

[54] **ELECTROPHOTOGRAPHIC COPYING MACHINE**[75] Inventors: **Toru Takahashi; Yoshio Ito**, both of Tokyo; **Hidejiro Kodowaki**, Yokohama, all of Japan[73] Assignee: **Canon Kabushiki Kaisha**, Tokyo, Japan[22] Filed: **May 15, 1972**[21] Appl. No.: **253,235**[30] **Foreign Application Priority Data**

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[52] U.S. Cl..... **355/3, 250/325**[51] Int. Cl..... **G03g 15/02**

[58] Field of Search..... 355/3, 16, 17, 11; 96/1; 250/324, 325, 366; 340/173 PP

[56] **References Cited****UNITED STATES PATENTS**

3,438,706 4/1969 Tonaka et al..... 355/11
 3,220,324 11/1965 Snelling 355/16
 3,527,941 9/1970 Culhane et al..... 355/3 X

3,536,483 10/1970 Watonabe et al..... 355/3 X
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 3,603,790 9/1971 Cleare..... 355/17

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[57]

ABSTRACT

An improvement of an electrophotographic copying machine is provided in which a plurality of grounded grid electrodes are interposed between image forming means and surface of a photosensitive member of the type comprising an electrically conducting support, a photoconductive layer and an insulating layer, wherein the image forming means includes a device for focusing a light image and simultaneously discharging the charged surface of the insulating layer. The perfect discharge of the surface of the photosensitive member can be attained with this apparatus an image having a high contrast, excellent tone reproducibility and uniform sensitivity may be reproduced without being adversely affected by the environmental conditions.

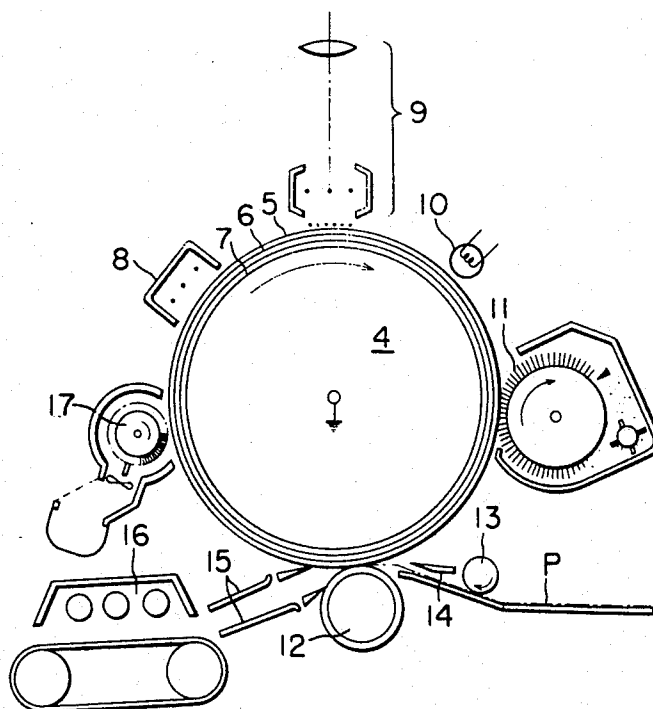
7 Claims, 11 Drawing Figures

FIG. 1a

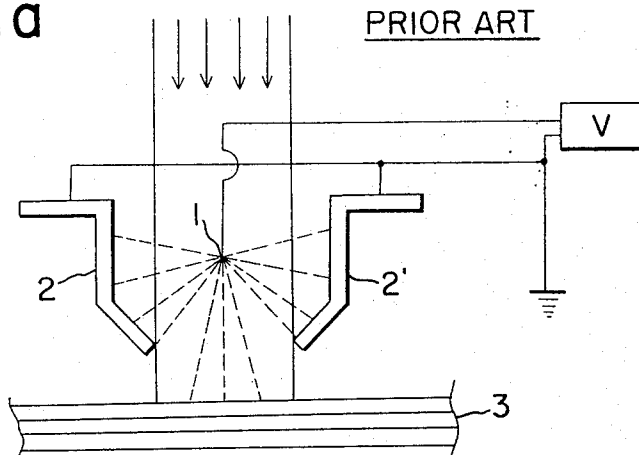


FIG. 1b

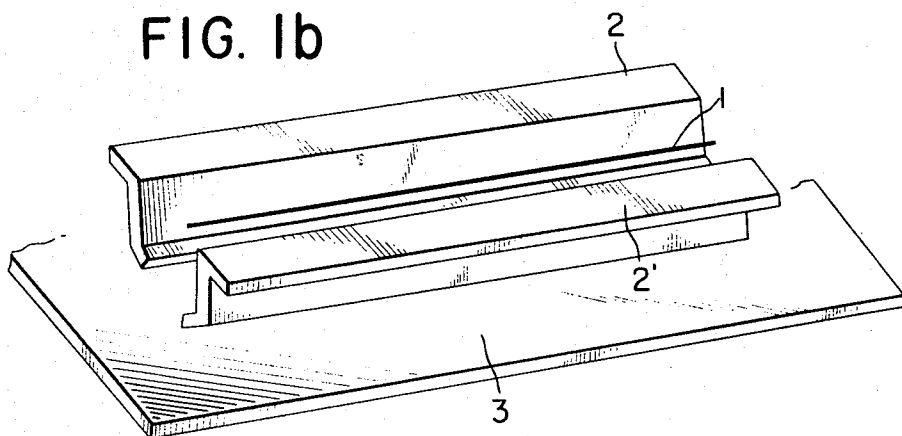


FIG. 3a

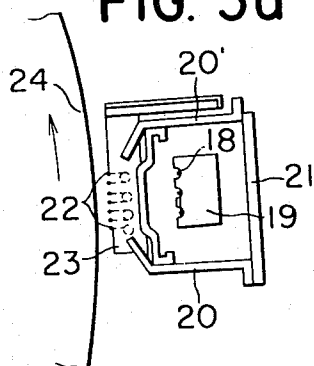


FIG. 3a'

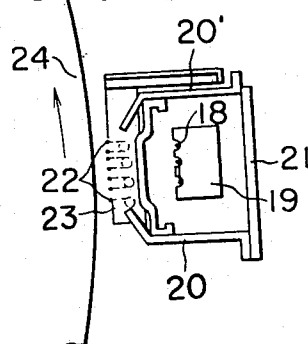


FIG. 2

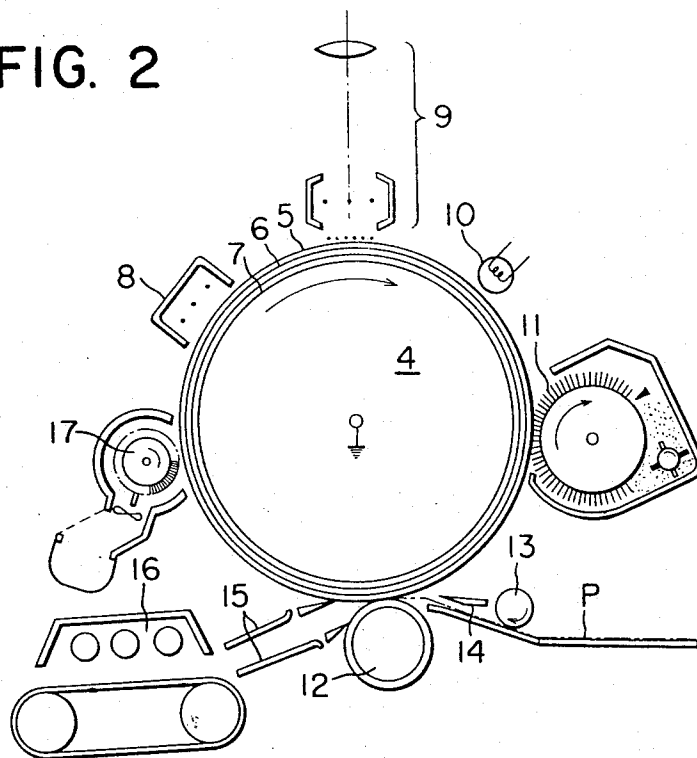


FIG. 6

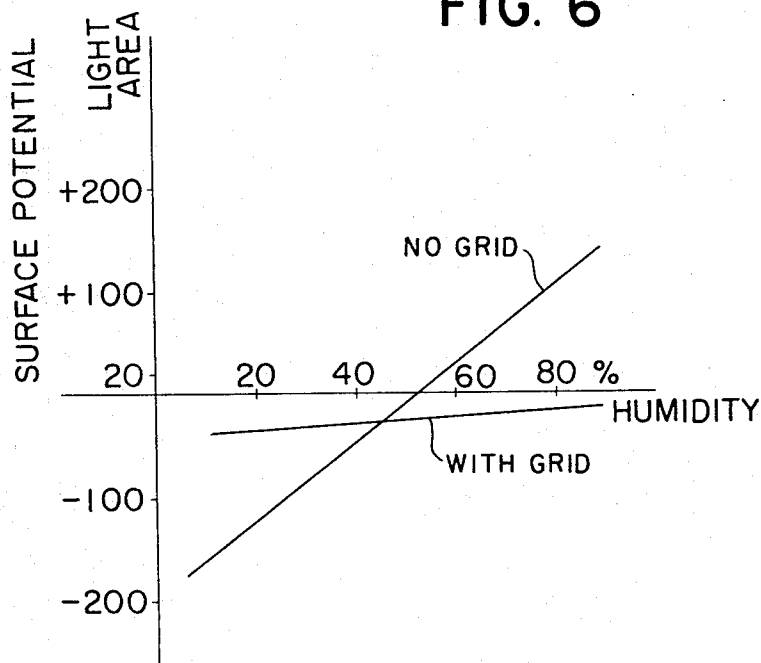


FIG. 3b

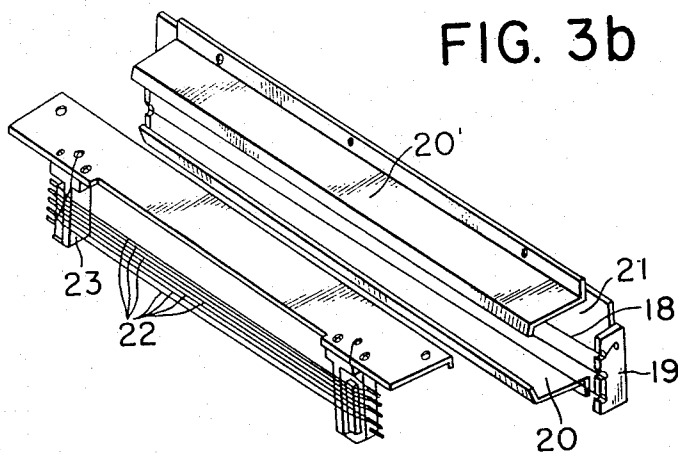


FIG. 4a

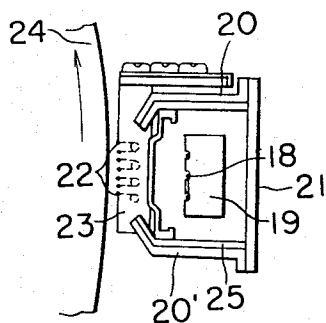


FIG. 4a'

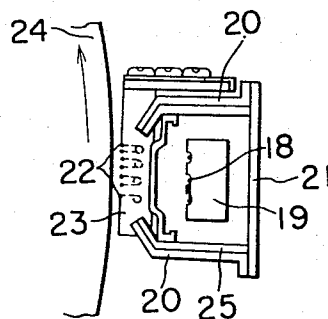


FIG. 4b

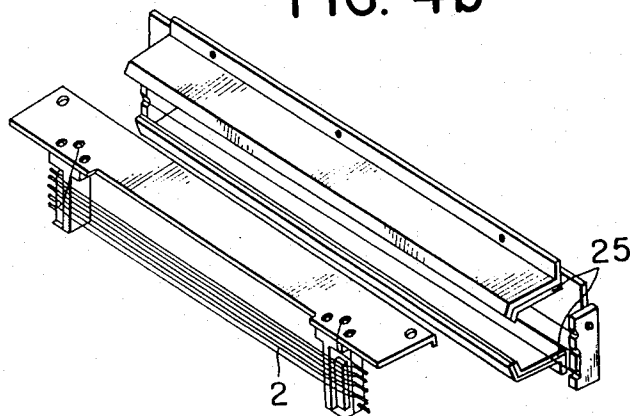
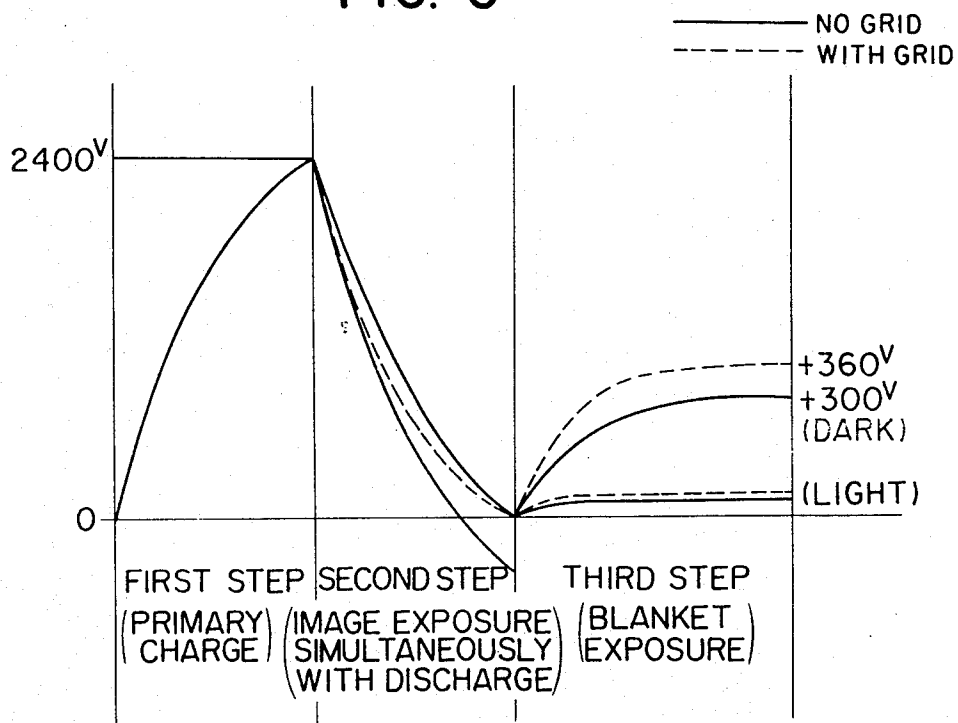


FIG. 5



ELECTROPHOTOGRAPHIC COPYING MACHINE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to an electrophotographic machine and more particularly an improved electrophotographic copying machine of the type which imparts a charge to or effects a d-c or a-c corona discharge upon the surface of a photosensitive member having an insulating surface, and simultaneously therewith projects a light image on that surface so that an electrostatic latent image having high contrast may be uniformly formed.

U.S. Pat. No. 3,438,706 owned by the same assignee discloses an electrophotographic process in which a photosensitive member comprises three layers consisting of an insulating layer, a photoconductive layer and an electrically conductive layer; or an insulating layer, a photoconductive layer and an insulating layer; or four layers consisting of an insulating layer, a photoconductive layer, an insulating layer and a conductive layer. In the first step, the surface of the insulating layer of the photosensitive member is imparted with a charge of positive polarity when the photoconductive layer is of N type material or with a charge of negative polarity when the photoconductive layer is of P type material so that a charge with the polarity opposite to that of the charge imparted upon the surface of the insulating layer is bound in the vicinity of the interface between the photoconducting layer and the insulating layer. In the second step, simultaneously with the projection of the light image of an original upon the surface of the charged surface of the insulating layer, the a-c corona discharge or d-c corona discharge with the polarity opposite to that of the charge imparted in the first step is imparted to the surface of the insulating layer so that the charge pattern on the surface of the insulating layer varies depending upon the black and white or bright and dark pattern of the copy. In the third step, the photosensitive member is uniformly illuminated by or exposed to the light blanket exposure so that the charge in the vicinity of the interface between the insulating layer and the photoconductive layer in the areas corresponding to the black or dark areas of the copy is released. Therefore, the electrostatic latent image whose contrast is so high that it may be detected as a variation in surface potential may be formed upon the surface of the photosensitive member. The electrostatic latent image thus formed is then developed into a visible toner image with charged pigment particles, and the toner image is transferred onto a recording medium, which is generally paper, under the effect of the internal or external electric field. The toner image transferred onto the recording paper is fused and fixed to the paper by heating with an infrared lamp. After the developed toner image has been transferred onto the recording paper, the surface of the photosensitive member is cleaned to remove the remaining developing agent for reuse. In the process described above, the charge imparted onto the surface of the photosensitive member will not be discharged only by the exposure to the light or by the corona discharge so that the photosensitive member must be discharged simultaneously by the light exposure and the corona discharge imparted to the surface of the photosensitive member.

In the electrophotographic process described above, it is very important that the surface potentials at the

bright and dark areas have the same magnitude when the light image is projected simultaneously with the discharge of the surface of the photosensitive layer in the second step. The potential difference between the unilluminated or dark and the illuminated or bright areas adversely affects the contrast of the electrostatic latent image. Therefore, it is preferred that the potential difference is minimized so that a high contrast may be obtained. However, the prior art corona discharging device which has been used in the second step of projecting the light image and simultaneously imparting the charge with the opposite polarity, or discharging the surface of the photosensitive member, is not satisfactory for attaining the above described condition.

DESCRIPTION OF THE PRIOR ART

In order to facilitate an understanding of the problems encountered in the prior art electrophotographic copying machines and of the advantage of the present invention, the prior art device for projecting a light image and simultaneously imparting a charge with a polarity opposite to that of the charge imparted by the first step or the a-c corona discharge will be briefly described with reference to FIG. 1 prior to the description of the preferred embodiments of the present invention.

A corona discharge wire of tungsten or the like is extended between a pair of spaced apart auxiliary electrodes 2 and 2' which define an optical aperture at the upper ends and an opening for corona discharge at the lower ends and which are generally grounded. A photosensitive member 3 having an insulating layer, the surface of which must be charged or discharged, is disposed in opposed relation to the opening for discharge of the device, and the high a-c voltage or the high d-c voltage with its polarity opposite to that of the charge on the surface of the insulating layer is applied to the corona wire. The uniform discharge of the surface of the photosensitive member 3 is effected when the latter is moved past the corona discharge electrode 1 and the auxiliary electrodes 2 and 2'. The lower opening serves not only for imparting the charge to the surface of the photosensitive member 3 but also for defining an optical slit through which the light image is projected onto the surface of the photosensitive member. The prior art device has the advantages that it is simple in construction and that it may discharge the surface of the photosensitive member without making contact with it, but it has the defect that when a d-c voltage is applied, the discharge of the surface of the photosensitive member becomes very difficult, and the surface of the photosensitive member is charged with the opposite polarity when the discharge speed is high. When an a-c voltage is applied, the surface of the photosensitive member may be discharged to zero volt but the variations in the surface potential after the discharge, the discharge speed, the discharge speed variation rate, and the discharge width are adversely affected by the environmental temperature and humidity and the variation in supply voltage. In the electrophotographic process of the type described above, in addition to the problem of the surface potential after the discharge, the above defects adversely affect the characteristics such as contrast, tone reproducibility, and uniform sensitivity, etc. of the electrostatic image. Therefore, the image formation factors tend to change so that the adjustment of the

electrophotographic copying machine becomes extremely difficult.

SUMMARY OF THE INVENTION

One of the objects of the present invention is therefore to provide an improved electrophotographic copying machine capable of reproducing the image with the high contrast, the better tone reproducibility and the uniform sensitivity.

Another object of the present invention is to provide an improved electrophotographic copying machine in which the discharge or charging in the second step of the electrophotographic process described above for projecting the light image and simultaneously charging or discharging the surface of the photosensitive member can be accomplished in an ideal manner so that a better image may be reproduced.

Another object of the present invention is to provide an improved electrophotographic copying machine in which a plurality of grounded grid electrodes are disposed in the proximity of the charging or discharging opening of the device used in the above-described second step of the electrophotographic process so that a better image may be reproduced.

Another object of the present invention is to provide an improved electrophotographic copying machine in which the arrangement of and especially the spacing between the grid electrodes disposed in the proximity of the charging or discharging opening of the device used in the second step are so adjusted that the better image may be reproduced.

Briefly stated, according to the present invention, a plurality of grounded grid electrodes are disposed in the proximity of the charging or discharging opening of the device used in the abovedescribed second step, and the spacing between the adjacent grid electrodes is adjusted so that the rate of variation of the discharge speed, the discharge speed, the discharged potential, and the relation between the discharge width and the exposure width may be controlled, thereby eliminating the defects encountered in the prior art electrophotographic machines described above.

According to one aspect of the present invention, the surface of a photosensitive member, consisting of a conductive support or base, a photoconductive layer and an insulating layer which constitutes the surface of the photosensitive member, is imparted with a positive or negative corona charge depending upon whether the photoconductive layer is of N or P type material, and in the second step when the light image is projected upon the surface of the photosensitive member, the surface thereof is imparted with a charge with the polarity opposite to that of the charge imparted in the first step by the d-c corona discharge or imparted with a a-c corona discharge. In a device used in the second step, a plurality of grid electrodes are interposed between the discharge means of the device and the surface of the photosensitive member. In the third step, the whole surface of the photosensitive member is illuminated or exposed to the blanket light. When the a-c or d-c corona discharge is made in order to remove the charge held on the surface of the insulating layer of the photosensitive member, the surface potential of the insulating layer approaches the grounded potential of the grid electrodes so that the discharge may be much enhanced. When the grid electrodes are not provided, the bright areas have surface potentials other than zero

volt because the bright areas have electrostatic capacitances higher than those at the dark areas so that the developing agent is apt to adhere to the bright areas, thus causing fogs.

The above and other objects, features and advantages of the present invention will become more apparent from the following description of the preferred embodiments thereof taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1a is a sectional view of a prior art device for projecting a light image and simultaneously discharging the surface of a photosensitive member;

FIG. 1b is a perspective view thereof;

FIG. 2 is a schematic side view of an electrophotographic copying machine in accordance with the present invention;

FIGS. 3a and 3a' are sectional views of a device for projecting a light image and simultaneously discharging the surface of the photosensitive member;

FIG. 3b is a perspective view thereof;

FIGS. 4a and 4a' are sectional views of a device for projecting a light image upon and simultaneously discharging the surface of the photosensitive member by the a-c corona discharge;

FIG. 4b is a perspective view thereof;

FIG. 5 is a graph illustrating the surface potential characteristic curves of the prior art electrophotographic copying machine and the photocopying machine in accordance with the present invention incorporating the grounded grid electrodes; and

FIG. 6 is a graph illustrating the effect of humidity variation on the surface potentials of the surface of the photosensitive member after the step of projecting the light image upon and simultaneously discharging the surface of the photosensitive member.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 2, a photosensitive drum 4 which rotates in the direction indicated by the arrow has a photosensitive layer formed around the outer periphery thereof and consisting of an insulating layer 5, a photoconductive layer 6 and an electrically insulating layer 7. Around the photosensitive drum 4 are disposed a first charger 8 for imparting the charge with a desired polarity upon the surface of the photosensitive drum 4, and a device 9 which imparts a charge with a polarity opposite to that of the charge imparted by the first charger 8 or impart the corona charge imparted by the first charger 8, or imparts an a-c corona when a light image of a copy is projected thereupon to form an electrostatic latent image. (The device 9 will be referred to as "a simultaneous-image-projection-and-charging device" hereinafter for brevity.) A grounded electrode grid is disposed in the lower opening of the device 9 in opposed relation to the drum 4. Next to the simultaneous-image-projection-and-charging device 10 is disposed a device for illuminating the whole surface of the photosensitive drum 4 so that the contrast of the electrostatic image may be improved. Next to the device 10 there is disposed a developing device 11 which is shown as comprising a dry process developing device having a magnetic or fur brush, but any wet process developing device of the type in which the photosensitive drum is partially submerged into a developing liquid solution

or a developing liquid solution may be sprayed over the photosensitive layer, may be employed. Next to the developing device 11 is disposed a developed or toner image transfer device or roller 12 to which is applied a bias voltage with the polarity opposite to that of the developing agent or toner so that a high efficiency is expected in transferring the toner image onto a recording medium P which is generally a sheet of paper. The recording paper P which is transported by a feed roller 13 and a guide 14 is pressed against the toner image upon the drum 4 by the transfer roller 12 so that the toner image may be transferred upon the recording paper P. In addition to the paper, the plastic sheets, the printing masters and the like may be used as the recording media. Next to the image transfer roller 12 is disposed the recording medium separating device which separates the recording paper P from the drum 4 so as to be fed through guide plates 15 into a heating-fixing device 16 where the toner is fused and fixed to the recording paper P. The copy is then discharged out of the photocopying machine.

The toner still remaining upon the surface of the photosensitive drum 4 after the image transfer may be cleaned by a cleaning device 17 which is shown as comprising a fur brush in the instant embodiment, but may be of any suitable type such as a rubber doctor blade.

FIGS. 3a and 3a' show sectional views of the simultaneous-image-projection-and-charging device which is denoted by 9 in FIG. 1. As illustrated the grid wires 22 may be equally spaced as shown in FIG. 3a, or their spacing may be varied as shown in FIG. 3a', wherein the distance between the wires is decreased in the direction of movement of the layer 24, thus gradualizing the equalization of the surface charges. Corona discharge wires 19 are supported by supporting members 19, and a pair of vertically spaced apart auxiliary electrodes 20 and 20' are disposed above and below the corona discharge wires and form an opening for discharge and an optical aperture through which the light image is projected upon the drum. The optical aperture is closed with a transparent electrode 21, and grounded grid electrodes 22 are disposed between the surface of the drum 4 and the discharge opening and are supported by supporting members 23.

The spacing between the grid electrodes 22 and the surface of the photosensitive layer 24 is preferably one to three millimeters; the spacing between the grid electrodes 22 and the corona discharge wires 18, 8 - 15 millimeters; and the spacing between the adjacent grid electrodes 22, two millimeters. The grid electrodes 22 may be disposed in equidistantly spaced apart relation or in such a manner that the spacings between the adjacent grid electrodes may be gradually reduced as shown in FIG. 3b in order to improve the discharge effect because the discharge speed is faster as the spacing between the adjacent grid electrodes 22 is wider whereas the surface potential of the photosensitive layer 24 approaches toward zero as the spacing becomes narrower. In the process in which an electrostatic latent image is formed only when a light image is projected simultaneously when the discharge is effected, the efficiency in light image projection may be enhanced when the discharge speed is faster so that the sensitivity may be improved. Furthermore, the discharge time may be reduced so that the dark decay of

the photosensitive layer may be decreased whereby the contrast of the image may be enhanced. Experiments conducted by the inventors show that a contrast of 460 volts was attained when the grid electrodes were not provided but when the latter were provided, the contrast was improved to 490 volts. Since the discharge opening also serves as an optical slit so that the length of the grid electrodes must be substantially equal to that of the optical slit.

In a simultaneous-light-image-projection-and-discharge device of the type shown in FIGS. 4a, 4a' and 4b, an a-c voltage is applied to the corona discharge wires so that the discharge efficiency may be much improved. Again, the spacing between the grid wires may be equal or varied as shown respectively in FIGS. 4a and 4a', and the device thus shown is similar in construction to that shown in FIG. 3 except that the auxiliary electrodes are covered with an insulating member 25. In the device shown in FIG. 4, the auxiliary electrodes 20 and 20' are grounded and a high voltage is applied to the corona discharge wires 18 from an a-c voltage source so that the positive voltage of a half cycle of the ac high voltage produces a positive corona discharge. As a result, the photosensitive layer 24 and the insulating member 25 are positively charged. The negative half cycle produces a negative corona discharge so that the electric fields produced around the corona discharge wires 18 and the insulating layer 25 become higher than when only the auxiliary electrodes 20 and 20' are provided because the insulating layer 25 has been charged positively in the preceding positive half cycle. In this case, the positively charged insulating layer 25 is neutralized by the negative corona discharge and then negatively charged. The negatively charged insulating layer 25 improves the positive corona discharge in a manner similar to that described above. The above positive and negative corona discharge operations are cycled and the efficiency in corona discharge can be much improved as compared with the device having no insulating layer 25. It is preferable to use a high frequency power source as the a-c power source for the simultaneous-image-projection-and-discharge device of the type shown in FIG. 4. In the device of the type shown in FIGS. 3a and 3a', the auxiliary electrodes 20 and 20', may be made solely of insulating material in order to increase the efficiency in a-c corona discharge. Since the effect of the grounded grid electrodes 22 can be attained as described hereinbefore with reference to FIG. 3, the efficiency in discharge may be much improved and the zero potential discharge may be accomplished in an ideal manner.

As described above, according to the present invention, the operation and efficiency of the discharge may be remarkably improved. The advantages of the simultaneous-image-projection-and-discharge devices in accordance with the present invention may be summarized as follows:

1. The discharge operation is reliable and dependable even if the environmental conditions and especially temperature conditions are varied.
2. The contrast of the image may be improved.
3. Irregular discharge due to the contamination and flaws of the discharge electrodes.

Next referring to FIG. 5, the advantages of the electrophotographic copying machine of the present invention incorporating the simultaneous-image-projection-and-discharge device will be described with relation to

the prior art photocopying machine. The data of the variation in surface potential of the photosensitive layer was obtained by the electrophotographic copying machine of the present invention and by the prior art photocopying machine of the type in which a photosensitive layer including an insulating layer is first charged by a first charger and charged again with the polarity opposite to that of the first charging, or by an a-c corona discharger, simultaneously when a light image is projected, whereupon the whole surface of the photosensitive layer is illuminated. When the prior art simultaneous-image-projection-and-discharge device is used after the surface of the photosensitive layer has been uniformly imparted with the high voltage charge of the order of 2,400 volts so that the areas representing white areas of the copy of the electrostatic latent image may be discharged to zero volt, the areas representing the black areas of the copy are discharged somewhat to the opposite polarity. So far it has been impossible to discharge both the bright and dark areas to a predetermined level. However, by the simultaneous-image-projection-and-discharge device in accordance with the present invention provided with the grounded grid electrodes, both bright and dark areas may be uniformly discharged to zero voltage. In the prior art machine, the contrast in voltage of the electrostatic latent image is low after the charge has been eliminated in the proximity of and from the interface between the photoconductive layer and the insulating layer by the whole-surface exposure, because of the potential difference in the bright and dark areas after the second step, that is, the simultaneous-image-projection-and-discharge. However, when the simultaneous-image-projection-and-discharge device having the grounded grid electrodes in accordance with the present invention is used, both the surface potentials at the dark and bright areas are discharged to zero volt so that the electrostatic latent image after the whole-surface illumination step may have the improved high contrast tone.

FIG. 6 illustrates the effect of environmental humidity upon the surface potential at the white area after the simultaneous-image-projection-and-discharge step, and prior to the whole-surface illumination. In the prior art machine, the effect of the humidity on the discharge efficiency is remarkable, but according to the present invention, the effect of the humidity may be negligible and the discharge efficiency is stable over the wide range of humidity variation.

From the foregoing description, it is seen that the electrophotographic copying machine in accordance with the present invention can reproduce copies at a high speed, with high contrast tone and uniform sensitivity. Since the effect of the humidity variation are minimized, the electrophotographic copying may be advantageously used in the areas of high temperatures.

The present invention is not limited to the embodiments described above, and various modifications and variations may be effected without departing the true spirit of the present invention.

We claim:

1. An electrophotographic copying machine comprising a photosensitive member having an insulating surface;

a first charger means for uniformly imparting a first charge upon the surface of said photosensitive member;

simultaneous-light-image-projection-and-discharge means for projecting a light image of an object to be copied upon the surface of said photosensitive member and simultaneously imparting a second charge to discharge said first charge imparted by said first charger means, said simultaneous-light-image-projection-and-discharge means comprising corona discharge electrodes, auxiliary electrodes surrounding said corona discharge electrodes and defining an optical aperture and an opening for discharge, and means for equalizing the surface charges including grounded grid electrodes disposed in the proximity of said discharge opening defined by said auxiliary electrodes; and means for blanket exposing the whole surface of said photosensitive member.

2. An electrophotographic copying machine as set forth in claim 1 wherein

said auxiliary electrodes are made of an electrically conducting material and are grounded.

3. An electrophotographic copying machine as set forth in claim 1 wherein

said grid electrodes comprise a plurality of wire electrodes.

4. An electrophotographic copying machine as set forth in claim 1 wherein

the spacing between the adjacent wire grid electrodes are made narrower in the direction of the movement of said photosensitive member relative to said simultaneous-light-image-projection-and-discharge means.

5. An electrophotographic copying machine comprising a photosensitive member having an insulating surface;

a first charger means for imparting a uniform first charge upon the surface of said photosensitive member;

simultaneous-light-image-projection-and-discharge means for projecting a light image upon the surface of said photosensitive member and simultaneously effecting an a-c corona discharge onto the surface of said photosensitive member, said simultaneous-light-image-projection-and-discharge means comprising corona discharge electrodes, grounded auxiliary electrodes surrounding said corona discharge electrodes and defining an optical aperture and an opening for discharge, an insulating member disposed over each of said auxiliary electrodes in opposed relation with said corona discharge electrodes, and means for equalizing the surface charges including grounded grid electrodes disposed in the proximity of said discharge opening; and

means for illuminating the whole surface of said photosensitive member.

6. An electrophotographic copying machine as set forth in claim 5 wherein

said grounded grid electrodes comprise a plurality of wire electrodes.

7. An electrophotographic copying machine as set forth in claim 6 wherein

the spacing between the adjacent wire grid electrodes are made narrower in the direction of the movement of said photosensitive member relative to said simultaneous-light-image-projection-and-discharge means.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,797,927

Dated March 19, 1974

Inventor(s) TORU TAKAHASHI, ET AL.

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

In the Abstract, line 4, after "and" insert --the--;

In the Abstract, line 11, after "apparatus" insert --so that--;

Column 1, line 26, after "material" insert --,--;

Column 3, line 35, "abovedescribed" should read --above-described--;

Column 4, line 26, "by the" should read --with an--;

Column 4, line 51, after "charger 8" insert --,--;

Column 4, lines 51/52, delete "or impart the corona charge imparted by the first charger 8,";

Column 4, line 52, after "corona" insert --discharge to the photosensitive layer of the drum 4, simultaneously--;

Column 4, line 59, after "device" delete "10";

Column 4, line 60, after "device" insert --10--;

Column 5, line 28, after "views" insert --and--;

Column 6, line 63, after "electrodes" insert --may be eliminated--;

Column 8, line 26, "in claim 1" should read --in claim 3--.

Signed and sealed this 30th day of July 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

UNITED STATES PATENT OFFICE
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