United States Patent

[11] 3,615,395

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[32] Priority **Sept. 28, 1966**
[33] **Japan**
[31] **41/64273**

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[54] **ELECTROSTATIC AND ELECTROPHOTOGRAPHIC VARIABLE CONTRAST IMAGE-FORMING METHODS**
15 Claims, 12 Drawing Figs.

[52] **U.S. Cl.** **96/1.4,**
96/1, 117/17.5, 355/3
[51] **Int. Cl.** **G03g 13/14,**
G03g 13/00
[50] **Field of Search** 96/1, 1.5;
101/149.2; 117/201, 37, 212, 218

[56] **References Cited**
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Assistant Examiner—M. B. Wittenberg
Attorney—Watson, Leavenworth & Kelton

ABSTRACT: A process for forming an electrostatic image in a plate having a photoconductive layer with an insulative overlayer wherein the insulative layer is charged in a first polarity, is then subjected to AC corona discharge while the photoconductive layer is exposed to a pattern of image radiation, and is then further charged with polarity opposite to said first polarity. The contrast of the formed electrostatic image may be adjusted by time-intensity characteristics of said further charging and exposure of the photoconductive layer to blanket radiation.

FIG. 1

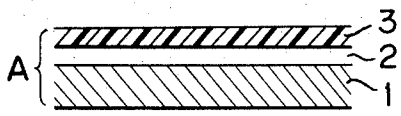


FIG. 2

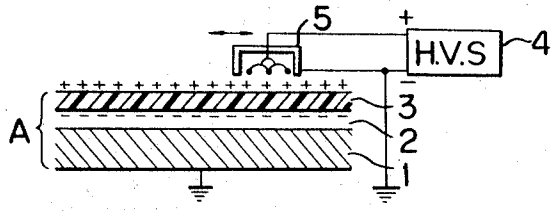


FIG. 3a

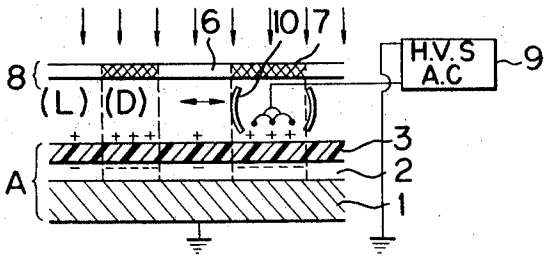


FIG. 3b

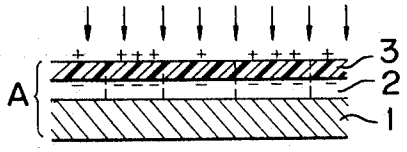


FIG. 4a

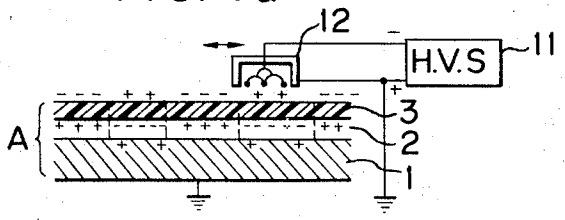


FIG. 4b

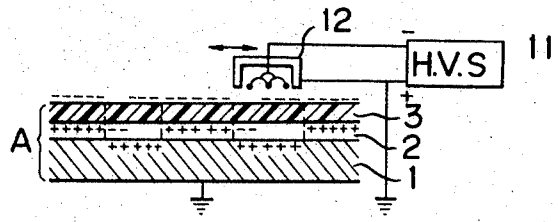


FIG. 5a

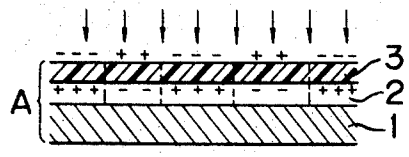


FIG. 5b

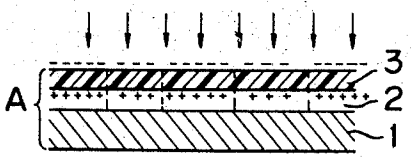


FIG. 7

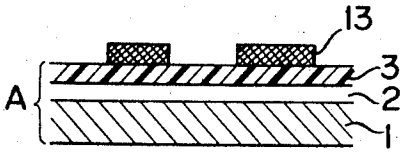


FIG. 8

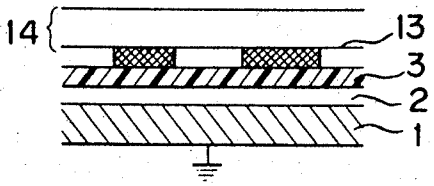


FIG. 6

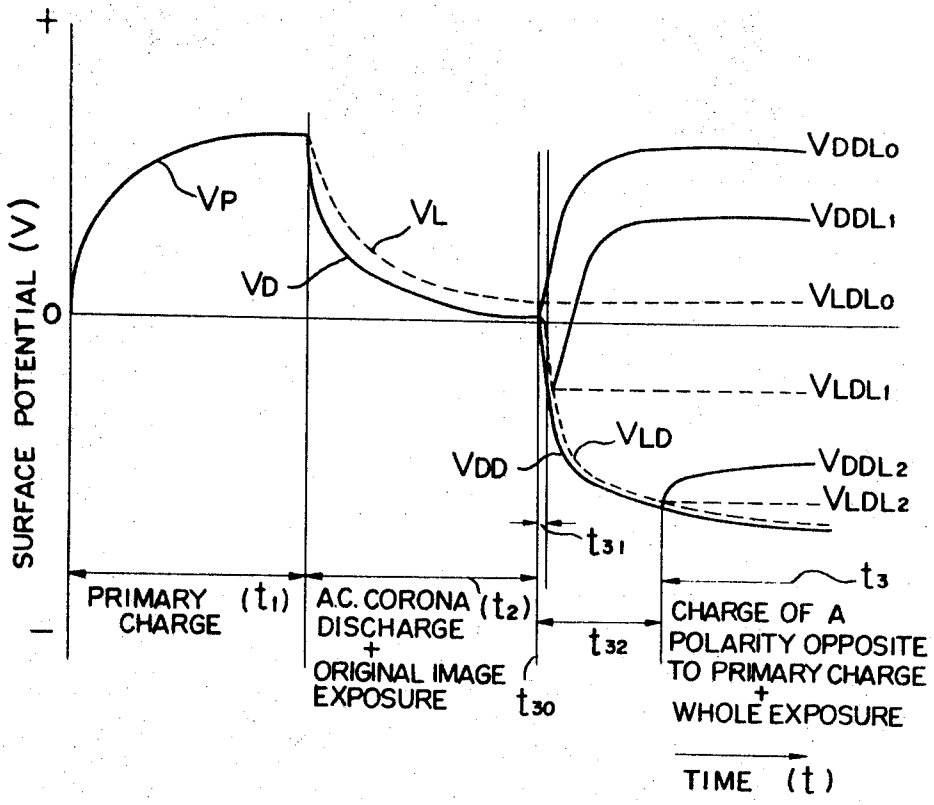
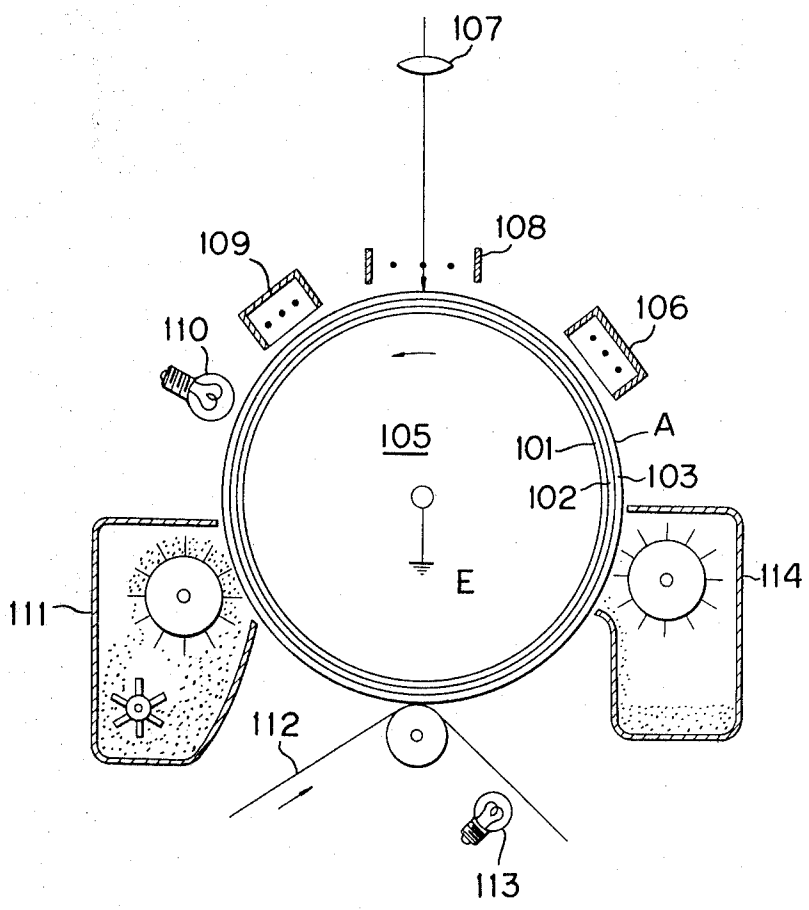

+
SURFACE POTENTIAL (V)
0
−
VP
VL
VD
VDDLo
VDDL1
VLDLo
VLDL1
VLD
VDD
VDDL2
VLDL2
t31
t3
PRIMARY CHARGE (t1)
A.C. CORONA DISCHARGE + ORIGINAL IMAGE EXPOSURE (t2)
t30
t32
CHARGE OF A POLARITY OPPOSITE TO PRIMARY CHARGE + WHOLE EXPOSURE
TIME (t)

FIG. 9



ELECTROSTATIC AND ELECTROPHOTOGRAPHIC VARIABLE CONTRAST IMAGE-FORMING METHODS

This invention relates to electrophotography and more particularly to processes for forming electrostatic images in electrophotography.

This invention is based on the invention of U.S. application, Ser. No. 571,538 filed on Aug. 10, 1966 relating to electrophotographic processes according to which a photosensitive plate includes a photoconductive layer disposed between a support member and a translucent insulating layer and wherein an electrostatic latent image is formed on said translucent insulating layer. This invention relates to improvements in such electrophotographic processes.

In the invention of Ser. No. 571,538 the surface of said translucent insulating layer is uniformly charged, and a charge of opposite polarity to the polarity of said uniform charge is strongly bound inside said photoconductive layer or at the interface between said photoconductive layer and said translucent insulating layer by utilizing the field of said uniform charge. Then, by making use of the external field of said bound charge, irradiation of the original image and AC corona discharge are carried out on the surface of the charged translucent insulating layer, and an electrostatic image according to light and dark pattern of the original image is formed on the surface of said charged translucent insulating layer. Following such process for forming an electrostatic image, light rays are irradiated on the entire surface of said translucent insulating layer thereby to form an electrostatic image having further increased contrast.

In accordance with this described process, the voltage of the charge for forming the electrostatic image bound inside of the photoconductive layer or in the vicinity of said interface is remarkably high compared with the conventional Carlson process, and therefore a sharp static image of remarkably higher contrast can be obtained than is provided by the conventional electrophotographic process. In addition, the photosensitive plate can be used repeatedly for a long time. These are advantages of the invention of Ser. No. 571,538. On the other hand, adjustment of the contrast of the electrostatic image is difficult, and since the electrostatic image has a large electrostatic field, when a positive-positive image is obtained by development thereof, toner strongly adheres to the charged insulative layer portions corresponding to dark areas of the original image. As a result, transfer of the developed image and cleaning developer from the photosensitive plate become difficult when the photosensitive plate is used repeatedly. In these processes of Ser. No. 571,538 special counter measures are required at some disadvantage.

For example, in one such measure for transferring images positive or negative corona discharge is applied to the surface of the translucent insulating layer either after strong bias transfer of the image or after development to reduce the electrostatic adhesive power between the toner and the surface of the translucent insulating layer. Thereafter the image is transferred. In either case, an electric source of high voltage is required. In the latter case, i.e., after development, corona discharge is applied from above the developed image, and therefore insulating and developing toner particles in the vicinity of the charger are charged, and because of a kind of dust collecting effect, these toner particles are absorbed by or adhered to the charging wire or the shield plates. This will bring about a deterioration of charging effect, a reduction of insulation in the charger, and a decrease of durability.

In the plate cleaning operation, a satisfactory result cannot be obtained unless elastic cleaning members such as rubber are employed to strongly brush the surface of the translucent insulating layer of the photosensitive plate or unless the brushing is carried out with appropriate bias voltage applied to the cleaning member and this causes the damage and the deterioration of the photosensitive plate.

An object of this invention is to provide a new electrophotographic process free from such disadvantages of presently known electrophotographic processes.

Another object of this invention is to provide a new electrophotographic process which provides high sensitivity, high contrast, and permits long photosensitive plate life.

A further object of this invention is to provide electrophotographic processes according to which sharp and fogless electrostatic images can be obtained.

Another object of this invention is to provide electrophotographic processes according to which electrostatic image contrast can be easily adjusted.

A further object of this invention is to provide electrophotographic processes according to which image transfer and plate cleaning can be easily carried out.

In this invention the surface of said translucent insulating layer is uniformly charged, and a charge of polarity opposite to the polarity of said uniform charge is bound inside the photoconductive layer or at the interface between said photoconductive layer and said translucent insulating layer. Then the irradiation of the original image and AC corona discharge are carried out on the surface of said translucent insulating layer, and an electrostatic image in accordance with the light and dark pattern of the original image is formed on the surface of the translucent insulating layer. Next charge of polarity opposite to the polarity of the first or primary charge is applied to the surface of the translucent insulating layer and to the charge which forms the light and dark pattern of the electrostatic image without changing the pattern. Thereafter, light rays are irradiated on the entire surface of said translucent insulating layer to increase the contrast of said electrostatic image.

The above-mentioned objects and a number of other objects, features and effects of this invention will be easily and clearly understood from the description of the embodiments of this invention as shown in the attached diagrams.

FIG. 1 is a diagram showing the fundamental structure of the photosensitive plate employed in practicing this invention.

FIG. 2 through FIG. 5 are diagrams showing the formation of electrostatic images on the photosensitive plate of FIG. 1 in accordance with the processes of this invention.

FIG. 6 is a graphic diagram showing changes in the surface potential of the photosensitive plate of this invention.

FIG. 7 and FIG. 8 are diagrams explaining processes for developing and transferring the electrostatic image formed in accordance with this invention.

FIG. 9 is a schematic diagram of an embodiment of apparatus for practicing the electrophotographic processes of this invention.

In FIG. 1 element 1 is a support member and element 2 is a photoconductive layer provided on support member 1. If necessary, a little amount of binder such as resin may be added to improve the adhesion between elements 1 and 2. Translucent insulating layer 3 is closely adhered on photoconductive layer 2.

Photosensitive plate A is thus composed substantially of support member 1, photoconductive layer 2, and translucent insulating (insulative) layer 3. A control layer which controls the transmission of charge may be formed between support member 1 and photoconductive layer 2, and further, independently thereof, a layer for binding electric charge on the surface of the photoconductive layer or in the vicinity of the surface of the photoconductive layer may be added.

Support member 1 can be formed of a conductive or insulative material, and where the support member is conductive, metal conductors such as tin, copper, or aluminum, or humidity absorbing paper or the like can be used. Aluminum foil adhered to paper is economical and it is preferable when used by winging on a drum.

Where the support member is insulative, it is possible to use the same materials used for forming translucent insulating layer 3 described hereinafter, but the same materials used in producing translucent insulating layer 3 need not always be used, and insulative materials in general can be used.

As the material for forming photoconductive layer 2, any of CdS, CdSe, metallic Se, ZnO, ZnS, Se, TiO_2, SeTe, PbO and S

or such like inorganic photoconductive materials, or anthracene, carbazole, or such like organic photoconductive materials can be used. The photoconductive layer may be obtained by coating these materials directly on the support member, or by mixing the photoconductive material with a binder. The photoconductive layer may be obtained by mixing two or more kinds of the above materials.

Highly sensitive photoconductive materials especially adapted for the process of this invention are CdS, CdSe, metallic Se, and the like. When these materials are used, it is possible to elevate the sensitivity up to higher than ASA100. The photoconductive layer containing mainly CdS and a little amount of ZnS is highly sensitive, and it is possible to obtain electrostatic images of high contrast by using such materials.

According to the processes of this invention described hereinafter, an electrostatic image is formed on the surface of the translucent insulating layer by making use of the charge bound persistently in the photoconductive layer of a photosensitive plate composed by providing an insulating layer on the photoconductive layer. Therefore, it is possible in this invention to use metallic Se of low resistivity which cannot be used in conventional methods because of the necessity to retain charge in the photoconductive layer itself, and it is also possible to use well-known conventional photoconductive materials which are not highly sensitive.

Photosensitive paper having ZnO dispersed in a resin generally employed as copying paper in the conventional Electro-Fax process is required to be white, and therefore dye-stuff cannot be added thereto to increase its sensitivity as a photosensitive plate. Thus, the sensitivity of such photosensitive plate cannot be increased to a satisfactory level. In this invention, the photosensitive plate itself is not used as a copying paper, but the electrostatic image is transferred from the plate onto copying paper. Therefore the photosensitive plate need not be white, and quite a large amount of dye-stuff can be added thereto as compared with the amount of dye-stuff which can be added to the conventional photosensitive plate.

According to this invention a ZnO photoconductive layer of several times higher sensitivity than that of the conventional photosensitive plate can be used. An excellent result can also be obtained when the photoconductive layer is obtained by doping lithium with ZnO.

Any materials can be used for translucent insulating layer 3 if they satisfy three conditions, i.e., that they have high resistance to abrasion, that they are of high electrical resistivity so that they can retain electrostatic charge, and that they transmit activating radiation. Films of fluorine resin, polycarbonate resin, polyethylene resin, cellulose acetate resin, polyester resin, or like films can be used in Fluorine invention. Fluorine resin film is easily cleaned and is a preferred material for carrying out the present invention because a photosensitive plate made of this material can be repeatedly used through the process steps of development, image transfer, and cleaning.

Photosensitive plates employable in the process of this invention include other photosensitive plates disclosed in application Ser. No. 571,538 in addition to those discussed above.

The following are the explanations of the processes of this invention for forming the electrostatic image on translucent insulating layer 3 of photosensitive plate A. The first explanation is with respect to the photosensitive plate whose support member 1 is made of conductive material.

FIG. 2 through FIG. 5 are diagrams showing the charge patterns of the photosensitive plate and process steps for forming the electrostatic image on the surface of the translucent insulating layer of the photosensitive plate. The initial or primary charging process step (FIG. 2) is followed by the process step of irradiation of the original image while applying AC corona discharge (FIG. 3*a*) and results in the formation of the electrostatic image as shown in FIG. 3*a* in accordance with the light and dark pattern of the original image. Then, the process step (FIGS. 4*a*, *b*) of charging in polarity opposite to the polarity of primary charging is carried out to form on the surface of the translucent insulating layer a further electrostatic image having the same pattern as in FIG. 3 but having an electric charge different from that in FIG. 3. The final process step (FIG. 5) of irradiating light rays on the entire surface of the translucent insulating layer (blanket radiation) produces electrostatic images having enhanced contrast as compared with previous electrostatic images on the translucent insulating layer.

The potentials on the surface of the translucent insulating layer during the respective process steps are shown in FIG. 6.

First of all, the surface of translucent insulating layer 3 of photosensitive plate A is charged uniformly in a predetermined polarity in a dark or a light place, such as in the positive, by conventional charging means such as the electrode-roller (not shown) or corona discharger 5 connected to high-voltage electric source 4 as is shown in FIG. 2.

When the surface of translucent insulating layer 3 is charged in the positive, translucent insulating layer 3 works as a condenser, and a charge of opposite polarity to the polarity of the primary charge is accumulated between translucent insulating layer 3 and photoconductive layer 2, as well as in the vicinity of the interface thereof. This charge is considered to comprise anyone of or a mixture of free carriers of photoconductive layer 2, photocarriers, and carriers injected from support member 1. Said accumulated charge is bound strongly in the photoconductor composing the photoconductive layer, and is of opposite polarity to the charge on the surface of the translucent insulating layer. In this process step, the potential on the surface of the translucent insulating layer 3 increases with time, as shown by Vp in FIG. 6, and in particular, the polarity of the primary charge in said charging process is determined by the property of the photoconductor. In other words, where the photoconductive layer is mainly composed of *n*-type semiconductor such as CdS or ZnO, it is preferable to charge in the positive, and where the photoconductive layer is mainly composed of *p*-type semiconductor, it is preferable to charge in the negative. But, this is not an absolute rule, and when the photoconductive layer is charged with opposite polarity to that of the charge in the above given examples, an electrostatic image can be obtained although the contrast is lowered.

Next, as is shown in FIG. 3*a*, while the light image, obtained by transmitting activating radiation through original image 8 having light area 6 and dark area 7, is irradiated on translucent insulating layer 3 by reflection or direct transmission, AC corona discharge is applied to translucent insulating layer 3 by AC corona discharger 10 connected to high-voltage AC electric source 9.

As the means for carrying out AC corona discharge with the irradiation of the original image onto the translucent insulating layer 3 of the photosensitive plate, it is preferable to use an AC corona discharger having a shield plate the upper portion of which is translucent or otherwise optically open, i.e., without an upper shield, and the original image is irradiated onto the photosensitive plate through said discharger. Where the photosensitive plate is moved relative to such means, the plate is subjected to image radiation and AC corona discharge simultaneously, i.e., at the same time, as shown in the apparatus of FIG. 9.

As is shown in FIG. 3*a*, when AC corona discharger 10 whose upper portion is optically open is moved, translucent insulating layer 3 is charged with the AC corona discharger in the period during which the light image of the original image is irradiated on the surface of the translucent insulating layer through the AC corona discharger. Of course, the AC corona discharger may be fixed, and the original image and the photosensitive plate may be moved relative thereto.

In this case, it is preferable that the effective discharge area of the AC corona discharger comprise the slit exposure width of the original image.

As mentioned above, when the irradiation of the original image and the AC corona discharge are carried out in light area L of the original image, as is shown in FIG. 3*a*, the positive charge formed by primary charging on the surface of

translucent insulating layer 3 is wholly or mostly discharged by the application of AC corona discharge. The amount of the discharge depends on the time and the strength of AC corona discharge. In this case, the resistance of photoconductive layer 2 is reduced by the original image irradiation and it becomes conductive. The negative charge bound at the interface between photoconductive layer 2 and translucent insulative layer 3, or in the vicinity of translucent insulating layer 3 and inside photoconductive layer 2, becomes free, and the negative charge is reduced in accordance with the reduction of the positive charge on the surface of translucent insulating layer 3. Most of the charge is discharged to conductive support member 1. Therefore, the surface potential of translucent insulative layer 3 is reduced with the time of AC corona discharge as shown by V_L in FIG. 6. In this case, when the voltage of AC corona discharge is sufficiently elevated, for example above 7 kv., and the discharge time is sufficient, it is possible to charge the translucent insulative layer surface more or less in the negative.

In dark area D of the original image, the positive charge formed on the surface of translucent insulating layer 3 by primary charging is discharged by the applied AC corona discharge, but the degree of discharge is less than in light area L of the original image. This is considered to be attributed to the fact that the negative charge bound inside of photoconductive layer 2 in the vicinity of translucent insulating layer 3 or at the interface of photoconductive layer 2 and translucent insulating layer 3, remains without being discharged by the AC corona discharge since the resistance of photoconductive layer 2 is high and the positive charge on the surface of the translucent insulating layer 3 is retained by the bound negative charge and therefore the degree of the discharge is low.

However, since the external field resulting from the negative charge bound inside photoconductive layer 2 is strong, the surface potential in dark area D of the original image is lower than the surface potential in light area L as shown by V_D in FIG. 6.

If light is irradiated on the entire surface of the translucent insulating layer at this time, the charge pattern shown in FIG. 3*b* would be produced.

As discussed above in connection with light area L, when the AC corona discharge voltage is sufficiently elevated, for example, above about 7 KV, and the discharging time is sufficient, the surface charge of insulating layer 3 is more neutralized, and sometimes the surface potential of the insulating layer is slightly changed into negative potential by the field of the negative charge bound in photoconductive layer 2.

A difference of surface potentials (V_L–V_D) in accordance with the light and dark pattern of the original image is produced on the surface of translucent insulating layer 3 by these process steps, and an electrostatic image of the original image is thus formed thereon.

The contrast of said electrostatic image is changed, as is shown in FIG. 6, by the irradiation of the original image and the time for AC corona discharge. Therefore, in order to obtain higher contrast, it is necessary to appropriately select the conditions of irradiation of the original image and the time for applying AC corona discharge taking various kinds of conditions such as the photosensitive plate and discharging atmosphere, or the like, into consideration. In particular, when the thickness of photoconductive layer is substantially thicker than the translucent insulating layer, and when the bound charge is strong, an excellent result can be obtained.

After the irradiation of the original image and AC corona discharge are carried out for an appropriate time as mentioned above to form the electrostatic image on the surface of the translucent insulating layer 3, further charging of opposite polarity to the polarity of the primary charge is carried out on the surface of translucent insulating layer 3 in a dark place by using corona discharger 12 connected to high-voltage electric source 11 as is shown in FIGS. 4*a*, *b*. The surface of translucent insulating layer 3 is directly charged in the negative by this process step as respects original image light area L since the positive charge on the surface of translucent insulating layer 3 is remarkably little, if any, in light area L of the original image. The amount of negative charge increases as the charging time passes. On the other hand, in dark area D of the original image, the positive charge on the surface of the translucent insulating layer is neutralized (FIG. 4*a*), and with the passing of charging time, the entire surface of the translucent insulating layer is charged in the negative (FIG. 4*b*).

Thus, the electrostatic image formed on the translucent insulative layer in the preceding process steps does not change in pattern, but the charging state of the insulative layer surface is changed. The charging state of the photosensitive plate after this process step is shown in FIG. 4*b* and the surface potential of the translucent insulating layer is shown in FIG. 6 by V_{LD} and V_{DD}. In the primary stage of this process step (see FIG. 6, period t_{31}), fatigue exists in the photoconductive layer in light area L of the original image as a result of the light image irradiation in the immediately preceding process step, and the photoconductive layer thus has conductivity in area L to a certain degree. Therefore the electrostatic capacity of the electrostatic charge of the photosensitive plate in light area L of the original image is larger than the electrostatic capacity of static charge in dark area D. Accordingly, in the primary stage of the further electrostatic charging, the surface of the translucent insulating layer in light area L of the original image is charged more negatively than that in dark area D of the original image, and the two areas differ in degree of change of previous charge. The charge pattern of the photosensitive plate in such primary stage is shown in FIG. 4*a*, and the surface potential of the translucent insulating layer changes with charging time, as shown by V_{LD}, V_{DD} (within period t_{31}) of FIG. 6.

As is described hereinafter, when light rays are irradiated on the whole surface of the translucent insulating layer within period t_{31} (the time of negative corona discharge), the electrostatic contrast is higher than the case wherein the whole surface of the translucent insulting layer is irradiated by light rays without carrying out this process step of further charging after the completion of the preceding process step at $t=t_{30}$.

When this process step of further charging is carried out, the preexposure effect (fatigue effect) caused by the immediately preceding process step in light area L of the original image decreases as time goes by, and the difference between the electrostatic capacities of the photosensitive plate in light area L and dark area D of the original image reduces, and the negative charge bound at the interface between the photoconductive layer and the translucent insulating layer, or inside the photoconductive layer in dark area D of the original image, which remains after the immediately preceding process step, is dark attenuated with time. The external field caused by said charge is reduced, and the surface of the translucent insulating layer is negatively charged so as to compensate the decrease of the external field.

The negative charges on the surface of the translucent insulating layer in both the light and dark areas of the original image thus gradually become equal and the contrast of the electrostatic image is gradually reduced. The charge pattern of the photosensitive plate in the light and dark areas of the original image at time $t=t_{32}>t_{31}$ (FIG. 6) is shown in FIG. 4*b*.

When corona discharge continues further, the negative charges on the surface of the translucent insulating layer in the light and the dark areas of the original image finally become equal and the contrast of the static image is almost eliminated.

The surface potentials of the translucent insulating layer in the light and dark areas of the original image are represented by V_{LD}, V_{DD} of FIG. 6.

Where the polarity of the primary charge is negative, positive polarity is employed in this further charging process step. While the applied charge polarities are different, the same phenomenon occurs.

The contrast of the electrostatic image, i.e., $(V_{DDL_2}-V_{LDL_2})$ obtained when light rays are irradiated on the entire surface of said translucent insulating layer at the charging time of $t=t_{32}$,

as is described hereinafter is less than the contrast, $(V_{DDL_1}-V_{LDL_1})$, obtained in the case of charging to $t=t_{31}$. This tendency to lower contrast increases as charging time increases, and contrast is further reduced when the charging is carried out at $t>t_{32}$.

Thus, in this further charging process step, wherein corona discharge of polarity opposite to that of primary charge is applied to the surface of the translucent insulating layer, the charge state of the electrostatic image is changed, and the contrast of the static image is changed depending on the amount of said further charging. When the strength of corona discharge and the charging time are appropriately selected, the contrast of the electrostatic image can be optionally and easily adjusted. The time for irradiating the original image may be controlled to a certain extent in the preceding process step wherein irradiation of the original image and AC corona discharge are carried out. Particularly, when slit exposure is carried out as is shown in FIG. 2, exposure time is required to be remarkably short, and therefore it is very difficult to adjust the contrast of the electrostatic image by adjusting the amount of AC corona discharge which is applied during such exposure. Practically speaking such discharge adjustment is almost impossible. However, in the further charging process step, corona discharge is carried out alone, and therefore the amount of corona discharge may be adjusted by selection of discharging time, without regard for other conditions. The amount of the corona discharge can be adjusted in accordance with the state of the electrostatic image formed in the immediately preceding process step, and therefore adjustment of the contrast of the electrostatic image can be readily carried out.

When light rays are irradiated on the entire surface of the translucent insulating layer after completion of said further charging process step as mentioned above, almost no change is brought about in the state of photoconductive layer 2 in light area L of the original image, and the charged pattern is almost in the same state as in the preceding process steps as is shown in FIG. 5*a*. Therefore, the surface potential of translucent insulating layer 3, is almost uniformly maintained as shown by V_{LDL} of FIG. 6.

In dark area D of the original image, whereas photoconductive layer 2 exhibited high resistivity because no light irradiation has been applied thereto in the preceding process steps, in the present process step of surface irradiation, the resistivity is abruptly lowered and layer 2 becomes conductive because light rays are irradiated thereon. Therefore the negative charge bound in photoconductive layer 2 by the primary charging step is discharged into the conductive support member.

The amount of said bound charge which is discharged is related to the state of the plate following the preceding process step. Thus, positive charge existed more or less on the surface of translucent insulating layer 3 in the primary stage of the preceding process step (FIG. 4*a*), and, even if photoconductive layer 2 were rendered conductive by practice of the surface irradiation process step at this stage, the negative charge is still more or less bound in photoconductive layer 2 by the field produced by the positive charge on the surface of translucent insulating layer 3. However, as negative charge is accumulated on the surface of translucent insulating layer 3 during continuance of the preceding process step, charge bound in photoconductive layer 2 is dark attenuated and therefore when this process step of surface irradiation is carried out, almost all the negative charge bound in photoconductive layer 2 is discharged into conductive support member 1.

Thus, electrostatic charge of opposite polarity to that of the primary charge and bound thereby in photoconductive layer 2 in dark area D of the original image, i.e., in this case, negative charge, is discharged and therefore the effect on the external field caused by said charge is eliminated, and the field caused by the charge on the surface of translucent insulating layer 3 acts as a strong external field. The surface potential in dark area D increases abruptly with exposure time as shown in V_{DDL} of FIG. 6.

As stated above, when entire surface exposure in accordance with this process step is carried out, the surface potentials V_{LD} and V_{DD} of translucent insulating layer 3 become V_{LDL} and V_{DDL} respectively, and the contrast of the electrostatic image formed on the surface of translucent insulating layer 3, i.e., $(V_{DDL}-V_{LDL})$, is remarkably increased.

The contrast of the electrostatic image is greatly changed according to the degree of charge application in the preceding process step. As is shown in FIG. 6, the electrostatic charge contrast, obtained by practicing this process step of surface irradiation in the primary stage of the preceding process step of further charging (wherein the charging time t is $t_{30}-t_{31}$), is gradually increased from $(V_{DDL_0}-V_{LDL_0})$ to $(V_{DDL_1}-V_{LDL_1})$ and the increased amount is remarkably great. When this process step is practiced after completion of the preceding process step, for example, this process step is practiced at the end of the charging time of the preceding process step i.e., at $t=t_{32}$ $(>t_{31})$, the contrast becomes $(V_{DDL_2}-V_{LDL_2})$ and in this way, the contrast of the electrostatic image may be gradually decreased. Therefore, an electrostatic image of optional contrast may be formed on the surface of translucent insulating layer 3 by appropriately selecting various conditions such as charging time in each charging process step.

The electrostatic image formed on the surface of translucent insulating layer 3 in accordance with the above-described method, can be visualized as visible image 13 as is shown in FIG. 7 by developing the electrostatic latent image in accordance with conventional developing methods, such as cascade development, magnet brushing development, powder cloud development, liquid development or the like.

The contrast of the electrostatic image formed by the process of this invention is remarkably high, and when a positive-positive image is produced, dark area D of the original image, which is comparatively weakly charged as compared with light area L of the original image, is developed with toner charged in the same polarity of that of the charge applied to light area L and under the effect of the strong field caused by the greatly accumulated charge on light area L of the original image, fogless image can be obtained. The halftone reproductivity of the developed image is generally related to the degree of the electrostatic contrast, and according to the process of this invention, it is possible to obtain an image having desired halftone because the contrast of the electrostatic image can be optionally adjusted in the process of this invention.

When an electrostatic image of high contrast is developed, it is preferable in cascade development to use a heavy carrier, such as a carrier coated with resin uniformly having electrostatic charge controlling material on the surface of the metal or nonmetal particles (over 0.3 mg.).

When the so-called magneto-brush development is adopted, excellent results can be obtained when the iron powder is coated with resin in order to prevent the leakage of the charge on the surface of the highly insulating layer through the carrier. When a liquid development method is adopted, halogenated hydrocarbons, such as dimethyl polysiloxane or such like highly insulating carrier liquid containing pigment or dye-stuff dispersed therein bring about excellent results.

Whatever kind of developing method should be adopted, the electrostatic image is formed on the insulating layer as mentioned above, and positive or negative electrostatic image can be visualized, and electrostatic images of remarkably high contrast can be obtained, and therefore fogless visible image of very high density can be obtained. It is also possible to obtain a developed image having excellent halftone reproductivity.

The visible image 13 formed on the translucent insulating layer can be transferred in accordance with the method described in the specification of U.S. Pat. No. 2,637,651 to Copley wherein the visible image is transferred by applying an external voltage such as corona discharge or bias voltage, or in accordance with the method described in copending application, Ser. No. 571,538 wherein the visible image and the translucent insulating layer are charged in an optional polarity by corona discharge after development, and the visible image is

transferred. The image formed by the process of this invention can be transferred sufficiently only by placing a copying material **14** on the visible image under an appropriate pressure as is shown in FIG. **8**, and transfer of image can then be carried out.

In the electrostatic image formed on the translucent insulating layer in accordance with the process of this invention the charge on the surface of the translucent insulating layer in dark area D of the original image is little, and the external field is little as compared with that of light area L. When a positive-positive image is produced, under the strong field caused by the electrostatic charge greatly imparted to light area L of the original image, dark area D of the original image is developed with toner which is charged in the same polarity as that of the translucent insulating layer charge, and therefore the electrostatic adherence between the developed image and the translucent insulating layer is not so strong. Therefore, the developed image can be easily transferred. Since the charge pattern of the electrostatic image is obtained by the process of this invention as above, in the transfer of the image, when a copying paper is placed on the developed image, positive charge is induced on the copying paper by the negative charge of light area L of the original image, and the field thereof has the effect of attracting toner to the copying paper, and the image transfer is carried out more effectively.

The visible image transferred on copying material **14** is fixed with heat generated by infrared ray etc. to produce an electrophotographic image.

If photosensitive plate A is used repeatedly, after the transfer of the image has been carried out, charged particles of toner remaining on the surface of the photosensitive plate are removed by cleaning with conventional cleaning means such as a fur-brush. In the cleaning operation, the visible image formed by the process of this invention can be sufficiently removed by light brushing since the electrostatic adherence thereof to the translucent insulating layer is comparatively weak.

The effect of said cleaning depends on the adhesion characteristic of the material of the insulating layer. The above-mentioned resins are preferable as the materials for forming the electrostatic image of this invention, but among all these resins, fluorine resin film is excellent in nonadhesion, and when cleaning operation is carried out, the separation of the charged coloring particles is accelerated, and the cleaning effect thereof is remarkable.

The following is an explanation of the process in which an electrostatic image is formed on the translucent insulating layer of a photosensitive plate whose support member is composed of insulative material. This process is different from the aforementioned process in which the support member is conductive only in point that primary charge is applied by the double corona discharge from both sides of photosensitive plate or by placing the photosensitive plate on a conductive baseplate, but the process thereafter is exactly the same, and the relations of charged patterns, surface potentials, etc., are the same as in the process mentioned before.

Therefore, the polarity and the property of the electrostatic image formed on the surface of the translucent insulating layer are also the same as in said aforementioned process.

The following are concrete embodiments of the formation of electrostatic image in accordance with the processes of this invention. However, these embodiments do not restrict this invention by any means.

EXAMPLE 1

A photoconductive layer comprising a mixture of CdS activated by copper and epoxy resin, was coated on a support member of aluminum foil about 100 μ in thickness, and a 12.5 μ thick Mylar film was placed thereon to prepare a photosensitive plate, and a +8 kv. DC corona discharge was applied to the Mylar layer of the photosensitive plate to uniformly charge the surface of said Mylar layer.

Next, a positive image of 20 lux was projected through a 25 mm. wide slit on said Mylar layer at a speed of 10 cm./sec., and at the same time a 6 kv. AC corona discharge was applied.

Next, 5.5 kv. negative DC corona discharge was applied at a speed of 10 cm./sec. by using a corona discharger whose slit width was 25 mm., and the entire surface of said Mylar layer was irradiated with a 20 lux tungsten lamp for 1 second.

As a result, an electrostatic image having high contrast of about 1,500 v. was formed on the surface of said Mylar layer.

EXAMPLE 2

In example 1, the negative corona discharge in the third process step, was −8 kv., and other conditions were the same as example 1, and as a result, the static image formed on the Mylar layer had a contrast of about 700 v.

Apparatus by which the process of this invention may be carried out is shown in FIG. **9**.

In FIG. **9** photosensitive plate A comprises three layers as mentioned above and is provided on a rotary drum **105** with support member **101** earthed (B). Layer **102** is a photoconductive layer, and layer **103** is a translucent insulating layer. The surface of the translucent insulating layer is charged positively by charger **106**, and then irradiation of the original image by means of optical system **107** and AC corona discharge by means of the AC corona discharger **108** are simultaneously carried out, and an electrostatic image is formed on photosensitive plate A. Thereafter negative charge is applied to the translucent insulating layer by charger **109** to change the charge forming the electrostatic image.

Next, the entire surface of the translucent insulating layer is irradiated with tungsten lamp **110**, if necessary, to increase the contrast of said electrostatic image. Then the electrostatic latent image is developed with developer mainly composed of the charged coloring particles (toner) by means of developer **111**. The visible image is then transferred onto copying material **112**, and the transferred image is fixed by fixing lamp **113**. The remaining toner on photosensitive plate A is cleaned therefrom by cleaning means **114** to complete one cycle of the process. Thereafter, the same process is repeatedly carried out. The apparatus of FIG. **9** may be horizontally placed.

According to the processes of this invention an electrostatic image which is highly sensitive, of high contrast, sharp and fogless, can be obtained. The electrostatic contrast thereof can be adjusted optionally and easily and the transfer of the image and cleaning of the plate can be readily carried out, and the photosensitive plate can be used repeatedly for a long time. Like remarkable advantages will be evident.

This invention is not restricted to the above embodiments, and the improvements and modifications within the scope of the spirit of this invention fall into the scope of this invention.

What is claimed is:

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 overlying insulative layer comprising the steps of:
   1. applying a charge of first polarity to said insulative layer;
      a. while exposing said photoconductive layer to a pattern of image radiation,
      b. applying an alternating current discharge to said insulative layer; discontinuing said exposing and alternating current discharge applying and then
   3. applying a further charge to said insulative layer of polarity opposite to the polarity of said charge of first polarity.

2. The process claimed in claim **1** including further a terminal step of exposing said photoconductive layer to blanket radiation.

3. The process claimed in claim **1** wherein said photoconductive layer is exposed to blanket radiation during said application of said further charge to said insulative layer.

4. The process claimed in claim **2** wherein said steps of exposing said photoconductive layer to said pattern of image radiation and applying said alternating current discharge to said insulative layer are performed simultaneously.

5. The process claimed in claim 2 wherein said photoconductive layer is of *n*-type semiconductivity and said first polarity charge is of positive polarity.

6. The process claimed in claim 2 wherein said photoconductive layer is of *p*-type semiconductivity and said first polarity charge is of negative polarity.

7. The process claimed in claim 2 wherein said photoconductive layer is exposed to said pattern of image radiation through said insulative layer.

8. The process claimed in claim 2 wherein said photoconductive layer is exposed to blanket radiation through said insulative layer in said terminal step.

9. The process claimed in claim 2 including the preliminary step of exposing said photoconductive layer to blanket radiation and performing said step of applying first polarity charge to said insulative layer while performing said preliminary step.

10. A process for forming an electrophotographic image comprising the electrostatic image-forming process claimed in claim 2 and the further steps of:

1. applying a developer to said plate to visualize the electrostatic image latent in said plate;
2. transferring said visualized image onto a transfer member; and
3. fixing said visual image on said transfer member.

11. A process for forming an electrophotographic image comprising the electrostatic image-forming process claimed in claim 9 and the further steps of:

1. applying a developer to said plate to visualize the electrostatic image latent in said plate;
2. transferring said visualized image onto a transfer member; and
3. fixing said visual image on said transfer member.

12. The process claimed in claim 2 wherein said photoconductive layer is exposed to said pattern of image radiation through a corona discharger applying said alternating current discharge to said insulating layer.

13. The process claimed in claim 2 wherein said plate includes a conductive base underlying said photoconductive layer.

14. The process claimed in claim 2 wherein said plate includes an insulative base underlying said photoconductive layer.

15. The process claimed in claim 2 wherein said photoconductive layer includes a mixture of *p*-type and *n*-type semiconductors.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,615,395 Dated October 26, 1971

Inventor(s) Keizo Yamaji and Masayoshi Ishihara

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Item [73], Title page, "Canon Camera Kabushiki Kaisha" should read --Canon Kabushiki Kaisha--.

Column 2, line 68, "winging" should read --winding--.

Column 3, line 50, "Fluorine" should read --this--.

Column 7, line 74, "in" should read --by--.

Column 9, line 54, after "of" insert --the--.

Column 10, line 59, before "a." insert --2.--.

Signed and Sealed this

Thirty-first Day of May 1977

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks