ELECTROPHOTOGRAFIC PROCESS AND APPARATUS

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2 Sheets-Sheet 1
ABSTRACT OF THE DISCLOSURE

A process for forming an electrostatic image in a plate having a photoconductive layer, an insulating overlayer and being characterized in having carrier charge of a polarity corresponding to the conductivity type of the photoconductive layer and bound in the region of the interface between the insulating and photoconductive layer, wherein the insulating layer is initially charged with a charge of opposite polarity in the photoconductive layer, and causing charge migration therein and therethrough to the interface of the insulating and photoconductive layers. The photoconductive layer is next exposed to a pattern of image light while the insulating overlayer is subjected to an electrostatic discharge whereby said interface charge is selectively attenuated to form said electrostatic image. The formed image is intensified in contrast by thereafter exposing the photoconductive layer to radiation.

This is a continuation of U.S. patent application Ser. No. 571,538, filed Aug. 10, 1966, now abandoned.

The present invention relates to electrophotography in general and, in particular, this invention relates to methods and apparatus for forming electrostatic and electrophotographic images.

Known electrophotographic methods include such conventional methods as the Electro Fax system, the Xerox system, the P.I.P. (Persistent Internal Polarization) system and the like. The Electro Fax and Xerox systems form electrostatic images by means of the so-called Carlson process as described in the specification of U.S. Pat. No. 2,297,691. According to these systems, the photoconductive layer of a photosensitive plate comprised of zinc oxide (Electro Fax), or non-crystalline selenium (Xerox) disposed on a base plate, is uniformly charged by corona discharge, and thereafter is irradiated with an original image to impart charge to the illuminated portion to form an electrostatic image in accordance with the light-and-dark pattern of the original image. The electrostatic image is developed by using electrophotographic powder (hereinafter called toner) to form a visual image, and then the said image is fixed (Electro Fax) or transferred onto a support such as paper and thereafter it is fixed (Xerox) to obtain an electrostaticographic image. In accordance with the P.I.P. system, the photosensitive plate comprises a mixture of phosphor and resin disposed on a conductive base plate and is pinched with two electrodes. A voltage is applied to the two electrodes to generate persistent internal polarization charge in the photoconductive layer, and then by irradiating the plate with an original image, an electrostatic image is obtained by persistent internal polarization charge in accordance with the light-and-dark pattern of the original image. Thereafter development and fixing processes are carried out in the same manner as in the above-mentioned cases, and an electrophotographic image is obtained.

In the above-mentioned systems, it is necessary to retain charge directly in the photoconductive layer, and therefore it is required that the material used for forming the said photoconductive layer should be of high resistivity, and for example, be restricted to specific photoconductive materials which can bind charge and which have high resistivity, such as non-crystalline selenium, ZnO+resin, ZnCdS+resin or the like.

Therefore, machines in present practical use have low sensitivity, and in the case of Electro Fax, the sensitivity is below ASA 5 even if acceleration of sensitivity should be carried out by using dyes, and even in the case of Xerox system, or P.I.P. system, the sensitivity is ASA 10 at maximum.

When the above-mentioned photosensitive plate is repeatedly used, scars on the surface, or other deterioration of the surface easily occurs, and the quality of the image deteriorates because of fatigue of the photoconductive material. Thus, such plates cannot withstand repeated use over long periods.

There has been proposed in this method described in the specific charge of opposite polarity of U.S. Pat. No. 3,124,456 according to which a photosensitive plate having a photoconductive layer composed of CdS or CdSe and binder resin on a conductive base is provided with a translucent insulating layer overlaid on the photoconductive layer. Irradiation of the original image and charging are carried out simultaneously from the translucent insulating layer side of the photosensitive plate and the electrostatic image is formed on the translucent insulating layer by making use of the difference of the buildup of the charge due to the difference of time constants caused by the different impedances of the photoconductive layer in the light and dark portions, respectively, of the original image. In accordance with this method, electrostatic image formation depends on the time constant difference brought about by the differences of impedance in the photoconductor and therefore the electrostatic contrast is not high. To obtain an excellent image by means of this method, the capacitance of the translucent insulating layer is lower than the capacitance of the photoconductive layer, and form a practical point of view the thickness of the translucent insulating layer should be restricted within the range from 2 to 6 μm.

Such thin insulating layers break down easily, and it is difficult to use the photosensitive plate over and over again for a long period of time.

Thus, in processes in which electrostatic image formation depends on the charge of impedance of the photoconductive layer, where the thickness of translucent insulating layer is increased, contrast is deteriorated, and image quality is lowered, which are drawbacks.

On the other hand, according to U.S. Pat. No. 3,041,167 issued to R. M. Blakney et al., a photoconductive layer is provided on a conductive base plate, and the photosensitive plate is obtained by protecting the surface thereof with an overcoating layer. In accordance with the Carlson process, an electrostatic image is formed by such electrophotography as mentioned above. However, a reverse charge of opposite polarity to that of the sensitizing charge is applied to the surface of the coating layer of the said photosensitive plate before the said sensitizing charge is carried out. After sensitizing charging, light is uniformly irradiated all over the surface of the coating layer of the said photosensitive plate; this attains at overcoming the fatigue of the photosensitive plate. Photo-carriers produced by the whole surface exposure and having a polarity opposite to that of the charge of the insulating layer are induced at the interface between the insulating layer and the photoconductive layer. Then the sensitizing charge is applied in darkness to the surface of the insulating layer to neutralize the charge to form a surface field.
due to the induced charged layer. Thus the photosensitive plate is sensitized. Next, the light image is exposed to the photosensitive plate to cause the charge on the exposed area to be reversed, thereby sensitizing the photosensitive plate. Therefore it is easy to bring about wear or breakdown or such like troubles and it is impossible to sufficiently protect the photosensitive plate.

In accordance with the present invention, quite different from the above-mentioned process, the translucent insulating layer is charged and by making use of the field thereof, charge is strongly bound on the photosensitive layer and translucent insulating layer and in the neighborhood thereof, and by making use of the external field of the said bound charge, alternating current corona discharge and irradiation of the original image are simultaneously and it is carried out to obtain a clear developed image of the original image due to the difference in surface potential of the translucent insulating layer at the light portion and the dark portion of the original image. Consequently, the electrostatic image is obtained by reversing the said surface potential by irradiating light uniformly all over the surface of the translucent insulating layer. Furthermore, this electrostatic image is remarkably high, and even when a photosensitive layer of a little thinner than or the same thickness as that of U.S. Pat. No. 3,041,167 is used, it is possible to obtain electrostatic charge ranging from 1000 v. to 1500 v., and thus it is possible to use a translucent insulating layer of 10 to 50 thickness. Further, it is possible to form said layer by the adhesion of insulating film without being limited to the method of resin coating, and thereby it is possible to protect the photosensitive layer sufficiently.

In copending U.S. application No. 563,899, filed July 8, 1966, an electrostatic image is formed in a photosensitive plate comprising a base, a photosensitive layer and a translucent insulating layer, by applying a primary charge (assuming positive charge) to the translucent insulating layer, exposing the photosensitive layer to the original image while applying secondary charge (assuming negative charge) to the translucent insulating layer, and thereafter exposing the entire surface of the translucent insulating layer to form thereon an electrostatic image. The electrostatic image is mainly produced at light areas of the original image by the binding of the secondary charge, i.e. negative charge. Therefore, it is necessary, in obtaining a positive-positive visual image, to attach negatively charged toner to the dark area of the photosensitive layer, or to apply positively charged toner to the light area of the original image in order to obtain positive-negative visual image. It follows therefore that when processing an original image having a large area or thick lines, in positive-positive development only the peripheral portions are emphasized and it is difficult to develop a clear developed image in the center portion. Further, as is generally known, in the developing process using "Tribo Charge," Tribo Charge is decreased under high humidity circumstances, and the electric property of the toner is increased by absorption of humidity or attachment of water. Consequently, with a large negative potential at light area, toner is induced to attach thereon and cause a foggy image. Moreover, in particular, when the carrier of the developer is iron powder, the charge bound on the translucent insulating layer is discharged through the carrier to cause a foggy image.

On the contrary, in accordance with the present invention, an electrostatic image is formed in a similar photosensitive plate, by applying a primary charge (assuming positive polarity) to the translucent insulating layer, exposing the original image simultaneously with the discharging of the primary charge by alternating current corona discharge, and thereafter exposing the whole surface to obtain an electrostatic image. Consequently, the electrostatic image is formed mainly by retained primary charge (positive polarity) at the dark area of the original image. Therefore, to obtain a positive-positive image, it is only necessary to attract negatively charged toner by the positive charge retained at the dark area of the original image, which easily enables wide area developing.

In accordance with the present invention, even if either or both of toner and carrier becomes conductive to cause an inducing phenomenon, there is no problem at all since the developing is carried out by the charge bound at dark area, and it produces a high density image. Furthermore, even if a high frictional force is applied to the charged area, since toner is firmly attached thereon, there is no fear of leakage of the charge and it is difficult to produce a foggy image. Moreover, since the high voltage source of alternant current discharge does not require a rectifier, it is very economical in practice.

An object of the present invention is to provide a new electrophotographic process and apparatus which can be repeatedly carried out and used for a long period of time by overcoming the drawbacks of the above-mentioned conventional electrophotographic methods.

Another object of the present invention is to provide an electrostatic image forming process comprising charging in positive or negative. In addition, the surface of the translucent insulating layer of a photosensitive plate comprising a photosensitive layer overlaid on a conductive base body, said translucent insulating layer being overlaid on the said photosensitive layer, by means of electrodes or corona discharge or the like; and then irradiating the original image on the said insulating layer, and during the same time applying the alternating current corona discharge thereto, and thus forming an electrostatic image defined by the surface potential generated in accordance with the light-and-dark pattern of the original image on the said translucent insulating layer.

Another object of the present invention is to provide an electrostatic image forming process comprising forming a first electrostatic image as mentioned above, and thereafter irradiating light all over the translucent insulating layer to reverse the said surface potential, and thereby forming a second electrostatic image of the original image of high contrast on the surface of the said insulating layer.

Another object of the present invention is to provide an electrophotographic process which comprises visualizing the electrostatic image formed as mentioned above by using developer, transferring the thus obtained visualized image onto a transfer material, fixing the same thereon to obtain an electrophotographic image of the original image, and repeatedly using the photosensitive plate by cleaning the surface of the insulating layer after the electrostatic image is transferred.

Another object of the present invention is to provide electrophotographic image forming process comprising visualizing the electrostatic image formed on the translucent insulating layer as mentioned above by using electroscopic developer, and then charging the translucent insulating layer containing the said visualized image with optional polarity, and then applying a transfer material thereon to transfer the visualized image, fixing the transferred image, for example, by means of heat, to obtain an electrophotographic image, and after having carried out the transfer of the image, cleaning the surface of the said insulating layer to remove the remaining developer, and using the said photosensitive plate over and over again.

The above-mentioned objects and other numerous objects of the present invention, and a number of characteristics and effects of this invention will be easily and clearly understood from the explanations of the embodiments of this invention shown in the drawings, in which:

FIG. 1 is a diagram showing the fundamental structure of an electrophotographic plate to be used in the process.
for forming the electrostatic image of the present invention;
FIGS. 2 through 4 are diagrams showing processes for forming an electrostatic image on the translucent insulating layer of the electrophotographic plate of FIG. 1;
FIG. 5 shows the potential on the surface of the insulating layer of the electrophotographic plate obtainable by the processes of FIGS. 2 to 4;
FIG. 6 shows a visible image obtainable on the surface of the insulating layer of the plate;
FIG. 7 shows a process for transferring the visible image from the electrophotographic surface and
FIG. 8 is an electrophotographic copying device embodying a process of the present invention.
FIG. 1 is a diagram which shows the fundamental structure of an electrophotographic plate used in the process for forming the electrostatic image of the present invention, and in the diagram, 1 is a base, 2 is a photoconductive layer coated on the base by using a sprayer, or a coater, or wheeler or the like, and if necessary, it is possible to add a little amount of binder material such as resins and the like. 3 is an insulating (insulative) layer which is adhesively adhered on phot conductive layer 2. Thus, photosensitive plate A has three layers, i.e., base 1, photoconductive layer 2, and insulating layer 3. It is also possible to form a control layer such as to control the transfer of charge between base 1 and photoconductive layer 2, and it is also possible to add or independently provide a layer for binding charge on the surface of photoconductive layer or in the neighborhood of the surface.
Base 1 is formed of conductive material. As a conductive base, tin, copper, aluminum, or like metal conductors can be used, but in particular, aluminum foil adhered on paper is economical and it is very convenient when used by rolling the paper or the like.
As the material which composes photoconductive layer 2, CdS, CdSe, ZnO, Se, Te, ZnS, or CdS—Te, and it is also possible to use any of the above-mentioned materials by directly coating same on the base, or in the form of mixture along with binder, or a mixture of more than two kinds of the above-mentioned materials.
Among these photoconductive materials, highly sensitive materials especially adapted for the present invention, are highly photoconductive materials such as CdS, CdS—Te, or the like, and when these materials are used, it is possible to elevate sensitivity up to ASA 100. On the other hand, a phot conductive layer obtained by adding a little amount of ZnS in a photosensitive layer mainly composed of CdS, is highly sensitive, and provides an electrostatic image of high contrast and high sensitivity.
Mixtures of CdS and ZnS have hitherto been used (in P.I.P. system), but in order to elevate the difference of photopolarization and dark polarization and internal polarization characteristics, the ratio of CdS to ZnS is selected to be within the range of 4:6 to 3:7.
On the contrary, in the case of the present invention, the ratio of CdS and ZnS is preferably within the range of 50:1 to 1:1, and it is possible to make advantageous use of the characteristics of the highly sensitive CdS.
Further in accordance with the process of the present invention, use is made of the charge bound persistently on the photoconductive layer of a photosensitive plate including an overlying insulating layer on the photoconductive layer as is described hereinafter, and an electrostatic image is formed on the surface of the insulating layer. Therefore, it is possible to use photoconductive materials of low resistivity, such as Se—Te, CdS or the like which have hitherto not been possible to use because of the necessity for the photoconductive layer itself to bind charge. At the same time, it is possible to use conventional photoconductive material even if not especially highly sensitive.
Photoconductive papers incorporating zinc oxide dispersed in a resin, which have hitherto been adopted in the conventional Electro Fax system, are required to be white because they are used as copying papers by themselves, and therefore it is impossible to add much dye to sensitize same, and it has not been possible to elevate the sensitivity of these papers significantly.
However, in accordance with the method of the present invention, the photosensitive plate is itself not used as copying paper, but a visualized image is made on transfer paper, and therefore it is not necessary for the photosensitive plate to be white, which enables one to add remarkably larger amount of dyes when compared with the amount of dyes used in conventional methods.
Therefore, it is possible to use, in accordance with the method of the present invention, a several times more sensitive zinc oxide photoconductive layer compared with conventional methods.
In the method of the present invention, a photoconductive layer obtained by doping lithium into ZnO presents excellent results.
As to the material which constitutes insulating layer 3, any material can be used which has high resistance against wear, high resistivity and capability of binding electrostatic charge, and translucency to activating radiation. Films of the following resins can be used, i.e., fluorine resin, polycarbonate resin, polyethylene resin, polyester resin, or the like. In particular, fluorine resin has a specific property which makes it easy to carry out cleaning, and therefore as is explained hereinafter, it is a preferable material in carrying out the method of the present invention for using the photoconductive plate over and over again through developing, transferring, and cleaning processes.
FIGS. 2 through 4 show processes for forming an electrostatic image on the translucent insulating layer 3 of photosensitive plate A, and the image of charge on the photosensitive layer A. Through the processes of primary charge (FIG. 2), and of irradiation of the original image while applying A.C. corona discharge (FIG. 3), the electrostatic image, obtained by generation of surface potential in accordance with the light-and-dark pattern of the original image as shown in FIG. 3, is formed on the surface of the translucent insulating layer.
Further, a reverse electrostatic image, wherein this surface potential is reversed as shown in FIG. 4, is formed on the surface of the insulating layer by uniformly exposing all of the surface of the translucent insulating layer 3.
The potential on the surface of the insulating layer in these processes is shown in FIG. 5. First of all, in a dark (unexposed) area or light (exposed) area, the surface of translucent insulating layer 3 of photosensitive plate A is charged in a definite polarity, for example, positive by means of the conventional charging means such as corona discharger 5 (FIG. 2) connected to high voltage source 4, or an electrode roller (not shown).
With the surface of insulating layer 3 charged in the positive, insulating layer 3 works as a condenser, and a charge of polarity opposite to the charging polarity is accumulated between insulating layer 3 and photoconductive layer 2, and in the neighborhood thereof.
This charge is considered to be composed of either free carriers of photoconductive layer 2, photo carriers, or carriers injected from the side of conductive base 1, or a mixture of these carriers.
The accumulated carriers are bound strongly by the barrier of the photo conductor which composes photoconductive layer 2, and photoconductive layer 2, on the other hand, is not photoconductive so that the surface of the insulating layer. In this state, there is no fear that the charge should escape in either a light or dark area for a long period of time, and furthermore, in a dark area, the carrier charge inside the insulating layer is persistent even if the charge on the surface of the insulating layer is discharged.
As is shown in FIG. 3, the light image is obtained on translucent insulating layer 3 by activating irradiation of original image 8, having light areas 6 and dark areas 7,
by means of a penetrating or reflecting system. At the same
time, by means of alternating current corona discharge
connected to high voltage alternating current circuit,
the alternating current corona discharge is applied to
insulating layer 3. The first charging polarity in the
above-discussed charging processes is determined by
the property of the photoconductor. In the case of a
photoconductive layer whose photoconductor is mainly
composed of CdS activated by copper, or ZnO, or such
n-type photoconductors, it is preferentially positive,
and in the case of the photoconductive layer
mainly composed of p-type photoconductors such as
amorphous selenium, Se-Te, it is preferable to charge in
the negative. However, this is not critical, and even in
the case wherein charge polarity is not as preferably
stated above, it is possible to obtain an electrostatic
effect although contrast is somewhat deteriorated.

As the means for carrying out the alternating current
corona discharge while irradiating the original image on
insulating layer 3 of the photosensitive plate, it is preferable
to irradiate the original image on the photosensitive
plate through the use of an alternating current corona
discharger having a shield plate whose upper portion is
translucent or an optically open shield plate having no
upper shield member. For example, as is shown in FIG. 3,
in the case of alternating current corona discharger 10, whose
upper portion is optically open, is moved while charging the
surface of insulating layer 3, the light image of the
original image is irradiated on the surface of the insulat-
ing layer through the alternating current corona dis-
charger. Of course, the alternating current corona dis-
charger may be fixed, and the original image and the
photosensitive plate may be moved relative thereto. At
this time, the effective area of discharge of the alternating
corona discharger should preferably constitute a slit ex-
posure width.

When the irradiation of the original image and the sec-
ondary charging alternating current corona discharge
are carried out, as in FIG. 3, in the light areas of the
original image, the primary charge in the positive on the
surface of insulating layer 3 is wholly or mostly dis-
charged thereby. The amount of this discharge depends
on the intensity and/or the time duration of the alter-
cating current corona discharge. Photoconductive layer
2 is reduced in resistivity by irradiation of the original
image and becomes conductive, and by means of the
primary charge, the negative charge bound at the inter-
face of photoconductive layer 2 and insulating layer 3,
or the portion of the interior of photoconductive layer 2
close to insulating layer 3 is freed, and in accordance with
the reduction of the surface charge of insulating layer 3,
it is reduced, and most of the charge is discharged into
the conductive base 1. Therefore, the surface potential of
insulating layer 3 is reduced in accordance with the time
duration of the alternating corona discharge, and the
specific characteristic is presented as \( V_{D} \) in FIG. 5.

In the above case, when the alternating corona dis-
charge voltage is sufficiently high, such as about 7 kv,
and discharge time is sufficiently long, it is possible to
charge the original image light areas of the insulative
layer more or less in the negative.

On the other hand, in the dark areas of the original
image, the positive charge, formed on the surface of in-
sulating layer 3 by means of the primary charge, is dis-
charged by irradiation and alternating current corona
discharge but as to the degree thereof, it is a little less
than that in the light area. This is considered to be
attributable to the fact that the negative charge bound be-
tween photoconductive layer 2 and insulating layer 3 or
on the portion of photoconductive layer 2 in the neigh-
borhood of insulating layer 3 by means of the primary charge,
remains without being discharged even if the alternating
current corona discharge is applied thereon because the
resistivity of photoconductive layer 2 is high, and be-
cause of the said negative charge, the positive charge of
the surface of insulating layer 3 is restrained, and there-
fore the degree of discharge is decreased.

As a result thereof, the surface potential in the dark
areas of the original image is lower than the surface
potential in the light area and the specific characteristic
is presented as \( V_{D} \) in FIG. 5.

When the alternating current corona discharge voltage is
sufficiently elevated in comparison to that of the above-
mentioned case, for example, over 7 kv, and when the
time for discharge charge is sufficiently long, the surface
charge of insulating layer 3 is readily neutralized, and sometimes
the surface potential of the insulating layer is turned
slightly negative by means of the field of the negative
charge bound on photoconductive layer 2. On the surface
of insulating layer 3 after the above-mentioned processes,
the surface potential (\( V_{D} - V_{P} \)) difference is generated
in accordance with the light-and-dark pattern of the
original image, and the electrostatic image of the original
image caused by this surface potential is formed.

The above-mentioned surface potential difference
(\( V_{D} - V_{P} \)) is changed, as is shown in FIG. 5, according
to the time of the alternating corona discharging and the
irradiation of the original image, and therefore in order
to obtain greater surface potential difference, it is neces-
sary to appropriately select the time for irradiation of the
original image and the time for carrying out corona dis-
charge.

With the photoconductive layer of the photosensitive
plate is thin, or when the bound charge is weak, the value
of the surface potentials \( V_{P} \) and \( V_{D} \) become almost equal,
and the surface potential difference (\( V_{D} - V_{P} \)) is almost
not observed. This can be considered due to the fact that
the bound charge is weak within the photoconductive
layer and it is comparatively quickly neutralized by means
of the electric field.

Next, when light is irradiated onto the whole surface
of insulating layer 3, after forming the electrostatic image
on the surface of insulating layer 3 by carrying out the
alternating current corona discharge and the irradiation
of the original image for an appropriate period of time,
there is no remarkable change in the state of the photo-
conductive layer in the light areas of the original image.
Therefore, the positive charge on the surface of the in-
sulating layer 3 in these areas is not reduced much, and
the surface potential is almost kept constant as shown
in characteristic \( V_{D} \) in FIG. 5. In the dark areas of the
original image, irradiation thereof with light was not car-
ried out in the preceding process, and photoconductive
layer 2 presented high resistivity. In this process light is
applied thereto and therefore layer 2 resistivity is
abruptly lowered, and it becomes conductive, and the
negative charge bound in the internal portion thereof is
mostly discharged into conductive base layer 1, and only
slightly bound by means of the positive charge on the sur-
face of insulating layer 3.

Thus, in this process, the field of the positive charge
on the surface of insulating layer 3 which had been working
comparatively strongly in the direction of the negative
charge bound on photoconductive layer 2, becomes an
external field, and the surface potential of the insulating
layer 3 is abruptly increased, and this characteristic \( V_{D} \)
is presented, along with the time for irradiating light on
the whole surface in FIG. 4.

When this uniform blanket light radiation is carried out,
the surface potentials \( V_{D} \), \( V_{P} \) of the insulating layer 3
respectively become \( V_{D} \) and \( V_{P} \), and the surface potential of
the dark areas of the original image becomes higher than
the surface potential of the light areas of the original image,
i.e., the potential is reversed from the preceding
process and simultaneously the surface potential difference
is increased.

By irradiating the whole surface and by taking into con-
sideration various conditions such as photosensitive plate
characteristics and times for prior charging, it is possible
to form an electrostatic image having large contrast on the surface of insulating layer 3.

In electrostatic image formation in accordance with the present invention, equilibrium is kept between the charge bound on the photoconductive layer and that on the surface of the insulating layer, and then alternating current discharge is applied to the surface of the insulating layer simultaneously with original image irradiation, and by means of the mutual effect of the both, a surface potential difference is formed on the surface of the insulating layer, and further, light is irradiated on the whole surface of the insulating layer. So, an electrostatic image is formed in accordance with the original image light-and-dark pattern, and therefore, when compared with conventional electrophotography, it is possible to obtain an electrostatic image of high contrast, having large surface potential difference and strong external field, and at the same time sensitively is remarkably increased.

Next the electrostatic image formed on the surface of the insulating layer is developed by means of cascade development, magnetic brush development, powder cloud development, or such like conventional developing methods, by using developer mainly composed of charged resin particles, and as is shown in FIG. 6, visible image 11 is obtained. At this time, the electrostatic image formed on the surface of the insulating layer is of high electrostatic contrast when compared with that of the Carlson process, and therefore it is preferable, in the case of cascade method, to use carrier, in particular, the heavier carrier obtained by coating the surface of metallic or non-metallic particles, whose granularity is more than 0.3 μm, with resin uniformly containing an electrostatic charge controlling agent.

When magnetic brush development is employed, in order to prevent the discharge of the surface charge of the highly insulating layer through the carrier, good results can be obtained when iron fillings coated with resin are used.

When liquid development is employed, a mixture of halogenated hydrocarbons such as Freon or the like, dimethyl polysiloxane (silicon oil), or such like highly insulating oils dispersed with pigments or dyes can be effectively used. If any of the developing methods should be employed upon an electrostatic image formed as above described, having an electrostatic pattern of negative or positive polarity and remarkably high contrast, it is possible to obtain a visible image of high density.

Next, visible image 11, as shown in FIG. 7, is transferred. If any charged material 13 such as a paper by means of the method according to which corona discharge, bias voltage, or like external voltage 12 is applied as is described in U.S. Pat. No. 2,637,651. Alternatively usable is the method according to which copying paper, having electrostatic capacitance larger than the electrostatic capacitance of the photoconductive material of the photosensitive plate, is closely adhered on the surface on which the electrostatic image is formed. A further alternative is the method according to which after development, the visible image and insulating layer are charged, and thereafter the developed image is transferred. Finally, the electrophotographic image can be obtained by fixing the transferred image through radiation of heat rays by means of infrared radiation, or the like.

In order to enable repetitive use of the photosensitive plate, the photosensitive plate is subjected to cleaning after the completion of transferring of the image by means of conventional cleaning methods, such as the fur brush method, or by a direct rubbing method wherein an elastic body is used to remove charged particles remaining on the surface of the photosensitive plate.

Beyond such plate cleaning, other cleaning should be preferably carried out to remove the electrostatic image charge on the photosensitive plate to increase the cleaning effect, and for this purpose, before carrying out cleaning by particle removal, an alternating current corona discharge is applied onto the insulating layer, and the electrostatic image charge is thereby removed. Then a fur brush or the like is employed as above described and excellent results can be obtained. In this case an opposite polarity potential to that of the developer colored particles is applied to the fur brush and thereby the effect of cleaning can be further improved, and in this case, it is possible to simultaneously provide the primary charge.

The effect of this cleaning depends on the properies of the material of the insulating layer, particularly its adheive characteristics, and therefore, the resins mentioned above are preferably used as the electrophotographic image forming materials. Among all these materials, fluo-rine resin film has excellent non-adhesive characteristics, and during cleaning, it accelerates the separation of developer colored particles, and remarkable cleaning can be attained, and in this respect it is most effective.

In the electrostatic image forming process of the present invention, the thickness of the translucent insulating layer 3 affects the quality of the electrostatic image along with the photoconductive layer. In particular, it affects sensitivity, contrast, and durability of the photosensitive plate, which are important factors, and in order to form an excellent electrostatic image and to transfer it to the photosensitive plate repeatedly for a long period of time, it is necessary that the thickness of the translucent insulating layer be within the range of 10 to 50μ.

Examples for forming the electrostatic image in accordance with the present invention are as follows:

EXAMPLE I

10 g. of vinyl chloride was added to 90 g. of cadmium sulphide activated by copper, and a little amount of thinner was added thereto, and the obtained mixture of photosensitive substance was coated by spraying same on an aluminum plate of thickness about 1 mm., so as to have the mixture of photosensitive substance become about 100μ thick. Then, on the surface of photoconductive film, a film of Mylar of thickness about 15μ was adhered by using an adhesive. A corona discharge of (+) 6 kV. was irradiated on the surface of the Mylar layer and a positive charge was uniformly bound. Then the original image was irradiated for about 0.1–0.3 second on the above-mentioned surface by means of a 10 lux tungsten lamp and at the same time, an alternating current corona discharge of AC 6 kV. was applied to the transparent plastic. Thereafter, the whole surface was uniformly illuminated by means of a tungsten lamp for 1 to 2 seconds and an electrostatic image was formed in accordance with the light-and-dark pattern of the original image. Then the electrostatic image was developed by means of the magnet brush method, and thereby a visible image of the markedly excellent quality having high image density was obtained.

EXAMPLE II

FIG. 8 shows a copying machine embodying a process of the invention. Photosensitive plate A comprising conduction base 1t, photoconductive layer 2t and insulating layer 3t is set around the periphery of drum 12t rotating in the direction of the arrow FIG. 8. Plate A is primary or firstly charged by corona discharger 4t, and the thus charged insulating layer 3t is irradiated by original image by lens 13t through discharger 8t and at the same time subjected to A.C. corona discharge to form thereon an electrostatic image, and thereafter the entire surface of the insulating layer is exposed to tungsten lamp 23t to form an electrostatic image according to dark-and-light pattern of the original image. Developer 14t includes magnet brush 15t for applying charged coloring particles to the electrostatic image to visualize it. The visualized image is transferred onto copying material 11t, which is moved in contact with the visualized image by transfer roller 16t, by applying corona discharger of polarity opposite to that of the charged particles through transfer corona discharger 10t.
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11

Then the copying material 11t moves along the periphery of the hot fixer drum 18t having an infrared ray lamp 17t inside thereof, and the transferred image is thereby fixed, and finally an electrophotographic image is obtained on receiver 19t.

After such transfer, photosensitive plate A is cleared of charge forming the electrostatic image still remaining on the surface of insulating layer 3t by means of AC corona discharger 28t, and then, at cleaner 21t, the powder image remaining on insulating film surface 3t is cleared by brushing same with rotary brush 22r having soft hair such as a fur brush on the periphery thereof, and the plate is thus prepared for repeated employment.

According to this device, primary charge is applied to the surface of the insulating layer of the photosensitive plate comprising a conductive support, a photosensitive layer and said insulating layer. An original image is then radiated, and at the same time AC corona discharge is applied to charge the surface of the insulating layer while keeping equilibrium with the charge induced on the photosensitive layer, and by means of the mutual effect of the two, the whole surface of the insulating layer is exposed to form the electrostatic image on the surface of the insulating layer, and the surface potential of the insulating layer is reversed, and an electrostatic image of the original image is formed. Therefore, it is possible to obtain an electrostatic image of surface potential having strong external charge field and increased sensitivity. The electrostatic image is formed on the insulating layer, and the development, transferring process and cleaning process are then carried out. By selecting the insulating layer of high resistivity and high resistance against wearing it is possible to prevent surface deterioration of the internal photosensitive layer and fatigue without deteriorating or damaging the surface thereof even if friction or pressure or such like physical effects are imparted thereto, and therefore, a photosensitive plate may be provided which can withstand repeated use for a long period of time.

We claim:

1. A process for forming an electrostatic image in a photosensitive plate having a photosensitive layer exhibiting p-type or n-type semiconductivity and an insulative layer comprising the steps of:

(a) applying a charge of one polarity to said insulative layer, and then
(b) while exposing said photosensitive layer to a pattern of image radiation applying an alternating current discharge to said insulative layer.

2. A process for forming an electrostatic image in a photosensitive plate having a photosensitive layer exhibiting p-type or n-type semiconductivity and an insulative layer comprising the steps of:

(a) applying a charge of one polarity to said insulative layer, and then
(b) while exposing said photosensitive layer to a pattern of image radiation applying an alternating current discharge to said insulative layer, and then
(c) exposing said photosensitive layer to blanket radiation.

3. A process for forming an electrostatic image on a photosensitive plate having a conductive base, a photosensitive layer overlying said base and exhibiting p-type or n-type semiconductivity and an insulative layer overlying said photosensitive layer, said photosensitive plate being characterized in having carrier charge of a polarity corresponding to the conductivity type of said photosensitive layer injectable from said conductive base into said photosensitive layer and bound in the region of the interface between said insulative and photosensitive layers, said process comprising the steps of:

(a) applying a first charge of a polarity opposite to the conductivity type of said photosensitive layer substantially uniformly onto said insulative layer to inject and bind carrier charge in the region of the interface between said insulative and photosensitive layers, and then
(b) then exposing said photosensitive layer to a pattern of image light while applying an alternating current corona discharge onto said insulative surface, and then
(c) exposing said photosensitive layer to activating light to discharge bound carrier charge remaining in the region of said interface and form a high contrast electrostatic image.

4. A process according to claim 3, wherein said insulative layer is transparent to both said image light and said activating light, and said photosensitive layer is exposed to said image light and said activating light through said transparent insulative layer.

5. A process for forming an electrophotographic image comprising the electrostatic image forming process claimed in claim 3 and the further terminal steps of:

(a) then exposing said photosensitive layer to activating light to discharge said activating light, and said photosensitive layer is exposed to said activating light through said transparent insulative layer.

6. A process according to claim 5, wherein said developer is a liquid developer and step (d) is carried out by bringing said liquid developer into contact with said photosensitive plate.

7. An apparatus for forming an electrostatic image comprising:

(a) a photosensitive plate having a photosensitive layer exhibiting p-type or n-type semiconductivity and an insulative layer,
(b) means for applying a charge of one polarity to said insulative layer,
(c) means for exposing said photosensitive layer to a pattern of image radiation while applying an alternating current discharge to said insulative layer, and
(d) means for exposing said photosensitive layer to blanket radiation.

8. An apparatus for forming an electrostatic image comprising:

(a) a photosensitive plate having a conductive base, a photosensitive layer overlying said base and exhibiting p-type or n-type semiconductivity and an insulative layer overlying said photosensitive layer, said photosensitive plate being characterized in having carrier charge of a polarity corresponding to the conductivity type of said photosensitive layer injectable from said conductive base into said photosensitive layer and bound in the region of the interface between said insulative and photosensitive layers,
(b) charging means for applying a first charge of a polarity opposite to the conductivity type of said photosensitive layer substantially uniformly onto said insulative layer to inject and bind carrier charge in the region of the interface between said insulative and photosensitive layers,
(c) means for exposing said photosensitive layer to a pattern of image light while applying an alternating current corona discharge onto said insulative layer, and
(d) means for exposing said photosensitive layer with activating light to discharge said activating light through said insulative layer.

9. An apparatus according to claim 8, wherein said insulative layer is transparent to both said image light and
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13. said activating light, and wherein means (c) and (d) include means for exposing said photoconductive layer through said transparent insulative layer.

14. An apparatus according to claim 10, wherein said developing means includes a liquid developer.

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