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ELECTROPHOTOGRAPHIC APPARATUS

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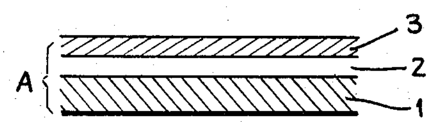
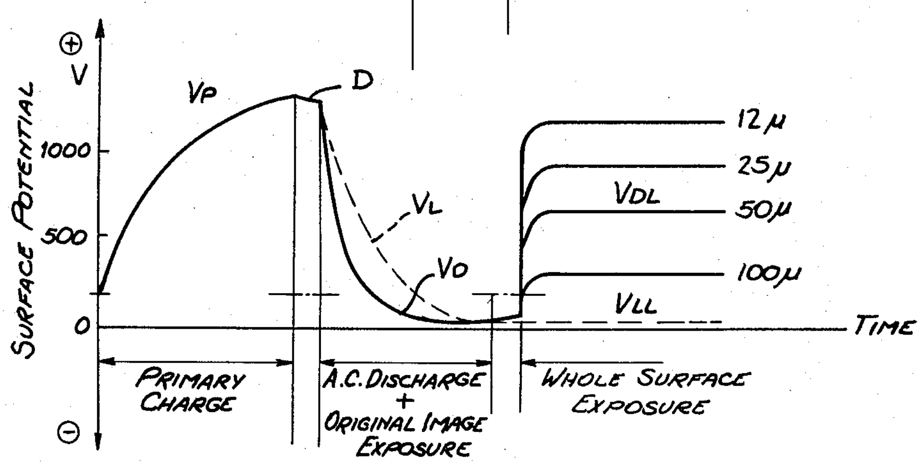


Fig. 1.

Fig. 2.



INVENTOR.
GIICHI MARUSHIMA
BY
Ward McElhannon Brooks & Fitzpatrick
ATTORNEYS

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ELECTROPHOTOGRAPHIC APPARATUS

Giichi Marushima, Tokyo, Japan, assignor to Canon Kabushiki Kaisha, Tokyo, Japan

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Int. Cl. G03g *13/22, 15/22*
U.S. Cl. 355—3 7 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus for forming an electrostatic image including a photosensitive plate having a base, a photoconductive layer overlying said base and an insulative layer overlying said photoconductive layer, said insulative layer having a thickness of from ten to fifty microns, including means for applying a charge of one polarity to said insulative layer, means for exposing said photoconductive layer to a pattern of image radiation while applying an alternating current discharge to said insulative layer to form an electrostatic image. The electrostatic image is intensified in contrast by thereafter exposing the photoconductive layer to radiation.

This application is a division of United States 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 apparatus for forming electrostatic and electrophotographic images and to photosensitive plates related thereto.

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 electroscopic 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 electrophotographic image. In accordance with 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 polarizing charge in the photoconductive layer, and then by irradiating the plate with an original image, an electrostatic image is obtained by persistent internal polarizing 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 as 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,

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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 a further method described in the specification 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 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 must be larger than the capacitance of the photoconductive layer, and from a practical point of view the thickness of the translucent insulating layer should be restricted within the range from 2 to 6μ.

Such thin insulating layers break down easily, and it is diffisult 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 change 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 said photosensitive plate; this aims 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 the dark to the surface of the insulating layer to neutralize the charge to form a surface field due to the induced charge layer. Thus the photosensitive plate is sensitized. Next, the light image is exposed to attenuate said induced charge and the latent image is formed by the charge remaining at the dark areas. This process is a Carlson-type process and the obtained contrast is as much as 300 to 500 volts.

In the photosensitive plate of the above-mentioned process, it is necessary that the overcoating layer be thin compared to the photoconductive layer. Therefore it is easy to bring about wear or breakdown or such like troubles and it is impossible to sufficiently protect the photoconductive layer.

An object of the present invention is to provide a new electrophotographic apparatus having a photosensitive plate of high sensitivity and high contrast which can be repeatedly used for a long period of time by overcoming the drawbacks of the above-mentioned conventional electrophotographic methods.

The above-mentioned object 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 used in the present invention; and

FIG. 2 shows relations between electrostatic image contrast and translucent insulating layer thickness.

In copending and commonly assigned U.S. patent application Ser. No. 571,538, filed Aug. 10, 1966, now abandoned, two electrostatic processes are disclosed.

One process involves forming an electrostatic image in a photosensitive plate having a conductive base, a photoconductive layer overlying the base and an overlying insulative layer, the plate being characterized in having carrier charge of a polarity corresponding to the conductivity type of the photoconductive layer injectable into the photoconductive layer and bound in the region of the interface between the insulative and photoconductive layers. In accordance with this process the insulative layer is initially charged with a polarity including injection and binding of carrier charge at the interface between the insulative layer and the photoconductive layer. The photoconductive layer is next exposed to a pattern of image light while the insulative layer is subjected to A.C. corona discharge whereby said interface charge is selectively discharged to form an electrostatic image. The electrostatic image is then intensified in contrast by thereafter exposing the photoconductive layer to radiation.

In another process disclosed in said copending U.S. application Ser. No. 571,538, an electrostatic image is formed on a photosensitive plate having an insulative base, a photoconductive layer overlying said insulative layer, and an insulative covering layer, and being characterized in exhibiting internal polarization when subjected to a charge. The insulative covering layer is initially charged in one polarity and is then subjected to A.C. corona discharge while the photoconductive layer is exposed to an image pattern. The photoconductive layer is thereafter exposed to activating light whereby an intensified electrostatic image is formed.

FIG. 1 is a diagram which shows the fundamental structure of an electrophotographic plate used in the processes for forming the electrostatic image in said U.S. application Ser. No. 571,538, 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 closely adhered on photoconductive 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 catching charge on the surface of photoconductive layer or in the neighborhood of the surface.

In the electrostatic image forming processes of the said copending application Ser. No. 571,538, it has been found that 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 in order to use 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.

When the translucent insulating layer is remarkably thin, less than 10μ, various kinds of drawbacks are introduced both in the process for forming an electrostatic image and in the production of the insulating layer. In other words, when the insulating layer is remarkably thin, thickness irregularity and pin holes are common, and it is difficult to obtain an insulating layer of high quality.

In the development of the latent image or in the copying of transferring process, uneveness is apt to be formed on the surface of the insulating layer because of the toner carried thereon, and when the insulating layer is remarkably thin, breakdown of insulation occurs easily at concaved portions by the application of high electrical fields in the charging process when irregularities are present. Breakdown of insulation is due to the partial deterioration of the insulating layer caused by corona discharge produced at small voids present in the insulating layer. When pin holes are present in the insulating layer, in the corona discharge, the pin hole portions are more quickly discharged, and this causes undesired foggy images.

On the other hand, in the charging process, corona discharge brings about the so-called corona deterioration wherein the surface of the insulating layer is burnt and when the thickness of the insulating layer is thin, the deterioration is accelerated by the high electrical field imparted in reverse proportion to thickness, and the photosensitive plate cannot withstand repeated application for a long period of time.

As mentioned above, when the translucent insulating layer is remarkably thin, there is likely to occur insulation breakdown, foggy image caused by pin holes, and acceleration of corona deterioration, all undesired phenomena.

In order to avoid these undesired phenomena, to obtain an excellent image, and to obtain a photosensitive plate which can withstand repeated usage for a long period of time, the thickness of the translucent insulating layer should be necessarily more than 10μ, as experiments have indicated.

On the other hand, when the thickness of the insulating layer is too thick, undesired fogginess occurs in the electrostatic image and image contrast is deteriorated.

In other words, when the translucent layer is thick the field on the surface of the insulating layer produced by the charge bound on the surface of the photoconductive layer is expanded resulting in image fogginess.

Furthermore, when the insulating layer is thick little charge is bound in the photoconductive layer in the primary charge step, and the external field produced thereby on the surface of the insulating layer is weak. Thus, when irradiation of the original image and alternating current corona discharge are carried out, the surface of the insulating layer being discharged is increased in the dark areas of the original image, and the surface potential between same and the light areas of the original image is reduced, and the contrast of the electrostatic image is deteriorated. When the whole surface of the insulating layer is thereafter uniformly irradiated with light, even though the charge bound in the photoconductive layer is then erased in the dark areas, the external field is not substantial because the surface of the insulating layer had been discharged by the alternating current corona discharge. As a result, the surface potential difference between the dark and light areas of the original image is not so apparent, and a high contrast electrostatic image is not provided.

Therefore, in order to obtain clear electrostatic image of high contrast there is a limitation on the thickness of the translucent insulating layer.

The inventors of the present invention carried out experiments with translucent insulating layers of various thicknesses and, by measuring the relation between the thickness of the insulating layer and the contrast of the electrostatic image formed, have succeeded in obtaining clear electrostatic image of high contrast when the thickness of the translucent insulating layer is less than 50μ. With photoconductive layers considered to produce the highest sensitivity and highest contrast in accordance with the present invention, namely, mixtures of sulfide of cadmium (CdS) or selenium compound (CdSe) or such like high photoconductor and vinyl resin as the binder at the ratio of ½ to $\frac{1}{10}$ by weight, the relation of contrast and translucent insulating layer thickness is shown in FIG. 19.

When a corona discharge of positive polarity is applied to translucent insulating layer 3, the surface potential of translucent insulating layer 3 is increased accordingly as the time passes, and the specific characteristic V_p is obtained.

After the completion of the primary charge, as shown at D in FIG. 2, the surface potential of insulating layer 3 is somewhat reduced. When light is irradiated onto the original image together with alternating current corona discharge, the surface potential of insulating layer 3 is indicated by the specific characteristics V_D at the dark areas of the original image and V_L at the light areas of the original image.

Next, when the whole surface of the insulating layer is irradiated, V_D and V_L, become the characteristics V_{DL} and V_{LL}, reversed when compared with the case of the preceding process, and at the same time the difference therebetween is increased. Thus, an electrostatic image of contrast equal to the surface potential difference, $V_{DL}-V_{LL}$ is formed on the formed on the surface of the insulating layer 3.

V_D and V_L shown in FIG. 2 are the characteristics for translucent insulating layer thickness of 50μ. These characteristics can be changed by changing the thickness of the transluent layer, and when the alternating current corona discharge voltage is made constant, the surface potential is reduced if the thickness of the translucent insulating layer becomes thick, and when the translucent insulating layer is too thick, as mentioned above, the difference between the surface potential at the dark areas V_D and the surface potential at the light areas V_L is reduced, and the contrast of the electrostatic image is deteriorated.

As determined in the experiments, excellent contrast is obtained when the thickness of the translucent insulating layer is less than 50μ.

Also, the difference of the surface potential $V_{DL}-V_{LL}$ between the light area and the dark area of the original image at the time when the irradiation is carried out throughout the whole surface, is greatly affected by the thickness of the translucent insulating layer 3, and as is shown in FIG. 2, the difference is increased as the translucent insulating layer becomes thinner.

In order to obtain excellent contrast, it is necessary to have surface potential difference over 500 v., and when the thickness of translucent layer 3 is more than 50μ, it is impossible to satisfy the said factor, and it is not preferable.

On the other hand, when the thickness of the translucent insulating layer is less than 50μ, the surface potential difference exceeds 500 v., and it is possible to obtain an electrostatic image of high contrast.

In the above-mentioned experiments, the thickness of the photoconductive layer was changed variously, and excellent results were obtained where the thickness of photoconductive layer 2 was within the range of 50 to 200μ. In these experiments, irradiation of the original image and application of alternating current corona discharge were carried out simultaneously. The same results were obtained when application of alternating current corona discharge was carried out right after irradiation of the original image.

I claim:

1. An apparatus for forming an electrostatic image comprising:
   - (a) a photosensitive plate comprising a base, a photoconductive layer overlying said base and an insulative layer overlying said photoconductive layer, said insulative layer having a thickness of from ten to fifty microns,
   - (b) means for applying a charge of one polarity to said insulating layer, and
   - (c) means for exposing said photoconductive layer to a pattern of image radiation while applying an alternating current discharge onto said insulative layer.

2. An apparatus for forming an electrostatic image comprising:
   - (a) a photosensitive plate comprising a base, a photoconductive layer overlying said base and an insulative layer overlying said photoconductive layer, said insulative layer having a thickness of from ten to fifty microns,
   - (b) means for applying a charge of one polarity to said insulative layer,
   - (c) means for exposing said photoconductive layer to a pattern of image radiation while applying an alternating current discharge to said insulative layer, and
   - (d) means for exposing said photoconductive layer to blanket radiation.

3. An apparatus according to claim 2, wherein said photoconductive layer exhibits p-type or n-type semiconductivity and said base comprises a conductive material.

4. An apparatus according to claim 2, wherein said photoconductive layer exhibits internal polarization characteristics.

5. An apparatus according to claim 4, wherein said base comprises an insulative material.

6. An apparatus according to claim 5, wherein said insulative base has a thickness of from ten to fifty microns.

7. An apparatus according to claim 2, wherein said photoconductive layer is from fifty to two hundred microns in thickness.

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JOHN M. HORAN, Primary Examiner

K. C. HUTCHISON, Assistant Examiner

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