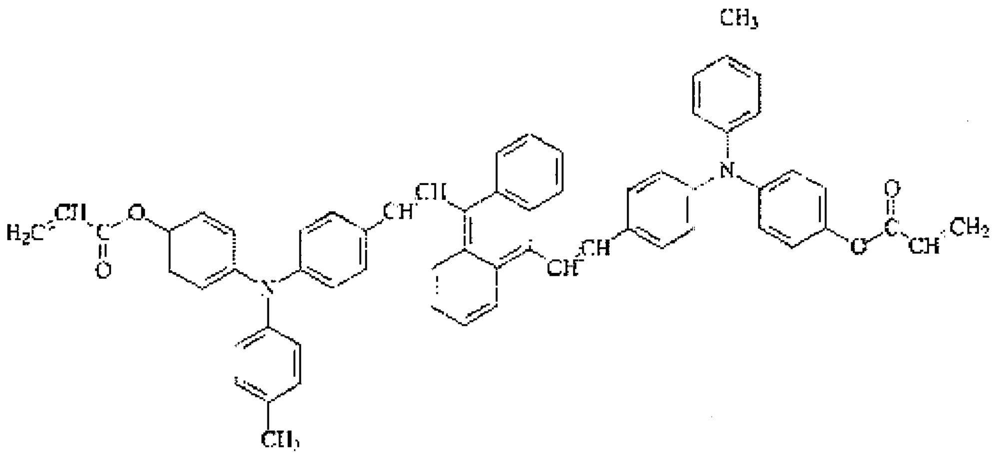


[0119] The radical polymeric compound having a charge transport structure for use in the present invention imparts a charge transport function to a cross-linked surface layer. The content of the radical polymeric compound is from 20 to 80 % by weight, and preferably from 30 to 70 % by weight, based on the total weight of a cross-linked surface layer. When the content is too small, the charge transport function of the cross-linked surface layer is not maintained, which may lead to the deterioration of the electric characteristics, for example, sensitivity degradation and residual voltage rise, during repetitive use. When the content is too large, the content of the radical polymeric monomer having at least three functional groups without a charge transport structure decreases. That is, the cross linking density decreases so that the anti-abrasion is not sufficient. Desired electric characteristics and anti-abrasion property vary depending on the process, it is difficult to jump to any conclusion but considering the balance of both characteristics and property, the addition amount is most preferable from 30 to 70 % by weight.

[0120] The liquid composition for use in the present invention may further contain additives, for example, various plasticizers (for the purpose of alleviation of stresses and improving adhesiveness), leveling agents, and low-molecular charge transport materials having no radical reactivity. Any known additives in the art can be used. Specific examples of such plasticizers include those used in common resins, for example, dibutylphthalate or dioctylphthalate. The content of the plasticizers is restricted to 20 parts by weight or less, preferably to 10 parts by weight or less relative to the total solid content of a liquid composition. Specific examples of such leveling agents include silicone oils, for example, dimethyl silicone oil or methylphenyl silicone oil, and polymers or oligomers having a perfluoroalkyl group in the side chains thereof . The suitable content thereof is not greater than 3 parts by weight relative to the total solid content of a liquid composition.

[0121] When the monomer having at least three radical polymerizable functional groups without a charge transport structure and the radical polymerizable compound having a charge transport structure are formed on a photosensitive layer, it is preferred to prepare a liquid composition having a low viscosity and suitable flowability. When each material has a low-viscosity, such materials can be mixed to prepare a liquid composition. In the case of spray coating, a sufficient flowability is desired to suitably perform atomization, Therefore, it is preferred that a liquid composition is diluted with an organic solvent for adjusting the viscosity. The organic solvent is preferably has a boiling point of from 90° C or lower, more preferably from 60 to 90° C and still more preferably from 60 to 80° C under one atmospheric pressure. These organic solvents can be used alone or in combination. The dilution ratio of the liquid composition by such an organic solvent is determined depending on the properties of the component of the liquid composition.

[0122] In the present invention, after application of such a liquid composition to form a surface layer, the surface layer is cured upon application of an external energy thereto. As the external energy, light energy is mainly used. Heat energy can be used in combination therewith.

[0123] As the heat energy, gases, for example, air or nitrogen gas, vapor, various kinds of heat media, infrared rays or electromagnetic rays can be used. The surface layer is heated from the coated side or the substrate side. The heating temperature is preferably from 100 to 170° C. When the heating temperature is too low, the reaction rate is low, which affects the productivity and causes unreacted materials to remain in the film. In contrast, when the heating temperature is too high, contraction of a film caused by cross-linking increases. Therefore, the resultant surface layer may have rough surface and/or cracking and be exfoliated at the interface to the immediately-adjacent layer. When a resin that tends to contract upon cross-linking is used, it is effective to use a method of preliminarily cross-linking at a temperature lower than 100° C followed by cross-linking at a temperature not lower than 100° C.

[0124] As the light energy, light sources, for example, ultrahigh pressure mercury lamp, high pressure mercury lamp, low-pressure mercury lamp, carbon arc and xenon arc metal halide lamp may be utilized. It is preferred to select a light source in consideration of light absorption of the titanocene derivative described in the present invention.

[0125] With regard to the emission wavelength of a light source, light having a wavelength in the ultraviolet ray range can be used because the titanocene derivative absorbs ultraviolet rays. It is preferred to consider the light absorption of the monomer having a radical polymerizable functional group with a charge transport structure as described above. Specifically, by using a light source having a maximum emission wavelength of 400 nm or longer, irradiation light is efficiently absorbed by titanocene because the monomer having a radical polymerizable functional group with a charge transport structure has a low absorption ratio in the range. Thus, it is easy to obtain a film uniformly cured from the surface to the inside thereof.

[0126] As the emission illuminance of a light source, it is preferred to irradiate a surface layer at an illuminance of 50 to 2,000 mW/cm^2 on the basis of a wavelength of 356 nm. It is more preferred to irradiate a surface layer within the above-mentioned illuminance range when the illuminance is measurable at wavelengths around the maximum emission wavelength. When the illuminance is low, it takes a long time to cure a surface layer, which is not preferred from the perspective of productivity. In contrast, when the illuminance is high, curing contraction easily occurs so that the resultant surface layer may have a rough surface and/or cracking and be exfoliated at the interface to the immediately-adjacent layer.

[0127] When a UV ray used for irradiation, the temperature of the sur face layer of an image bearing member rises due to, for example, heat ray generated from the light source. When the temperature of the surface is excessively raised, the surface layer is easily contracted upon curing. Also, since low-molecular components contained in the immediately-adjacent layer move to the surface layer, the surface layer is not suitably cured and the electric properties of an image bearing member are degraded. Therefore, the temperature of the surface of an image bearing member during irradiation of a UV ray is set typically at 100° C or lower and preferably at 80°C or lower. As the cooling method of an image bearing member, a cooling-auxiliary agent can be encapsulated inside an image bearing member or an image bearing member can be cooled down by a gas of liquid therein.

[0128] The thickness of a surface layer is preferably from 1 to 20 μm and more preferably from 3 to 15 μm from the perspective of protection of a photosensitive layer, When a surface layer is too thin, a photosensitive layer is not protected from mechanical abrasion between an image bearing member and a contacting device thereto and proximate electric discharge from a charging device. Furthermore, since a film surface is hardly leveled during film formation, the film surface may have a rough surface. In contrast, when the surface layer is too thick, the total thickness of the layers of an image bearing member is thick so that the image reproducibility is degraded by charge diffusion.

[0129] To prevent the interlayer exfoliation between a surface layer and a photosensitive layer resulting from adhesion failure, an adhesive layer may be disposed therebetween if desired.

[0130] As the adhesive layer, the above-mentioned monomer with no charge transport structure may be used, or a non-cross-linkable polymer may be used. Specific examples of the non-cross-linkable polymer include, but not limited to, include polyamides, polyurethanes, epoxy resins, polyketones, polycarbonates, silicone resins, acrylic resins, polyvinylbutyrals, polyvinylformals, polyvinylketones, polystyrenes, poly-N-vinylcarbazoles, polyacrylamides, polyvinylbenzals, polyesters, phenoxy resins, vinylchloride-vinylacetate copolymers, polyvinylacetates, polyphenylene oxides, polyvinylpyridines, cellulose resins, caseins, polyvinyl alcohols, and polyvinyl pyrolidones. These monomers and non-cross-linkable polymers may be used alone or in combination. In addition, the monomers may be used in combination with the non-cross-linkable polymers as long as the adhesiveness of the mixture is sufficient. Charge transport materials described in the present invention may be also used. To improve the adhesiveness, suitable additives may be used.

[0131] It is possible to form an adhesive layer by applying a liquid composition in which a compound prepared according to a preferred prescription is dissolved or dispersed in a solvent, for example, tetrahydrofuran, dioxane, dichloroethane, and cyclohexane to a photosensitive layer, Specific methods of application include an immersion coatingmethod, a spray-coatingmethod, abead-coatingmethod, or a ring-coating method, The thickness of an adhesive layer is preferably from 0.1 to 5 μm, and more preferably from 0.1 to 3 μm.

[0132] Next, the photosensitive layer is described. As described above, the photosensitive layer can have a function-separated laminate structure or a single layer structure. In the case of a laminate structure, a photosensitive layer is typically formed of a charge generating layer and a charge transport layer . In the case of a single layer, a photosensitive layer has a charge generating function and charge transport function. Hereinafter, a photosensitive layer having a laminate structure and a photosensitive layer having a single layer structure will be described.

[0133] The charge generating layer is a layer mainly containing a charge generating material having a charge generating function and can contain a binder resin in combination. As the charge generating material, inorganic materials and organic materials can be used.

[0134] Specific examples of the inorganic materials include crystal selenium, amorphous-selenium, selenium-tellurium-halogen, selenium-arsenic compounds, and amorphous-silicon. With regard to the amorphous-silicon, those in which a dangling-bond is terminated with a hydrogen atom or a halogen atom, and those in which boron atoms or phosphorous atoms are doped are preferably used.

[0135] As for the organic materials, any known material in the art can be used. Specific examples thereof include phthalocyanine pigments, for example, metal phthalocyanine and metal-free phthalocyanine; azulenium salt pigments; squaric acid methine pigments; azo pigments having a carbazole skeleton; azo pigments having a triarylamine skeleton; azo pigments having a diphenylamine skeleton; azo pigments having a dibenzothiophene skeleton; azo pigments having a fluorenone skeleton; azo pigments having an oxadiazole skeleton; azo pigments having a bis-stilbene skeleton; azo pigments having a distilyloxadiazole skeleton; azo pigments having a distylylcarbazole skeleton; perylene pigments, anthraquinone or polycyclic quinone pigments; quinoneimine pigments; diphenylmethane and triphenylmethane pigments; benzoquinone and naphthoquinone pigments; cyanine and azomethine pigments, indigoid pigments, and bis-benzimidazole pigments.

[0136] These charge generating materials may be used alone or in combination.

[0137] Specific examples of the binder resin optionally used in a charge generating layer include polyamides, polyurethanes, epoxy resins, polyketones, polycarbonates, silicone resins, acrylic resins, polyvinylbutyrals, polyvinylformals, polyvinylketones, polystyrenes, poly-N-vinylcarbazoles, polyacrylamides, polyvinylbenzals, polyesters, phenoxy resins, vinylchloride-vinylacetate copolymers, polyvinyl acetates, polyphenylene oxides, polyvinyl pyridines, cellulose resins, caseins, polyvinyl alcohols, and polyvinyl pyrolidones.

[0138] These binder resins may be used alone or may be used as a mixture of two or more. The content of the binder resin is from 0 to 500 parts by weight and preferably from 10 to 300 parts by weight based on 100 parts by weight of a charge generating material. The binder resin can be added before or after the dispersion of the materials for a charge generating layer.

[0139] The method for forming a charge generating layer is typified into a vacuum thin-film forming method and a casting method using a liquid dispersion. Specific examples of the vacuum thin-film forming include a vacuum evaporation method, a glow discharge decomposition method, an ion-plating method, a sputtering method, a reactive sputtering method, or a CVD method. Charge generating layers can be excellently formed by these method using the above-mentioned inorganic materials or organic materials. In the casting method, the above-mentioned inorganic or organic charge generating material is dispersed with a binder resin in a solvent, for example, tetrahydrofuran, dioxane, dioxsolan, toluene, dichloromethane, monochlorobenzene, dichloroethane, cyclohexanone, cyclopentanone, anisole, xylene, methylethylketone, acetone, ethylacetate, butylacetate using, for example, a ball mill, an attritor, a sand mill, a bead mill. Thereafter, suitably diluted liquid dispersion is applied to the surface of a substrate to form a charge generating layer. Leveling agents, for example, dimethyl silicone oil, and methylphenyl silicone oil, can be added, if desired..

[0140] The diluted liquid dispersion can be applied by a dip coating method, a spray coating method, a bead coating method, or a ring coating method.

[0141] The thickness of a charge generating layer is preferably from 0,01 to 5 μm, and still more preferably from 0,05 to 2 μm.

[0142] The electric charge transport layer is a layer having a charge transport function and containing a charge transport material and a binder resin.

[0143] As the charge transport materials, there are positive hole transport materials and electron transport materials.

[0144] Specific examples of the electron transport materials include electron accepting materials, for example, chloranil, bromoanil, tetracyanoethylene, tetracyanoquinodimethane, 2,4,7-trinitro-9-fluorenone, 2,4,5,7-tetranitro-9-fluorenone, 2,4,5,7-tetranitroxanthone, 2,4,8-trinitorothioxanthone, 2,6,8-trinitoro-4H-indeno[1,2-b]thiophene-4-on, 1,3,7-trinitorodibenzothiophene-5,5-dioxide, and diphenoquinone derivatives.

[0145] These electron transport materials can be used alone or in combination.

[0146] Specific examples of the positive hole transport materials include poly-N-vinylcarbazole or derivatives thereof, poly-γ-carbazolylethylglutamate or derivatives thereof, pyrene-formaldehyde condensates or derivatives thereof, polyvinylpyrene, polyvinylphenanthrene, polysilane, oxazole derivatives, imidazole derivatives, monoarylamine derivatives, diarylamine derivatives, triarylamine derivatives, stilbene derivatives, α-phenylstilbene derivatives, benzidine derivatives, diarylmethan derivatives, triarylmethane derivatives, 9-styrylanthracene derivatives, pyrazoline derivatives, divinylbenzene derivatives,hydrazone derivatives,indene derivatives, butadiene derivatives, pyrene derivatives, bisstilbene derivatives, enamine derivatives, and other known hole-transporting materials. These positive hole transport materials can be used alone or in combination.

[0147] Specific examples of the binder resin include thermoplastic or thermocuring resins, for example, polystyrenes, styrene-acrylonitrile copolymers, styrene-butadiene copolymers, styrene-maleic acid anhydride copolymers, polyesters, polyvinylchlorides, vinylchloride-vinylacetate copolymers, polyvinyl acetates, polyvinylidene chlorides, polyarylate resins, phenoxy resins, polycarbonates, acetylcellulose resins, ethylcellulose resins, polyvinylbutyrals, polyvinylformals, polyvinyltoluenes, poly-N-vinylcarbazoles, acrylic resins, silicone resins, epoxy resins, melamine resins, urethane resins, phenol resins, and alkyd resins. It is also possible to use a polymeric charge transport materials having a charge transport function, for example, a polycarbonate resin, a polyester resin, a polyurethane resin, a polyether resin, a polysiloxane resin or an acrylic resin having an arylamine skeleton, a benzidine skeleton, a hydrazone skeleton, a carbazole skeleton, a stilbene skeleton or a pyrazoline skeleton; and polymeric materials having a polysilane skeleton.

[0148] The content of the charge transport material is suitably 20 to 300 parts by weight, preferably 40 to 150 parts by weight based on 100 parts by weight of the binder resin. Polymeric charge transport materials can be used alone or in combination with binder resins.

[0149] With regard to the solvent, for example, tetrahydrofuran, dioxane, toluene, dichloromethane, monochlorobenzene, dichloroethane, cyclohexanone, methylethylketone or acetone, are used. These solvents can be used alone or in combination.

[0150] In addition, a plasticizer and a leveling agent can be added. As a plasticizer for use in a charge transport layer, typical plasticizers for resins, for example, dibutylphthalate, and dioctylphthalate can be used. The content of the plasticizer is typically 0 to 30 parts by weight based on 100 parts by weight of a binder resin. As for the leveling agent that can be used in combination in a charge transport layer, silicone oils, for example, dimethylsilicone oil, methylphenyl silicone oil, or polymers or oligomers having a perfluoroalkyl group in their side chains. The content of a leveling agent is suitably from 0 to 1 part by weight based on 100 parts by weight of a binder resin.

[0151] The thickness of a charge transport layer is preferably 30 μm or less and more preferably 25 μm or less in terms of resolution and responsiveness. The minimum thickness of the charge transport layer varies depending on the system, particularly depending on charge potential, etc. and is preferably 5 μm or more.

[0152] A photosensitive layer having a single layer has a charge generating function and a charge transport function. A photosensitive layer can be formed by dissolving or dispersing a charge generating material, a charge transport material, and a binder resin in a suitable solvent, applying the solution to the surface of a substrate followed by drying. A plasticizer, a leveling agent, an antioxidizing agent, etc. can be added, if desired.

[0153] As for the binder resin, the binder resins mentioned above for the charge transport layer can be used. The binder resins mentioned above for the charge generating layer can be mixed. The above-mentioned charge transport polymers can also be suitably used. The content of the charge generating material is preferably from 5 to 40 parts by weight, and the content of the charge transport material is preferably from 0 to 190 parts by weight, and more preferably from 50 to 150 parts by weight based on 100 parts by weight of the binder resin. A photosensitive layer can be formed by applying a liquid composition in which a charge generating material, a binder resin, and a charge transport material are dispersed in a solvent, for example, tetrahydrofuran, dioxane, dichloroethane, and cyclohexane using a dispersing device, to the surface of a substrate by a dip coating method, a spray coating method, a bead coating method, or a ring coating method. The thickness of a photosensitive layer is suitably from about 5 to about 25 μm.

[0154] The image bearing member of the present invention can have an undercoat layer between a substrate and a photosensitive layer. Typically, such an undercoat layer contains a resin. Considering that a photosensitive layer is applied to the resin, the resin preferably is hardly soluble in a typical organic solvent. Specific examples of such a resin include water-soluble resins, for example, polyvinyl alcohol, casein, sodium polyacrylate; alcohol-soluble resins, for example, copolymerized nylon, methoxymethylated nylon; and curable resins forming a three-dimensional network structure, for example, polyurethanes, melamine resins, phenol resins, alkyd-melamine resins and epoxy resins. In addition, to the undercoat layer, there can be added fine powder pigments of metal oxides, for example, titanium oxide, silica, alumina, zirconium oxide, tin oxide, and indium oxide to prevent moiré and lower the residual potential. Such an undercoat layer can be formed using a suitable solvent and coating method, as described for the above-mentioned photosensitive layer. Further, in the present invention, a silane coupling agent, a titanium coupling agent, a chrome coupling agent, etc. can be used to form an undercoat layer. Furthermore, an undercoating layer can be formed by using a material formed by anodizing Al_2O_3, or an organic compound, for example, polyparaxylylene (parylene) or an inorganic comopund, for example, SiO_2, SnO_2, TiO_2, ITO, and CeO_2 by a vacuum thin-film forming method.

[0155] The thickness of such an undercoat layer is suitably from 0 to 5 μm.

[0156] As for the substrate, materials having a volume resistance of not greater than 10^{10} $\Omega\cdot$cm can be used. For example, there can be used plastic or paper having a film form or cylindrical form covered with a metal, for example, aluminum, nickel, chrome, nichrome, copper, gold, silver, and platinum, or a metal oxide, for example, tin oxide and indium oxide by depositing or sputtering. Also aplatemade of aluminum, an aluminum alloy, nickel, and a stainless metal can be used. Further, a tube manufactured from the plate by a crafting technique, for example, extruding and extracting, and surface-treatment, for example, cutting, super finishing and glinding, is also usable. In addition, the endless nickel belt and the endless stainless belt described in JOP S52-36016 can be used as the substrate.

[0157] An electroconductive substrate can be formed by applying to the substrate described above a liquid of application in which electroconductive powder is dispersed in a suitable binder resin as the substrate for use in the present invention.

[0158] Specific examples of such electrconductive powder include carbon black, acetylene black, metal powder, for example, powder of aluminum, nickel, iron, nichrome, copper, zinc and silver, and metal oxide powder, for example, electroconductive tin oxide powder and ITO powder.

[0159] Specific examples of the binder resins which are used together with the electroconductive powder include thermoplastic resins, thermosetting resins, and optical curing resins, for example, a polystyrene, a styrene-acrylonitrile copolymer, a styrene-butadiene copolymer, a styrene-anhydride maleic acid copolymer, a polyester, a polyvinyl chloride, a vinyl chloride-vinyl acetate copolymer, a polyvinyl acetate, a polyvinylidene chloride, a polyarylate (PAR) resin, a phenoxy resin, polycarbonate, a cellulose acetate resin, an ethyl cellulose resin, a polyvinyl butyral, a polyvinyl formal, a polyvinyl toluene, a poly-N-vinyl carbazole, an acrylic resin, a silicone resin, an epoxy resin, a melamine resin, an urethane resin, a phenol resin, and an alkyd resin. Such an electroconductive layer can be formed by dispersing the electroconductive powder and the binder resins mentioned above in a suitable solvent, for example, tetrahydrofuran (THF), dichloromethane (MDC), methyl ethyl ketone (MEK), and toluene and applying the resultant to a substrate.

[0160] Furthermore, a combination of a suitable cylindrical substrate and a heat contraction tube provided thereon as an electroconductive layer can be used as the electroconductive substrate for use in the present invention. The heat contraction tube contains a raw material, for example, polyvinyl chloride, polypropylene, polyester, polystyrene, polyvinylidene chloride, polyethylene, chloride rubber or polytetrafluoroethylene based fluorine resin, and the electroconductive powder mentioned above.

[0161] Further, in the present invention, to improve the environment resistance, in particular, to prevent the degradation of sensitivity and the rise in residual potential, an antioxidizing agent can be added to layers, for example, a surface layer, a photosensitive layer, a charge generating layer, a charge transport layer, an undercoat layer, an intermediate layer, and a light shielding layer.

[0162] Specific examples of the antioxidizing agent include phenol compounds, paraphenylene diamines, hydroquinones, organic sulfur compounds, and organic phosphorous compounds,

[0163] Specific examples of the phenol compound include 2,6-di-t-butyl-p-cresol, butylated hydroxyanisol, 2,6-di-t-butyl-4-ethylphenol, stearyl-β-(3,5-di-t-butyl-4-hydroxyphenyl)propionate, 2,2'-methylene-bis-(4-methyl-6-t-butylphenol), 2,2'-methylene-bis-(4-ethyl-6-t-butylphenol), 4, 4'-thiobis-(3-methyl-6-t-butylphenol), 4,4'-butylidenebis-(3-methyl-6-t-butylphenol), 1,1,3-tris-(2-methyl-4-hydioxy-5-t-butylphenyl)butane, 1,3,5-trimethyl-2,4,6-tris(3,5-di-t-butyl-4-hydroxybenzyl)benzene,tetrakis-[methylene-3-(3',5'-di-t-butyl-4'-hydroxyphenyl)propionate]methane, bis[3, 3'-bis (4'-hydroxy-3'-t-butylphenyl)butyric acid] glycol ester, and tocopherols.

[0164] Speciifc examples of the paraphenylene diamines include N-phenyl-N'-isopropyl-p-phenylenediamine, N,N'-di-sec-butyl-p-phenylenediamine, N-phenyl-N-sec-butyl-p-phenylenediamine, N,N'-di-isopropyl-p-phenylenediamine, and N,N'-dimethyl-N,N'-di-t--butyl-p-phenylenediamine. Examples of the hydroquinones include 2,5-di-t-octylhydroquinone, 2,6-didodecylhydroquinone, 2-dodecylhydroquinone, 2-dodecyl-5-chloiohydroquinone, 2-t-octyl-5-methylhydroquinone, and 2-(2-octadecenyl)-5-methylhydroquinone,

[0165] Specific examples of the organic sulfur compounds include dilauryl-3, 3'-thiodipropionate, distearyl-3,3'-thiodipropionate, and ditetradecyl-3,3'-thiodipropionate.

[0166] Specific examples of the organic phosphorous compounds include triphenylphosphine, tri(nonylphenyl)phosphine, tri(dinonylphenyl)phosphine, tricresylphosphine, and tri(2,4-dibutylphenoxy)phosphine.

[0167] These compounds are known as antioxidizing agents for rubbers, plastics, and oils, and commercial products thereof are readily available.

[0168] The addition amount of the antioxidizing agent is preferably 0.01 to 10 parts by weight based on the total weight of the layer to which the antioxidizing agent is added.

[0169] The image forming apparatus and the process cartridge of the present invention will be described in detail with reference to the accompanying drawings.

[0170] The image forming apparatus of the present invention includes an image bearing member having the cross-linked surface layer described above and performs charging and irradiating the image bearing member to form a latent electrostatic image, developing the latetnt image with a developer, transferring the developed image to a transfer (recording) medium, fixing the transferred image and cleaning the surface of the image bearing member.

[0171] The image forming apparatus in which a latent electrostatic image is directly transferred to a transfer body before development does not necessarily have the above-mentioned processes.

[0172] Fig. 1 is a schematic diagram illustrating an example of the image forming apparatus. The image forming apparatus uses a charging device 3 to uniformly charge an image bearing member 1. Known charging systems can be used. For example, a corotron device, a scorotron device, a solid discharging element, a needle electrode device, a roller charging device and a conductive brush device can be used as the charging device. An image irradiation device 5 is used to form a latent electrostatic image on the uniformly charged image bearing member 1 has a light source (i.e., a light-emitting unit), for example, fluorescent light, tungsten lamp, halogen lamp, mercury lamp, sodium lamp, light-emitting diode (LED), semiconductor laser (LD), and electroluminescence (EL). To irradiate an image bearing member with only a light having a desired wavelength range, it is possible to use various filters, for example, sharp-cut filters, band pass filters, near-infrared cut filters, dichroic filters, interference filters, and color conversion filters.

[0173] A developing unit 6 is used for visualizing the latent electrostatic image formed on the image bearing member 1. As the developing method, there are a one component developing method and a two component development method using a dry toner, and a wet-developing method using a wet toner. When an image bearing member is positively (or negatively) charged and irradiated, a positive (or negative) latent electrostatic image is formed on the image bearing member. When the latent electrostatic image is developed with a negatively (or positively) charged toner (volt-detecting fine particles), a positive image is formed, When the latent electrostatic image is developed using a positively (or negatively) charged toner, a negative image is formed.

[0174] A transfer charging device 10 is used for transferring a toner image visualized on the image bearing member 1 to a transfer body 9. To more preferably performing the transferring, apre-transfer charging device 7 can be used. It is possible to use an electrostatic transfer method using a transfer charging device or a bias roller; a mechanical transfer method, for example, an adhesion trasnfer method or a pressure trasnfer method; and a magnetic trasnfer method. In the electrostatic trasnfer method, the charging device mentioned above can be used.

[0175] A separation charging device 11 and a separation pawl 12 are used to separate the transfer body 9 from the image bearing member 1. The charging device mentioned above can be used as the separation charing device 11. There are other separation methods, for example, electrostatic absorption inducing separation, side edge belt separation, front edge grip conveyance and curvature separation.

[0176] A fur brush 14 and/or a cleaning blade 15 are used for cleaning a toner remaining on the image bearing member 1 after transfer. A pre-cleaning charging device 13 can be used for efficiently performing cleaning. For the other cleaning methods, there are web methods and magnet brush methods. These methods can be employed alone or in combination.

[0177] A discharging unit can be optionally used for removing a latent image on the image bearing member 1. As the discharging unit, a discharging lamp 2 or a discaring device can be used. The irradiation light source and the charging device mentioned above can be used.

[0178] In addition, for processes that are performed not in the vicinity of the image bearing member 1, i.e., reading an original, sheet-feeding, fixing, paper-discharing, known devices and methods in the art can be used.

[0179] The image forming method and the image forming apparatus of the present invention use the image bearing member of the present invention in the image formation unit described above.

[0180] The image formation unit may be fixed in and incorporated into copiers, facsimiles, and printers, or may be detachably incorporated into these devices in a form of a process cartridge. Fig. 2 is a diagram illustrating an example of the process cartridges.

[0181] A process cartridge for use in an image forming apparatus is a device (or component) that integrates an image bearing member 101 therein, includes at least one device selected from a charging device 102, a developing device 104, a transfer device 106, a cleaning device 107 and a discharging device (not shown) and is detachably mounted to the body of an image forming apparatus.

[0182] The image forming process using the device exemplified in Fig. 2 will be described. While the image bearing member 101 rotates in the direction indicated by the arrow, a latent electrostatic image corresponding to the exposed image is formed on the surface of the image bearing member 101 through charging and irradiating the surface thereof by a charging device 102 an irradiating device 103. This latent electrostatic image is developed with a toner by the developing device 104, and the toner image is transferred to a transferring body 105 by a transfer device 106. The surface of the image bearing member 101 after the image transfer is cleaned by the cleaning device 107 and discharged by a discharging device (not shown) to be ready for the next cycle.

[0183] The compound having a charge transport structure in the present invention can be synthesized by a method described, for example, in Japanese Patent No. 3164426. An example of the synthesizing method will be described below,

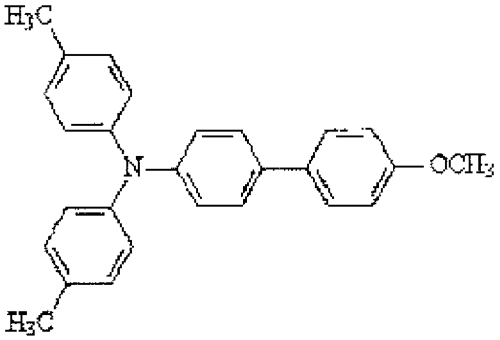
(1) Synthesis of Hydroxy Group-Substituted Triarylamine Compound (Chemical Structure B)

[0184] 240 ml of sulfolane is added to 113.85 g (0.3 mole) of a methoxy group-substituted triarylamine compound (represented by the following chemical structure 1), and 138 g (0.92 mole) of sodium iodide. The resultant is heated to 60° C in nitrogen gas stream. 99 g (0.91 mole) of trimethylchlorosilane is dropped to the resultant solution in one hour. Thereafter, the solution is stirred for 4.5 hours at around 60° C and the reaction is terminated. To the reaction liquid, approximately 1,500 ml of toluene is added, and the reaction liquid is cooled down to the room temperature followed by repetitive washing with water and a sodium carbonate aqueous solution. Then, the solvent is removed from the toluene solution, and the solution is purified by column chromatography (absorption medium: silica gel; developing solvent: toluene:ethyl acetate = 20:1). Cyclohexane is added to the obtained cream-colored oil to precipitate crystal. 88.1 g (yield=80.4%) of white-color crystal represented by the following chemical strcuture 2 is thus obtained.
Melting point: 64.0° C. to 66.0° C.
Element analytical value: (%)

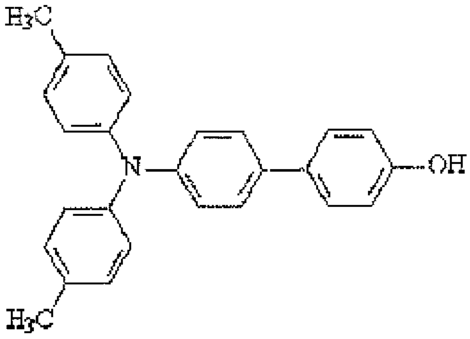
Table 1

	C	H	N
Measured value	85.06	6.41	3.73
Calculated value	85.44	6.34	3.83

Chemical structure 1



Chemical structure 2



(2) Synthesis of Triarylamine Group-Substituted Acrylate Compound

[0185] 82.9 g (0.227 mole) of the hydroxy group-substituted triarylamine compound obtained in the (1) (Chemical structure B) is dissolved in 400 ml of tetrahydrofuran, and a sodium hydroxide solution (NaOH: 12.4 g, water: 100 ml) is dropped into the dissolved solution in nitrogen gas stream. The solution is cooled down to 5° C., and 25.2 g (0.272 mole) of acrylic acid chloride is dropped thereto in 40 minutes. Thereafter, the solution is stirred for 3 hours at 5° C, and the reaction is terminated. The reaction liquid is poured to water and extracted using toluene. The extract is repetitively washed with a sodium hydrogen carbonate aqueous solution and water. Thereafter, the solvent is removed from the toluene solution, and the solution is purified by column chromatography (absorption medium: silica gel; developing solvent: toluene) . Then, n-hexane is added to the obtained colorless oil to precipitate crystal. 80.73g (yield constant: 84.8%) of white-color crystal of Compound Example No. 1 illustrated above is obtained.
Melting point: 117.5° C. to 119.0° C.
Element analytical value: (%)

Table 2

	C	H	N
Measured value	83.13	6.01	3.16
Calculated value	83.02	6.00	3.33

(3) Synthesis of Acrylic Acid Ester Compound

(Preparation of 2-hydroxybenzyl diethylphosphonate)

[0186] 38.4 g of 2-hydroxybenzyl alcohol (manufactured by Tokyo Kasei Co., Ltd.), and 80 ml of o-xylene are placed in a reaction container equipped with a stirrer, a thermometer, and a dropping funnel. 62.8 g of triethyl phosphite (manufactured by Tokyo Kasei Co., Ltd.) is slowly dropped into the solution at 80° C in nitrogen gas stream, and the reaction is further conducted at the same temperature for 1 hour. Thereafter, generated ethanol, solvent of o-xylene, and unreacted trimethyl phosphite are removed from the solution by reduced-pressure distillation. 66 g of 2-hydroxybenzyl diethylphosphonate (boiling point: 120.0° C/1.5 mmHg) (yield constant: 90%) is thus obtained. (Preparation of 2-hydroxy-4'-(N,N-bis(4-methylphenyl)amino) stilbene)

[0187] 14.8 g of potassium-tert-buthoxide, and 50 ml of tetrahydrofuran are placed in a reaction container equipped with a stirrer, a thermometer and a dropping funnel. A solution in which 9.90 g of 2-hydroxybenzyl diethylphosphonate and 5.44 g of 4-(N,N-bis(4-methylphenyl)amino)benzaldehyde are dissolved in tetrahydrofuran, is slowly dropped in the reaction vessel at the room temperature in nitrogen gas stream, and then the reaction is condcuted at the same temperature for 2 hours. Thereafter, water is added to the solution while water-cooling the solution. 2 normal hydrochloric acid aqueous solution is added to the solution to acidify the solution. Tetrahydrofuran is removed from the acidified solution using an evaporator and the resultant coarse product is extracted with toluene. The toluene phase is washed with water, a sodium acid carbonate aqueous solution, and saturated saline in this order and magnesium sulfate is added thereto for dehydration. After filtration, toluene is removed to obtain an oil-like coarse product. The coarse product is further purified by column chromatography with silica gel and precipitated in hexane to obtain 5.09 g of 2-hydroxy-4'-(N, N-bis(4-methylph.enyl)amino)stilbene(yield constant: 72%; melting point: 136.0° C. to 138,0° C),

(Preparation of 4'-(N,N-bis(4--methylphenyl)amino) stilbene-2-yl-acrylate)

[0188] 14.9 g of 2-hydroxy-4'-(N,N-bis(4-methylphenyl) amino)stilbene, 100 ml of tetrahydrofuran and 21.5 g of a 12% concentration sodium hydroxide aqueous solution are poured in a reaction container equipped with a stirrer, a thermometer, and a dropping funnel. 5.17 g of acrylic acid chloride is dropped in the solution at 5° C in 30 minutes in nitrogen gas stream. Thereafter, the reaction is performed at the same temperature for 3 hours. The reaction liquid is poured into water, and extracted using toluene. The extract is condensed, and the condensate is purified by column chromatography with silica gel. The obtained coarse product is re-crystallized using ethanol and 13.5 of yellow needle-like crystal of 4'-(N, N-bis(4-methylphenyl)amino) stilbene-2-ylacrylate (Compound Example No. 2 illustrated above) (yield constant: 79.8%; melting point 104,1° C to 105.2° C) is obtained.

[0189] The result of the element analysis is shown below. Element analytical value: (%)

Table 3

	C	H	N
Measured value	83.06	6.06	3.18
Calculated value	83.57	6.11	3.14

[0190] As described above, by reacting 2-hydroxybenzyl phosphorous acid ester derivative with various amino-substituted benzaldehyde derivatives, it is possible to synthesize a number of 2-hydroxystilbene derivatives. Furthermore, acrylating or methacrylating the 2-hydroxystilbene derivatives, various kinds of acrylic acid ester compounds can be synthesized.

[0191] Having generally described preferred embodiments of this invention, further understanding can be obtained by reference to certain specific examples which are provided herein for the purpose of illustration only and are not intended to be limiting. In the descriptions in the following examples, the numbers represent weight ratios in parts, unless otherwise specified.

EXAMPLES

EXAMPLE 1

Preparation of Image bearing member

[0192] To the surface of an aluminum cylinder having a diameter of 30 mm, the liquid composition for an undercoat layer, the liquid composition for a charge generating layer and a liquid composition for a charge transport layer of the following composition, are sequentially applied and dried to from an undercoat layer having a thickness of 3.5 μm, a charge generating layer having a thickness of 0.2 μm, and a charge transport layer having a thickness of 18 μm.

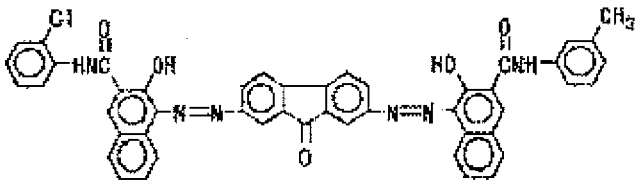
Liquid composition for Undercoat Layer

· Alkyd resin (Beckozole 1307-60-EL, available from Dainippon Ink and Chemicals, Inc.)	6 parts
· Melamine resin (Super- beckamine, available from Dainippon Ink and Chemicals, Inc.)	4 parts
· Titanium oxide	40 parts
· Methylethylketone	50 parts

Liquid composition for Charge generating Layer

Bis-azopigment represented by the following chemical structure (3)	2.5 parts
· Polyvinylbutyral (XYHL, manufactured by Union Carbide Corp.)	0.5 parts
· Cyclohexanon	200 parts
· Methylethylketone	80 parts

Chemical structure (3)



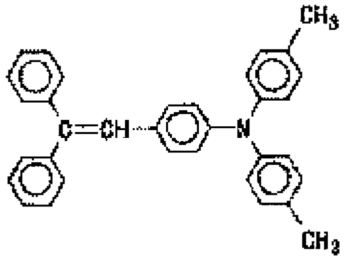
Liquid composition for Charge transport Layer

· Bisphenol Z polycarbonate (Panlight TS-2050, manufactured by Teijin Chemicals, Ltd.)	10 parts

(continued)

Liquid composition for Charge transport Layer	
· Low-molecular charge transport material represented by the following chemical structure (4) · Tetrahydrofuran	7 parts 100 parts
· Tetrahydrofuran solution of 1% silicone oil (KF50-100 manufactured by Shin-Etsu Chemical Co., Ltd.)	CS, 1 part

Chemical structure (4)



[0193] Next, the liquid composition for a surface layer having the following composition is applied to the surface of the laminate structure having the substrate, the undercoat layer, the charge generating layer, and the charge transport layer. The surface of the laminate structure is irradiated with a UV lamp system (V bulb; manufactured by Fusion Corp.) under the following conditions: lamp output: 200 W/cm; luminous intensity: 450 mW/cm2; and irradiation time: 120 seconds to conduct cross-linking reaction. Thus, a surface cured film having a thickness of 5.2 μm is obtained. Thereafter, the surface layer is dried at 130° C for 30 minutes to thereby obtain an image bearing member having the conductive substrate, the undercoat layer, the charge generating layer, the charge transport layer and the surface layer. As seen in the the light emission wavelength of the V bulb illustrated in Fig. 3, the maximum peak wavelength is 400 nm or higher.

Liquid composition for Surface Layer	
Monomer having at least three radical polymerizable functional groups without a charge transport structure Trimethylolpropantriacrylate (KAYARAD TMPTA, manufactured by Nippon Kayaku Co., Ltd.) Molecular weight: 296, Number of functional groups: trifunctional, Molecular weight/Number of functional groups = 99	10 parts
· Radical polymerizable compound having a monofunctional charge transport structure (Compound Example No. 4 illustrated above) Absorption end wavelength 360 nm	10 parts
· Photo-polymerization initiator bis (cyclopentadienyl) -bis(2,6-difluoro-3-(pyrrole-1-yl)phenyl)titanium (IRGACURE 784, manufactured by Chiba Specialty Chemicals K.K.) Absorption end wavelength 549 nm	
	1 part
Tetrahydrofuran	100 parts

EXAMPLE 2

[0194] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having a radical polymerizable functional group with a charge transport structure of Example 1 is changed to the monomer having the following structure.

Monomer having a radical polymerizable functional group with a charge transport structure (Triarylamine Compound Example No. 1) Absorption end wavelength: 369 nm	10 parts

EXAMPLE 3

[0195] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having a radical polymerizable functional group with a charge transport structure of Example 1 is changed to the monomer having the following structure.

Monomer having a radical polymerizable functional group with a charge transport structure (Triarylamine Compound Example No. 13) Absorption end wavelength: 397 nm	10 parts

EXAMPLE 4

[0196] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having a radical polymerizable functional group with a charge transport structure of Example 1 is changed to the monomer having the following structure.

· Monomer having a radical polymerizable functional group with a charge transport structure (Triarylamine Compound Example No. 8) Absorption end wavelength: 423 nm	10 parts

EXAMPLE 5

[0197] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having a radical polymerizable functional group with a charge transport structure of Example 1 is changed to the monomer having the following structure.

Monomer having a radical polymerizable functional group with a charge transport structure (Triarylamine Compound Example No. 21) Absorption end wavelength: 439 nm	10 parts

EXAMPLE 6

[0198] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having a radical polymerizable functional group with a charge transport structure of Example 1 is changed to the monomer having the following structure.

· Monomer having a radical polymerizable functional group with a charge transport structure (Triarylamine Compound Example No. 24) Absorption end wavelength: 471 nm	10 parts

EXAMPLE 7

[0199] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having a radical polymerizable functional group with a charge transport structure of Example 1 is changed to the monomer having the following structure.

· Monomer having a radical polymerizable functional group with a charge transport structure (Triarylamine Compound Example No. 22) Absorption end wavelength: 467 nm	10 parts

EXAMPLE 8

[0200] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having at least three radical polymerizable functional groups without a charge transport structure contained in the cross-linked surface layer of Example 1 is changed to the following monomer.

· Monomer having at least three radical polymerizable functional groups without a charge transport structure Dipentaerythritol hexaacrylate (KAYARAD DPHA, manufactured by Nippon Kayaku Co., Ltd.) Average molecular weight: 536, Number of functional groups: 5.5	10 parts

EXAMPLE 9

[0201] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having a radical polymerizable functional group with a charge transport structure of Example 1 is changed to the monomer having the following structure, and the lamp is changed to a lamp (H bulb, manufactured by Fusion Corp.) having the following light emission wavelength to cure the surface layer.

· Monomer having a radical polymerizable functional group with a charge transport structure (Triarylamine Compound Example No. 1) Absorption end wavelength: 369 nm	10 parts
Bulb Light emission wavelength (illustratred in Fig. 4)	

EXAMPLE 10

[0202] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having a radical polymerizable functional group with a charge transport structure of Example 1 is changed to the monomer having the following structure, and the lamp is changed to a lamp (H bulb, manufactured by Fusion Corp.) having the following light emission wavelength to cure the surface layer.

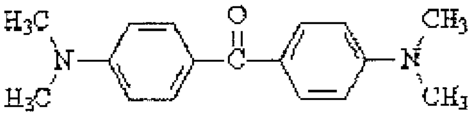
· Monomer having a radical polymerizable functional group with a charge transport structure (Triarylamine Compound Example No.. 8) Absorption end wavelength: 423 nm	10 parts
· Bulb Light emission wavelength (illustratred in Fig. 4)	

COMPARATIVE EXAMPLE 1

[0203] An image bearing member is prepared in the same manner as in Example 2 except that the photo-polymerization initiator of Example 2 is changed to a compound represented by the following chemical structure (5).

Photo-polymerization initiator 4,4'-bis(dimethylamino) benzophenone (Michler's ketone, manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD.) Absorption end wavelength 398 nm	0.6 parts

Chemical Structure (5)



COMPARATIVE EXAMPLE 2

[0204] An image bearing member is prepared in the same manner as in Example 3 except that the photo-polymerization initiator of Example 3 is changed to the compound represented by the chemical structure 5 illustrated above.

· Photo-polymerization initiator 4,4'-bis(dimethylamino) benzophenone (Michler's ketone, manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD.)	0.6 parts

COMPARATIVE EXAMPLE 3

[0205] An image bearing member is prepared in the same manner as in Example 4 except that the photo-polymerization initiator of Example 3 is changed to the compound represented by the chemical structure 5 illustrated above.

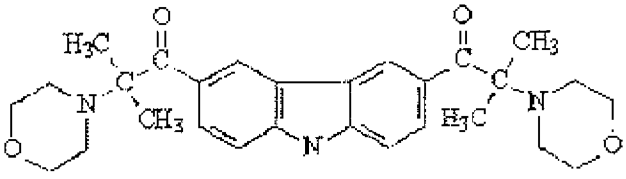
· Photo-polymerization initiator 4,4'-bis(dimethylamino) benzophenone (Michler's ketone manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD.)	0.6 parts

COMPARATIVE EXAMPLE 4

[0206] An image bearing member is prepared in the same manner as in Example 2 except that the photo-polymerization initiator of Example 2 is changed to a compound represented by the following chemical structure (6).

· Photo-polymerization initiator Carbazole-phenone initiator (Adecaoptomer N-1414, manufactured by Asahi Denka Co., Ltd.) Absorption end wavelength 370 nm	0.6 parts

Chemical Structure (6)



COMPARATIVE EXAMPLE 5

[0207] An image bearing member is prepared in the same manner as in Example 3 except that the photo-polymerization initiator of Example 3 is changed to a compound having the chemical structure 6 illustrated above,

[0208] Carbazole-phenone initiator (Adecaoptomer N-1414, manufactured by Asahi Denka Co., Ltd.)

COMPARATIVE EXAMPLE 6

[0209] An image bearing member is prepared in the same manner as in. Example 4 except that the photo-polymerization initiator of Example 3 is changed to a compound having the chemical structure 6 illustrated above.

Carbazole-phenone initiator (Adecaoptomer N-1414, manufactured by Asahi Denka Co., Ltd.)	0.6 parts

COMPARATIVE EXAMPLE 7

[0210] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having a radical polymerizable functional group with a charge transport structure of Example 1 is changed to the monomer having the following structure.

· Monomer having a radical polymerizable functional group with a charge transport structure (Triarylamine Compound Example No. 33) Absorption end wavelength: 527 nm	10 parts

COMPARATIVE EXAMPLE 8

[0211] An image bearing member is prepared in the same manner as in COMPARATIVE Example 7 except that the photo- polymerization initiator of Comparative Example 7 is changed to a compound represented by the chemical structure 5.

· Photo-polymezization initiator 4,4'-bis(dimethylamino) benzophenone (Michler's ketone, manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD.)	0.6 parts

COMPARATIVE EXAMPLE 9

[0212] An image bearing member is prepared in the same manner as in Comparative Example 7 except that the photo-polymerization initiator of Comparative Example 7 is changed to a compound represented by the chemical structure 6.

Photo-polymerization initiator Carbazole-phenone initiator (AdecaoptomerN-1414, manufactured by Asahi Denka Co., Ltd.)	0.6 parts

COMPARATIVE EXAMPLE 10

[0213] An image bearing member was prepared in the same manner as in Example 10 except that the photo-polymerization initiator of Example 10 was changed to a compound represented by the chemical structure 5.

Photo-polymerization initiator 4,4'-bis(dimethylamino) benzophenone (Michler's ketone, manufactured by TOKYO CHEMICAL INDUSTRY CO., LTD.)	0.6 parts

COMPARATIVE EXAMPLE 11

[0214] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having at least three radical polymerizable functional groups without a charge transport structure contained in the liquid composition for the cross-linked surface layer of Example 1 is changed to 10 parts of the following monomer having two radical polymerizable functional groups with no charge transport structure.

· Monomer having two radical polymerizable functional groups with no charge transport structure 1,6-hexanedioldiacrylate (Molecular mass: 226, Number of functional groups: bifunctional, manufactured by Wako Pure Chemical Industries, Ltd.)	10 parts

COMPARATIVE EXAMPLE 12

[0215] An image bearing member is prepared in the same manner as in Example 1 except that the monomer having at least three radical polymerizable functional groups without a charge transport structure of the composition used for the liquid composition for the cross-linked surface layer of Example 1 is excluded and the content of the monomer having a radical polymerizable functional group with a charge transport structure is changed to 20 parts.

COMPARATIVE EXAMPLE 13

[0216] An image bearing member is prepared in the same manner as in Example 1 except that the radical polymerizable compound having a charge transport structure of the composition used for the liquid composition for the cross-linked surface layer of Example 1 is excluded and the content of the monomer having at least three radical polymerizable functional groups without a charge transport structure is changed to 20 parts.

COMPARATIVE EXAMPLE 14

[0217] An image bearing member is prepared in the same manner as in Example 1 except that the radical polymerizable compound having a charge transport structure of the composition used for the liquid composition for the cross-linked surface layer of Example 1 is excluded and 10 parts of a low-molecular charge transport material represented by the chemical structure 4 used for the liquid composition for charge transport layer is contained.

Table 4

	Initiator	Charge transport material	Absorption end wavelength		Light source maximum emission wavelength
			Initiator	Charge transport material	
Ex. 1	titanocene	NO. 4	549 nm	360 nm	410 nm

(continued)

	Initiator	Charge transport material	Absorption end wavelength		Light source maximum emission wavelength
			Initiator	Charge transport material	
Ex. 2	titanocene	NO. 1	549 nm	369 nm	410 nm
Ex.. 3	titanocene	NO. 13	549 nm	397 nm	410 nm
Ex. 4	titanocene	NO. 8	549 nm	423 nm	410 nm
Ex. 5	titanocene	NO. 21	549 nm	439 nm	410 nm
Ex. 6	titanocene	NO. 24	549 nm	471 nm	410 nm
Ex. 7	titanocene	NO. 22	549 nm	467 nm	410 nm
Ex. 8	titanocene	NO. 4	549 nm	360 nm	410 nm
Ex. 9	titanocene	NO. 1	549 nm	369 nm	360 nm
Ex. 10	titanocene	NO. 8	549 nm	423 nm	360 nm
Com. 1	Michler's ketone	NO. 1	398 nm	369 nm	410 nm
Com. 2	Michler's ketone	NO. 13	398 nm	397 nm	410 nm
Com. 3	Michler's ketone	NO. 8	398 nm	423 nm	410 nm
Com. 4	carbazole- phenone	NO. 1	370 nm	369 nm	410 nm
Com. 5	carbazole- phenone	NO. 13	370 nm	397 nm	410 nm
Com. 6	carbazole- phenone	NO. 8	370 nm	423 run	410 nm
Com. 7	titanocene	NO. 33	549 nm	527 nm	410 nm
Com. 8	Michler's ketone	NO. 33	393 nm	527 nm	410 nm
Com. 9	carbazole- phenone	NO. 33	361 nm	527 nm	410 nm
Com. 10	Michler's ketone	NO. 8	393 nm	423 nm	360 nm
Com. 11	titanocene	NO. 4	549 nm	360 nm	410 nm
Com. 12	titanocene	NO.4	549 nm	360 nm	410 nm
Com. 13	titanocene	NO. 4	549 nm	360 nm	410 nm
Com. 14	titanocene	NO. 4	549 nm	360 nm	410 nm

Surface Smoothness Test

[0218] As the evaluationmethodof the surface smoothness of the obtained image bearing members, the surface of the image bearing members are evaluated as to the surface roughness Rz (10 point average roughness, accordingtoJISB0601-1994 standards) relative to the evaluation length of 2.5 mm and the standard length of 0.5 mm, using SURFCOM 1400D (manufactured by TOKYOSEIMITSU CO., LTD.). 12 points are measured which are 2 points at 50 mm from both ends of the drum in the axial direction thereof and 1 point at the drum and these 3 points are measured at 90 degrees in the circumferential direction of the drum. Then, the average value is defined as the surface roughness Rz of the drum. Curability Test

[0219] As an indicator of the curing progress of a cross-linked surface layer, a solubility test is performed to the organic solvent. A drop of tetrahydrofuran (THF) is dropped to the surface of the image bearing member. Subsequent to natural dry, the change in the surface form is visually checked. The portion of the surface that is not cured is partially dissolved, resulting in ring-shaped irregularities and tarnish.

Durability Test

[0220] Durability is performed as follows: Select and abrade a portion of the cross-linked surface layer of the image bearing member with 10 cm wide in the axial direction thereof and about 1.5 μm deep using a wrapping film (manufactured by Sumitomo 3M Ltd.) having a surface roughness of 0.3 μm; Incorporate the image bearing member into a process cartridge for an image forming apaprtus; Incorporate the process cartridge into a machine remodled based on Imagio MF 2200 (manufactured by Ricoh Company Ltd.) utilizing a semiconductor laser having a wavelength of 655 nm as the light source; Set the initial umbra potential to -700V at the portion of the cross-linked surface layer that are not abraded with the wrapping film; Perform a run test of 50,000 A4 sheets while measuring the layer thickness of the abraded portion and evaluating the image at the initial stage and 10,000th, 30,000th, and 50,000th sheet; and Measure the potential of the non-irradiated (umbra) and the irradiated portion at the position measured for the initial umbra potential as the electric characteristis when the run test is finished.

[0221] The layer thickness of the image bearing member is measured using an eddy-current thickness measuring device (manufactured by Fisher Instrument Company).

Table 5

	Initial surface roughness Rz (μm)	Curing test
Example 1	0.20	insoluble
Example 2	0.22	insoluble
Example 3	0.23	insoluble
Example 4	0.21	insoluble
Example 5	0.24	insoluble
Example 6	0.24	insoluble
Example 7	0.23	insoluble
Example 8	0.26	insoluble
Example 9	0.30	insoluble
Example 10	0.29	insoluble
Comparative Example 1	0.21	insoluble
Comparative Example 2	0.22	insoluble
Comparative Example 3	0.20	soluble
Comparative Example 4	0.24	insoluble
Comparative Example 5	0.22	soluble
Comparative Example 6	0.27	soluble
Comparative Example 7	0.20	insoluble
Comparative Example 8	0.25	soluble
Comparative Example 9	0.23	soluble
Comparative Example 10	0.21	soluble
Comparative Example 11	0.51	soluble
Comparative Example 12	Not curable	
Comparative Example 13	1.35	insoluble
Comparative Example 14	0.23	soluble

[0222] As seen in the evaluation results shown in Table 5, the image bearing members of Examples 1 to 10 of the present invention have excellent surface smoothness. In addition, any of the surface layers of these image bearing members are insoluble to the organic solvent.. Meaning that the surfaces of the image bearing members are sufficiently cured.. In contrast, the image bearing member of Comparative Example 11 using the bifunctional monomer for the cross-linked surface layer, and the image bearing member of Comparative Example 13 using only the monomer having at least three radical polymerizable functional groups without a charge transport structure for the cross-linked surface layer have extremely bad surface smoothness. For the image bearing members of Comparative Examples 3, 5, 6, 8 and 9, the absorption end wavelength of the monomer having a radical polymerizable functional group with a charge transport structure is on a longer wavelength side than that of the photo-radical polymerization initiator. Therefore, judging from the results, it is difficult to efficiently generate radicals so that the surface layers are thought to be insufficiently cross-linked. With regard to the image bearing member of Comparative Example 10, the maximum emission wavelength of the used light source is shorter than that of the used charge transport material. Thus, this also leads to poor curing due to the inefficient radical generation.

[0223] Next, the durability is tested as to the image bearing members of Examples 1 to 10 and Comparative Examples 1 to 11 and 13 to 14. The results are shown in Table 6.

Table 6

	Abraded amount			Initial surface voltage (-V)		Surface voltage when run test complete (-V)	
	10,000th	30,000th	50,000th	Umbra	Irradiated	Umbra	Irradiated
Ex. 1	0.19	0.39	0.63	700	75	680	80
Ex. 2	0.22	0.42	0.61	700	70	675	75
Ex. 3	0.23	0.47	0.70	700	60	675	65
Ex. 4	0.20	0.44	0.62	700	65	690	70
Ex. 5	0.21	0.38	0.65	700	70	680	70
Ex. 6	0.15	0.35	0.59	700	65	680	65
Ex. 7	0.22	0.41	0.61	700	65	690	65
Ex. 8	0.25	0.44	0.72	700	80	680	85
Ex. 9	0.23	0.40	0.69	700	80	675	90
Ex. 10	0.19	0.46	0.66	700	75	690	85
Com. 1	Image densitiy from the beginning. Run test cancelled.			700	250	-	-
Com. 2	Image densitiy from the beginning. Run test cancelled.			700	265	-	-
Com. 3	Image densitiy from the beginning. Run test cancelled.			700	260	-	-
Com 4	0.42	1.23	3.12	700	100	670	185
Com. 5	0.55	1.92	5.18	700	120	690	170
Com. 6	0.80	3.12	8.01	700	95	690	155
Com. 7	0.29	0.56	1.99	700	75	670	125
Com. 8	Image densitiy from the beginning. Run test cancelled.			700	280	-	-
Com. 9	1.02	4.11	9.21	700	85	670	75
Com. 10	Image densitiy from the beginning. Run test cancelled.			700	310	-	-
Com. 11	0.81	1.65	2.64	700	70	680	110
Com. 13	Image densitiy from the beginning. Run test cancelled.			700	250	-	-
Com. 14	1.29	2.62	4.88	700	85	660	75

[0224] As seen in the results shown in Table 6, the image bearing members of Examples 1 to 10 of the present invention have a low potential at irradiated portions and excellent electric property at the initial stage and around 50,000th sheet in the durability test.

[0225] In contrast, for the image bearing members of Comparative Examples 1 to 3, 8, and 10 using a photo-polymerization initiator having a long wavelength other than titanocene derivatives, and the image bearing member of Comparative Example 13 using a cross-linked surface layer containing only a radical polymerizable monomer having no charge transport group, the electric properties thereof significantly deteriorate.

[0226] The image bearing members of Examples 1 to 10 have a small thickness reduction, meaning high-durability, in the durability test of 50,000 sheets.

[0227] In contrast, as for the image bearing members of Comparative Examples 4 to 6 using a photo-radical polymerization initiator other than titanocene derivatives for the surface layer, the image bearing members of Comparative Examples 7 and 9 in which the absorption end wavelength of the charge transport material used for the surface layer is longer than that of the photo-radical polymerization initiator, the image bearing member of Comparative Example 11 using a monomer having two functional groups with no charge transport structure, and the image bearing member of Comparative Example 14 containing a low-molecular charge transport material in the surface layer, any of these image bearingmembers has a large amount of abrasion of the surface layer when the run test is finished. With regard to the image bearing members of Comparative Examples 4 to 6, 7 and 9, the abrasion is observed in the middle of the run test, meaning that each surface layer is not uniformly cured to the inside thereof. The evaluation of the image density is shown in Table 7.

Table 7

	Image density			
	Initial	10,000th	30,000th	50,000th
Ex. 1	A	A	A	A
Ex. 2	A	A	A	A
Ex. 3	A	A	A	A
Ex. 4	A	A	A	A
Ex. 5	A	A	A	A
Ex. 6	A	A	A	A
Ex. 7	A	A	A	A
Ex. 8	A	A	A	A
Ex. 9	A	A	A	A
Ex. 10	A	A	A	A
Com. 4	A	A	B	C
Com. 5	A	A	B	C
Com. 6	A	A	C	C
Com. 7	A	B	C	C
Com. 9	A	B	C	C
Com. 11	A	B	C	C
Com. 14	A	B	C	C
Evaluation Criteria A: Excellent B: Slightly low C: Low				

[0228] As seen in Table 7, the image bearing members of Examples 1 to 10 of the present invention produce excellent images having no reduction in image density. In contrast, for the image bearing members of Comparative Examples, the image density decreases.

[0229] Accordingly, it is found that the image bearing member of the present invention has excellent surface smoothness, a low-potential at irradiated portions, high-durability and longer operating life. As described above, the image bearing member uses a monomer having at least three radical polymerizable functional groups without a charge transport structure, a monomer having a radical polymerizable functional group with a charge transport structure, and a titanocene derivative as a photo-radical polymerization initiator, and has the absorption end wavelength in the light absorption spectrum of the monomer having a radical polymerizable functional group with a charge transport structure is 40 nm or more shorter than that of the titanocene derivative. In addition, it is also found that the image forming method, the image forming apparatus, and the process cartridge therefor using the image bearing member of the present invention have high performance and high reliability.

[0230] This document claims prior ity and contains subj ectmatter related to Japanese Patent Application No. 2006-149088 filed on May 30, 2006.

[Effects of the Invention]

[0231] The present invention is an image bearing member including a substrate, a photosensitive layer overlying the substrate, a surface layer overlying the photosensitive layer. The surface layer is formed by applying to the photosensitive layer a liquid composition containing a monomer having at least three radical polymerizable groups without a charge transport structure, a monomer having a radical polymerizable functional group with a charge transport structure and a photo-radical polymerization initiator containing a titanocene derivative and curing the liquid composition with irradiation of light. The monomer having a radical polymerizable functional group with a charge transport structure has an optical absorption spectrum such that an absorption end wavelength thereof is at least 40 nm shorter than an absorption end wavelength of the titanocene derivative. Thereby, the image bearingmember has an excellent abrasion resistance, an excellent smooth surface property, and a low voltage at irradaiated portions for a long period of time.

Claims

1. An image bearing member comprising:

    a substrate;
    a photosensitive layer overlying the substrate;
    a surface layer overlying the photosensitive layer, the surface layer being formed by applying to the photosensitive layer a liquid composition comprising a monomer having at least three radical polymerizable groups without a charge transport structure, a monomer having a radical polymerizable functional group with a charge transport structure and a photo-radical polymerization initiator comprising a titanocene derivative and curing the liquid composition with irradiation of light,
    wherein the monomer having a radical polymerizable functional group with a charge transport structure has an optical absorption spectrum such that an absorption end wavelength thereof is at least 40 nm shorter than an absorption end wavelength of the titanocene derivative.

2. The image bearing member according to Claim 1, wherein the absorption end wavelength in an optical absorption spectrum of the monomer having a radical polymerizable functional group with a charge transport structure is at least 370 nm.

3. The image bearing member according to Claim 1, wherein the absorption end wavelength in an optical absorption spectrum of the monomer having a radical polymerizable functional group with a charge transport structure is at least 400 nm.

4. The image bearing member according to any one of Claims 1 to 3, wherein the monomer having a radical polymerizable functional group with a charge transport structure has one radical polymerizable functional group.

5. The image bearing member according to any one of Claims 1 to 4, wherein a light source having a maximum peak wavelength in a wavelength range of not shorter than 400 nm is used for the irradiation of light.

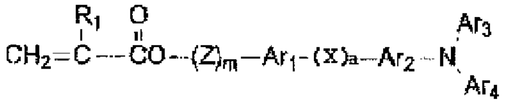
6. The image bearing member according to any one of Claims 1 to 5, wherein the radical polymerizble functional group of the monomer having a radical polymerizable functional group with a charge transport structure is at least one of an acryloyloxy group and a methacryloyloxy group.

7. The image bearing member according to any one of Claims 1 to 6, wherein the radical polymerizable functional groups of the monomer having at least three radical polymerizable functional groups without a charge transport structure are at least one of an acryloyloxy group and a methacryloyloxy group.

8. The image bearing member according to any one of Claims 1 to 7, wherein the ratio (M/F) of the molecular weight (M) of the monomer having at least three radical polymerizable functional groups without a charge transport structure to the number of functional groups (F) thereof is not greater than 250.

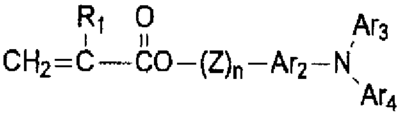
9. The image bearing member according to any one of Claims 1 to 8, wherein a charge transport portion of the monomer having a radical polymerizable functional group with a charge transport structure has a triarylamine structure.

10. The image bearing member according to any one of Claims 1 to 9, wherein the monomer having a radical polymerizable functional group with a charge transport structure is at least one of the following monomers represented by chemical formulae (1) and (2),



$$CH_2=\overset{\overset{R_1}{|}}{C}-\overset{\overset{O}{\|}}{C}O-(Z)_m-Ar_1-(X)_a-Ar_2-N\begin{matrix}Ar_3\\ Ar_4\end{matrix}$$

Chemical formula (1)

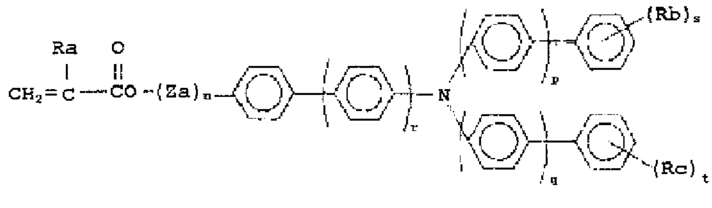


$$CH_2=\overset{\overset{R_1}{|}}{C}-\overset{\overset{O}{\|}}{C}O-(Z)_n-Ar_2-N\begin{matrix}Ar_3\\ Ar_4\end{matrix}$$

Chemical formula (2)

wherein R_1 represents hydrogen atom, a halogen atom, a substituted or non-substituted alkyl group, a substituted or non-substituted aralkyl group, an aryl group, cyano group, nitro group or a substituted or non-substituted alkoxy group, or $-COOR_7$ (R_7 represents hydrogen atom, a substituted or non-substituted alkyl group, a substituted or non-substituted aralkyl group, or a substituted or non-substituted aryl group); a halogenated carbonyl group or $CONR_8R_9$ (R_8 and R_9 independently represent hydrogen atom, a halogen atom, a substituted or non-substituted alkyl group, a substituted or non-substituted aralkyl group, or a substituted or non-substituted aryl group); Ar_1 and Ar_2 independently represent a substituted or unsubstituted arylene group; Ar_3 and Ar_4 independently represent a substituted or unsubstituted aryl group; X represents a substituted or non-substituted alkylene group, a substituted or non-substituted cycloalkylene group, a substituted or non-substituted alkylene ether divalent group, oxygenatom, sulfur atom, or vinylene group; Z represents a substituted or non-substituted alkylene group, a substituted or non-substituted alkylene ether divalent group or an alkyleneoxy carbonyl divalent group; a represents 0 or 1 and m and n independently represent 0 or an integer of from 1 to 3.

11. The image bearing member according to any one of Claims 1 to 10, wherein the monomer having a radical polymerizable functional group with a charge transport structure is the following monomer represented by the following chemical formula (3),



Chemical formula (3)

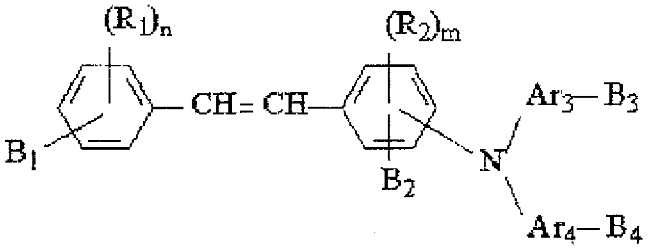
wherein u, r, p, q represent 0 or 1, s and t independently represent. 0 or an integer of from 1 to 3, Ra represents hydrogen atom or methyl group, each of Rb and Rc independently represents an alkyl group having 1 to 6 carbon atoms, and Za represents methylene group, ethylene group, $-CH_2CH_2O-$, $-CHCH_3CH_2O-$, or $-C_6H_5CH_2CH_2-$,

12. The image bearing member according to any one of Claims 1 to 11, wherein the monomer having a radical polymerizable functional group with a charge transport structure is an acrylic acid ester compound represented by the following chemical formula (4):

$$B_1\text{-}Ar_1\text{-}CH{=}CH\text{--}Ar_2\text{-}B_2 \qquad \text{Chemical formula (4)}$$

wherein Ar_1 represents a monovalent or divalent group having a substituted or non-substituted aromatic hydrocarbon skeleton; Ar_2 represents a monovalent or divalent group having an aromatic hydrocarbon skeleton having at least one tertiary amino group, or a monovalent or divalent group having a heterocyclic compound having at least one tertiary amino group; and at least one of B_1 and B_2 is present and independently represents an acryloyloxy group, amethacryloyloxy group, vinyl group, an alkyl group having an acryloyloxy group, a methacryloyloxy group or vinyl group, or an alkoxy group having an acryloyloxy group, a methacryloyloxy group or vinyl group.

13. The image bearing member according to any one of Claims 1 to 12, wherein the monomer having a radical polymerizable functional group with a charge transport structure is represented by the following chemical formula (5):



Chemical formula (5)

wherein R_1 and R_2 independently represent a substituted or non-substituted alkyl group, a substituted or non-substituted alkoxy group, or a halogen atom and n represents 0 or an integer of from 1 to 5 andmrepresents 0 or an integer of from 1 to 4; Ar_3 and Ar_4 independently represent a substituted or non-substituted aryl group or arylene group, or a substituted or non-substituted benzyl group; and B_1, B_2, B_3, and B_4 are the same as defined for B_1 and B_2 in Chemical formula (4) and only one or two of B_1, B_2, B_3 and B_4 simultaneously exist in the monomer .

14. The image bearing member according to any one of Claims 1 to 13, wherein the titanocene derivative is bis(cyclopentadienyl)-bis(2,6-difluoro-3-(pyrrole-1-yl)phenyl)titanium.

15. The image bearing member according to any one of Claims 1 to 14, wherein the photosensitive layer comprises a charge generating layer and a charge transport layer overlying the charge generating layer.

16. An image forming method comprising:

charging the image bearing member of any one of Claims 1 to 15;
forming a latent electrostatic image on a surface of the image bearing member;
developing the latent electrostatic image with a toner to visualize the latent electrostatic image;
transferring the visualized image to a recording medium;
fixing the transferred image on the recording medium; and
cleaning the surface of the image bearing member.

17. A process cartridge comprising:

the image bearing member of any one of Claims 1 to 15;
an optional charging device configured to charge the surface of the image bearing member;
an optional irradiating device configured to irradiate the surface of the image bearing member to form a latent electrostatic image thereon;

an optional developing device configured to develop the latent electrostatic image formed on the image bearing member with a toner; and
an optional transferring unit configured to transfer the visible image to a recording medium; and
an optional cleaning unit configured to clean the surface of the image bearing member,
wherein the process cartridge is detachably attached to a main body of an image forming apparatus.

18. An image forming apparatus comprising:

the process cartridge of Claim 17; and
a fixing device configured to fix the image on the recording medium.

FIG. 1

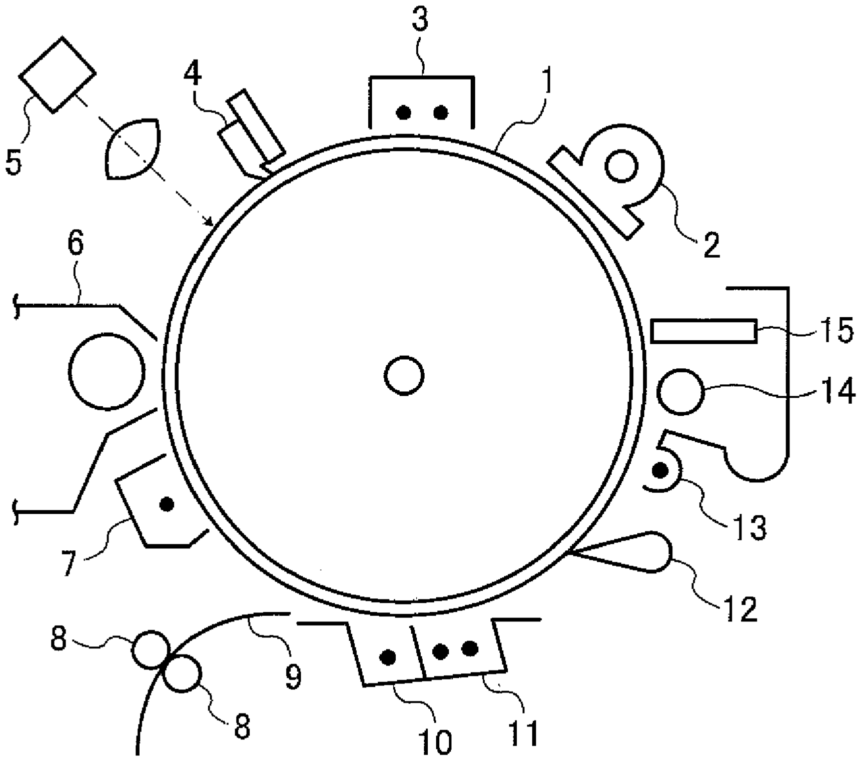


FIG. 2

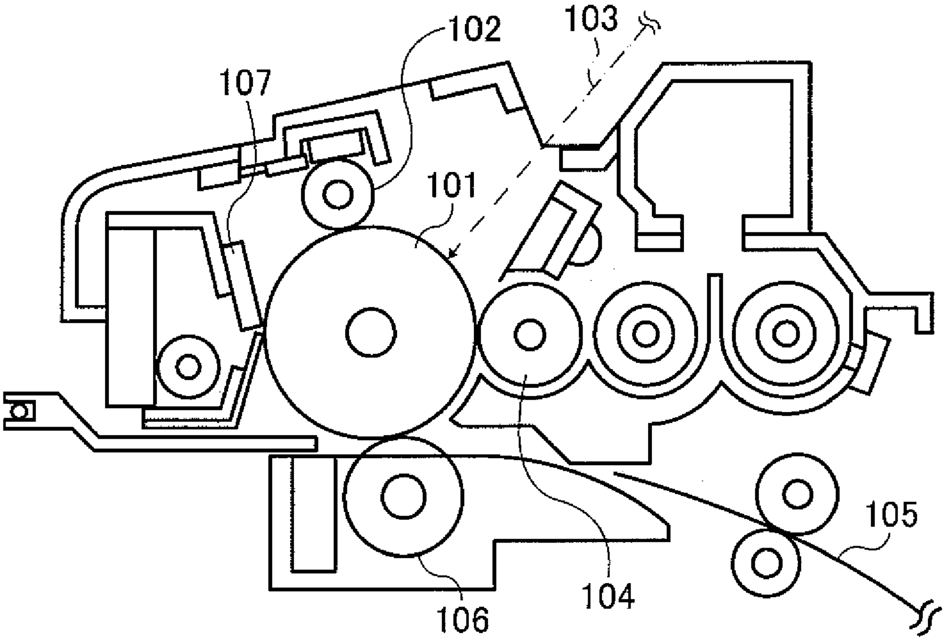


FIG. 3

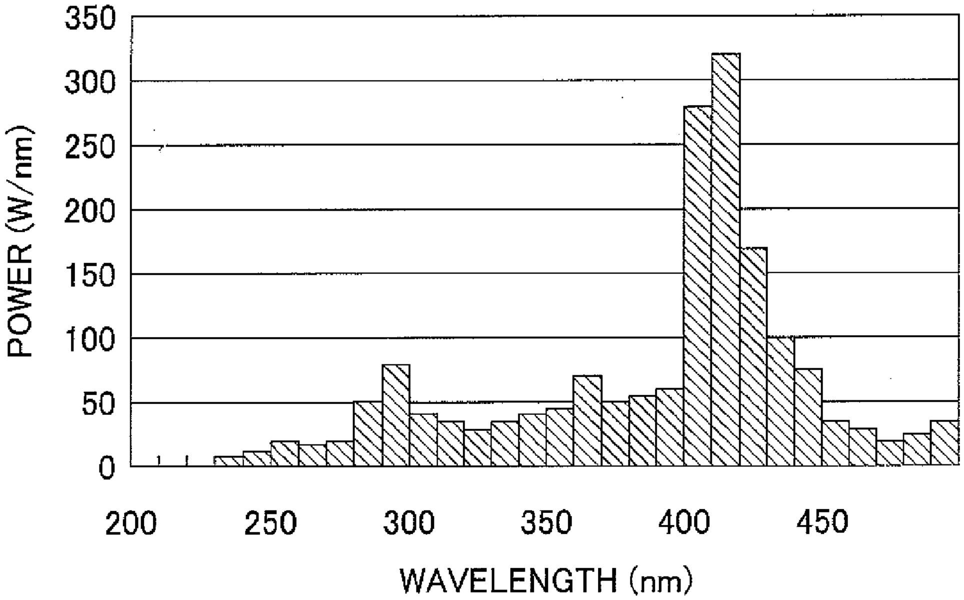
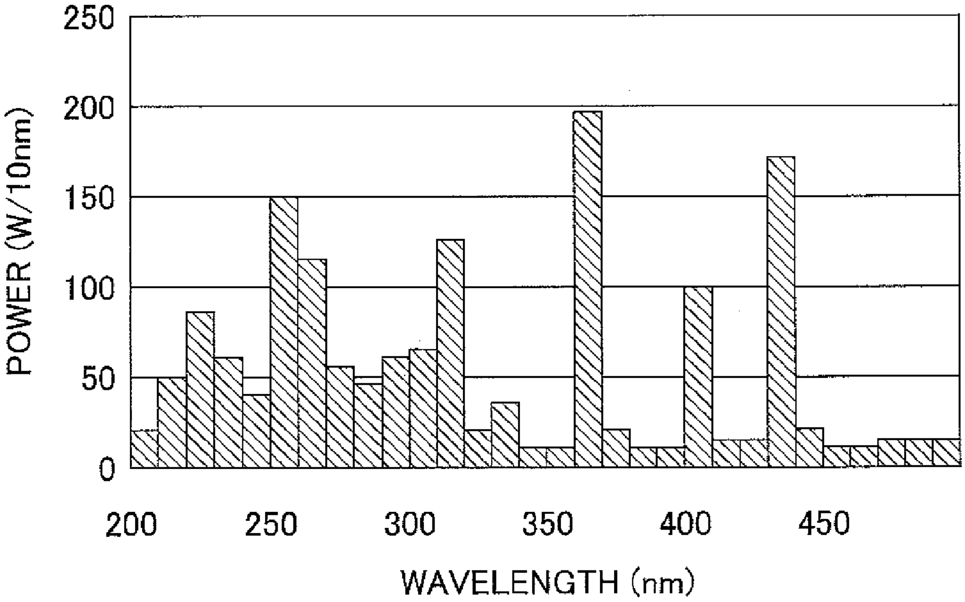

350
300
250
200
150
100
50
0
POWER (W/nm)
200
250
300
350
400
450
WAVELENGTH (nm)

FIG. 4


250
200
150
100
50
0
POWER (W/10nm)
200
250
300
350
400
450
WAVELENGTH (nm)

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EUROPEAN SEARCH REPORT

Application Number
EP 07 10 9124

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	3 September 2007	Weiss, Felix

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