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[54] REVERSAL DEVELOPING METHOD USING PHOTOCONDUCTIVE DEVELOPING ELECTRODE

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Related U.S. Application Data

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[51] Int. Cl. G03g 13/06; G03g 13/22

[58] Field of Search .... 96/1 R, 1 C, 1 SD, 1 LY; 117/17.5, 37 LE; 118/637; 355/3 DD, 10

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Primary Examiner—Roland E. Martin, Jr.

[57] ABSTRACT

A developing technique and apparatus is provided wherein an insulator having thereon an electrostatic latent image is positioned across a gap from an electric field controlling insulator. The gap is provided with developing particles, charged with the same polarity as the electrostatic latent image. The electric field controlling insulator is designed to have a surface potential characteristic similar to the insulator upon which the electrostatic latent image is formed, and is charged to the same level and with the same polarity as the image. As a result, the electric field controlling insulator will have a field variation compensation effect relative to the electric potential otherwise generated by the electric field controlling insulator.

10 Claims, 2 Drawing Figures

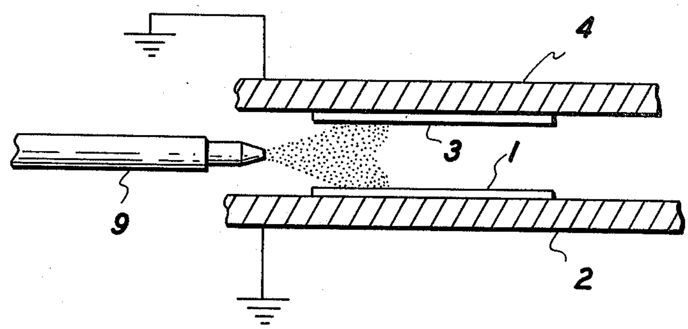
4
3
1
9
2

FIG. 1

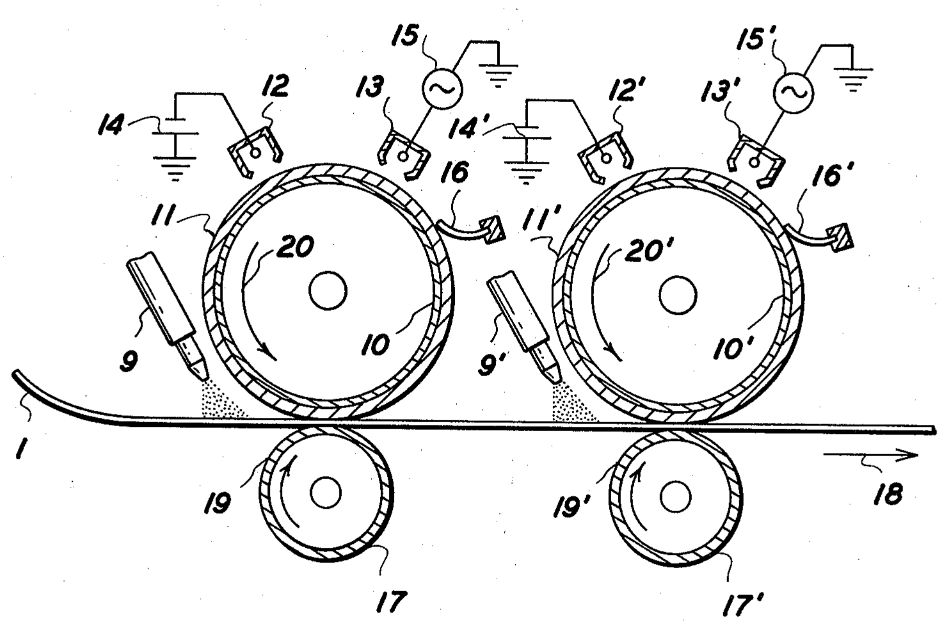
15
15'
14
12
13
14'
12'
13'
16
16'
11
20
11'
20'
9
10
9'
10'
1
19
19'
18
17
17'

FIG. 2

REVERSAL DEVELOPING METHOD USING PHOTOCONDUCTIVE DEVELOPING ELECTRODE

This is a division, of application Ser. No. 210,883, filed Dec. 22, 1971 is now U.S. Pat. No. 3,800,744.

This invention relates to electrostatographic development methods and apparatus and particularly to a development method and apparatus for the reversal development of electrostatic latent images.

Devices and development techniques are known in which electrostatic latent images are formed on an insulator, such as a photoconductive insulating layer, in the form of a variation in electric charge patterns. Such electrostatic latent images are developed by application of charged developing particles thereto. The relative charges of the image and particles are such that the quantity of developing particles attracted to the image-containing insulator surface will vary inversely with the quantity of charge forming the electrostatic latent image. In other words, the portion of the surface having maximum electric charge will have little or no developing particles attracted thereto, whereas the portion of the surface having a lesser charge will have correspondingly greater amounts of developing particles adhered thereto. Such techniques may be referred to as reversal development.

As is known in conventional electrostatographic reversal development, when developing particles having a polarity identical to the latent image are directed towards an electrostatic latent image on an insulator, the particles are not attracted to that portion of the image having a charge of the same polarity as the particle but rather to the portion of the image having an electrical charge of relatively opposite polarity. Adherence of developing particles occurs principally in areas of electric field gradients and relatively few particles adhere to that portion of the image having a uniform charge density level.

One known technique of eliminating the foregoing disadvantage is to provide a developing electrode with an externally applied DC voltage equivalent to the charge retention portion of the image surface, that is, the surface electric potential of the electrostatic latent image portion which has the maximum clectric charge density. The charge dissipating or image portion is thus characterized by an electric field, between the developing electrode and the image storing insulating layer, proportional to the difference between the maximum charge density of the image and the developing electrode. This method however suffers from certain decremental effects. Particularly, the insulator material containing the latent image has a surface potential characteristic resulting in the electrostatic latent image portion of an insulator decaying during dark or non-imaging periods with the passage of time. This time dependent decremental dark decay will vary markedly in accordance with the type of insulator employed and with ambient conditions, and it is extremely difficult to vary the voltage applied to the development electrode to compensate for each decremental variation of the image strength.

Further, when the insulating medium containing the image is flexible, it is difficult to control development. Particularly, in reversal development, variation in distance between the fixed development electrode and the image will alter the field characteristics and thus the degree of particle adherence. As a result, unwanted development variation may be observable in the developed image.

It is therefore the prime object of this invention to provide a novel and unique method and apparatus permitting charged particle development with a particle adherence distribution necessary for development.

It is a further object of this invention to provide a novel and unique method and apparatus for permitting charged particle development which will take image decremental effects into account.

It is another object of this invention to provide a novel and unique reversal development method and apparatus which will prevent developed image variation as a result of variations occurring in the distance between the development potential applicator and the image surface.

It is a still further object of this invention to provide a novel and unique apparatus for developing an electrostatic latent image formed on an insulator by the use of charged development particles.

The foregoing objects are achieved by a method and apparatus wherein an insulator having thereon an electrostatic latent image formed as a pattern of charged and discharged areas is positioned across a gap from an electric field controlling insulator which is, in turn, charged to the same level and polarity as the image charged area. The gap is provided with developing particles, also charged to the same level and polarity as the electrostatic latent image pattern charged area. The electric field controlling insulator is designed to have a surface potential characteristic similar to the insulator upon which the electrostatic latent image is formed. As a result of the foregoing arrangement, the electric field controlling insulator, which replaces the prior art developing electrode, provides a continuous field variation compensation effect relative to the electric potential otherwise generated by the electric field controlling insulator since both the insulator and image surface will provide similar variations to their respective charge levels due to any variation resulting from the physical characteristics of the respective layers.

In electrophotographic methods by reversal development, particularly employing a flexible layer with electrostatic latent images, it is difficult to maintain the correct distance from the image layer to the developing electrode. As a result, the development may have a tonal non-uniformity corresponding to any distance variation. The present invention overcomes the foregoing problem by replacing the fixed external voltage source supplying a developing electrode with the electrostatically charged field controlling insulator which is provided with the desired charge level but since the fixed external source is absent, it will compensate for distance variation between the latent image surface and the development electrode, and thereby produce developed images of higher quality.

The foregoing objects and brief description of the present invention, as well as further objects, advantages and features will become more apparent in view of the following more detailed description and appended drawings wherein:

FIG. 1 is a front elevation illustrating the operative principle of the invention, and,

FIG. 2 schematically represents a front elevation view of a preferred embodiment in accordance with the invention.

Referring to FIG. **1**, electrically photosensitive papers **1** and **3** having the same composition are shown, each having uniformly charged photoconductive insulating surface layers on the facing sides thereof, and each contacting conductive plates **2** and **4** respectively on the other side thereof. After both papers have been uniformly charged to the same polarity, paper **1** is exposed to the image to be reproduced to form an electrostatic latent image thereon. The photoconductive insulating layers of both of the electrically photosensitive papers **1** and **3** are positioned to face each other across a gap having a relatively small fixed dimension, and each of conducting plates **2** and **4** is grounded. With the foregoing construction, the maximum charge density portion, i.e., the non-image portion of the electrostatic latent image of electrically photosensitive paper **3** corresponds approximately to the uniform charge density portion of electrically photosensitive paper **1.** When a charge pattern corresponding to an image is formed on paper **1,** an electric field in proportion to the difference between the image charge pattern and the maximum charge density portion of paper **3** will be generated in the gap or developing space between said photosensitive papers **1** and **3.**

Developer is supplied to this developing space by means of a developer supplying nozzle **9.** The form of developer can, for example, be an insulating liquid such as kerosene having dispersed therein fine carbon black powder as developing particles. The mixture may include electric charge stabilizers and dispersant stabilizers.

Where an electrostatic latent image is to be formed by negative charge, developing particles are negatively charged beforehand. The developing particles thus supplied to said developing space adhere, by electrostatic attraction, to the lesser charge density portion which forms the electrostatic latent image and do not adhere to the portion having maximum charge density.

Thus, the electrically photosensitive paper 1 containing the image to be developed is exposed to a charged electrically photosensitive paper 3 which is of the same composition as the photosensitive paper **1.** By replacing the prior art developing electrode and its externally applied fixed voltage source with a charged photosensitive layer of the same composition as the layer containing the electrostatic latent image, any variation in characteristic of the image surface due to ambient or decremental effects will be compensated by a corresponding change in the characteristic of the electric field controlling insulator **3.** Development is thus realized under optimum conditions, since the surface electric potential of the photosensitive surface **3** and the maximum charge density portion of the electrostatic latent image on photosensitive surface **1** are equalized at all times.

In general, where an electrostatic latent image is formed by exposing the uniformly charged photosensitive paper **1** to a light image, the maximum charge density portion of the paper **1** is more or less reduced when compared with that prior to image exposure, and the electric field thus generated between such surface and the photoconductive insulating layer of the photosensitive paper **3** acting as the electric field controlling insulator will result in fog. To prevent the fog condition, the photoconductive insulating layer of the photosensitive paper **3** may be uniformly exposed or charged to the desired degree beforehand, and such fog can be prevented.

In prior methods wherein a fixed voltage is applied from an external source to a developing electrode, it has been found that desired differences in density are difficult to achieve, particularly with an image developed under conditions of uncontrollable differences of distance from the electrode to the photosensitive image surface or paper. If the distance between the developing electrode and the photosensitive paper becomes relatively smaller, the electric field becomes stronger, resulting in more developing toner applied during developing and consequently a variation in tone is obtained. The field strength increases since the voltage at the developing electrode from the outside power source is maintained stable at all times.

The foregoing disadvantage is obviated by the present invention wherein an electric field controlling insulator **3** is charged to serve as the developing electrode, and no fixed external power source is employed. Where a stronger field exists, the quantity of toner for adherence would tend to increase at an early stage since the electric field would be increased where the distance between the photosensitive paper and electric field controlling insulator is smaller than at other portions. However, in the absence of a fixed external source, the excess electrostatic energy accumulated on the electric field controlling insulator is consumed by the early adherence of particles, resulting in a decrease of the electric field potential at that area. As a result, the quantity of toner subsequently attracted for adherence at that area is reduced, and any non-uniformity which would otherwise be generated by this distance variation is automatically controlled by this self-compensating effect.

The arrangement shown in FIG. **1** is presented only as an explanation of the principles according to this invention. In actual use, it is somewhat uneconomical to actually perform development by means of the structure as shown therein, primarily because of the need for obtaining face-to-face registry of two sheets of electrophotosensitive paper. Further, there is a difficulty in supplying developer to the developing space between two sheets of paper.

Accordingly, FIG. **2** illustrates a preferred embodiment which employs the principle of the invention while eliminating the above difficulties. An electrically photosensitive paper **1** having an electrostatic latent image thereon is conveyed in the direction of the arrow **18** by means of a pair of developing rollers **10** and **10'**, and a pair of supporting rollers **17** and **17'**. Rollers **10** and **10'** and supporting rollers **17** and **17'** are rotated in the directions of the arrows **20** and **20'** and **19** and **19'** respectively, by an appropriate power source, which is not shown. One of the rollers may of course be actuated by friction derived by the rotation of the other roller.

The pair of developing rollers **10** and **10'** which may be of a metal construction are provided thereon with surfaces comprising electric field controlling insulators **11** and **11'**. In compliance with the rotation of rollers **10** and **10'**, these electric field controlling insulators **11** and **11'** are cleaned with cleaning brushes **16** and **16'** and the charge thereon is removed by alternating current corona discharge electrodes **13** and **13'** provided with voltage from alternating current high voltage power sources **15** and **15'**. These sources may, by way of example, provide an AC voltage in the range of from 2–10KV. Thereafter, in the direction of rotation, the insulators **11** and **11'** are provided with voltage by direct current high voltage sources **14** and **14'**. These sources may by way of example, provide D.C. voltage in the range of 2–10KV. Thereafter, the insulators **11** and **11'** are charged by corona discharge current from corona discharge electrodes **12** and **12'**. The polarity of charging is designed to be same as that of the charge which forms the electrostatic latent image.

Developer is supplied by nozzles **9** and **9'** to the portion or area where the charged electric field controlling insulators **11** and **11'**, and electrically photosensitive paper **1** are facing each other. In this embodiment, the latent image on the photosensitive paper **1** is positioned to directly contact the electric field controlling insulators **11** and **11'**. In general however, electrically photosensitive papers are designed, for example, with a surface layer comprising a mixture of photoconductive zinc oxide powder in a resin binder applied to the paper in a thickness of 5–20 microns. Normally the roller positions would allow substantial contact along the common line of passage of the paper **1** with the rollers **10** and **10'** but because of irregularities due to the coating on the paper surface, complete contact is not realized. Further, the surface results in the formation of an insulating liquid film thereon, and as a result, the surface is retained without contacting the electric field controlling insulators, thereby maintaining the desired spacing. Since the electric field controlling insulators **11** and **11'** are however normally non-electroconductive, there is no otherwise undesirable effects relative to the electrostatic latent image even though the insulators **11** and **11'** contact, in appearance, the latent image on photosensitive paper **1**.

The electrostatic latent image gradually approaches the electric field controlling insulators **11** and **11'** by means of the rotation of developing rollers **10** and **10'**. Development is effected as the photosensitive paper **1** converges toward a line of apparent contact with the insulators **11** and **11'**, finally contacts the insulators in appearance and then moves away from the insulators.

In many cases, one cycle of the above procedure is insufficient for development, and therefore it is preferred to repeat the cycle more than the two times shown, particularly in cases where additional development is necessary or gradational control is desired.

The direct current corona discharge mechanism charges the insulators to a level at which toner will adhere to the electrostatic image, or in other words, a charge level equivalent to the portion of the image having the highest electric potential. Such potential would generally be in the range of 30 to 200 volts, however a range of from several to 800 volts may be employed depending upon the photosensitive paper to be used.

When the latent image portion of the paper subjected to development advances to further development by developing roller **10'**, after having been developed by a developing roller **10**, sufficient time will have passed for the electric potential of the electrostatic latent image to decrease due, for example, to the dark decrement described above. Therefore, the charging of the electric field controlling insulator **11'** by direct current corona discharge may, of necessity, be designed to be effected at a level less than that of the electric field controlling insulator **11**, thereby maintaining the desired charge difference.

In practice, the electric field controlling insulators used according to this invention will be subjected to repeated use. Accordingly, it is advantageous that the insulators be free from electroconductivity effects and it is therefore preferable that the insulation be designed so as to have an electrical surface characteristic which will correspond to the image surface while in liquid developer, particularly in regard to dark decrement effects. For example, in the case where a photosensitive paper is employed having a photoconductive insulating layer mainly comprising a mixture of photoconductive powder and insulating resin, the main component of the electric field controlling insulator should be made of an identical mixture in order to correspond to the property of the paper while in the liquid developer. The resistance is preferably controlled by an appropriate low resistance element, and a bulking agent. The electric field controlling insulator thus obtained can, by comparison, easily withstand repeated use. Slight variations in surface characteristics such as the property of decrement in the dark between the insulator having the electrostatic latent image thereon and the electric field controlling insulator may be disregarded, since the results will still be satisfactory. If however, correction is desired, the difference in decrement property of the insulator having the electrostatic latent image thereon and the field controlling insulator can be compensated by charging one relative to the other to the desired level in a uniform manner, whereby the best development may be carried out at all times. For example, if the decrement of electric potential of the electric field controlling insulator should be less than that of the charge on the photosensitive layer, it is still possible to prevent fog by decreasing, prior to development, the charge quantity of the electric field controlling insulator.

Any residual electric charge on the photosensitive insulator may be eliminated prior to the next charging cycle by uniformly exposing said insulator to light prior or subsequent to cleaning by cleaning brushes **16** and **16'**, or by use of a photoconductive insulator with the property of being resistant to charge after repeated use as the electric field controlling insulating layer, for example, a selenium evaporated metal layer.

Since the electric field controlling insulator is preferably charged to a level equivalent to that portion of the electrostatic latent image having a high electric potential as mentioned above, the use of a plurality of developing rollers allows the charge quantity of desired rollers to be successively decreased, thereby controlling gradation.

The rotating speed of the outside periphery of a developing drum is preferably designed to coincide to the moving speed of the photosensitive paper, primarily to enable the utilization of the self-compensating effect as described above, and also to prevent streaking in the developed image which would result from different relative speeds.

A conveying belt or other drive means may be used in place of retaining rollers **17** and **17'**. The requirement is only for a means of conveying the image surface to the developing drum. The developing drum may not only be cylindrical but the two drums shown may be combined into one, with both end portions having a slightly larger diameter than that of the middle portion, with a spacing from the image surface of at least 1 mm. If the space is too large, development becomes difficult due to edge effect.

While we have illustrated and described particular embodiments of our invention, it will be understood that various modifications may be made therein without departing from the spirit of the invention.

What is claimed is:

1. A method for performing reversal development of an electrostatic image comprising the steps of forming a latent image upon a first grounded photoconductive insulator as a pattern of charged and discharged areas, charging a second grounded photoconductive insulator spaced from the first photoconductive insulator, to the same level and polarity as said first photoconductive insulator charged area, and applying liquid developing particles to the space between said insulators, said liquid developing particles charged to the same level and polarity as said first photoconductive insulator charge area.

2. A method according to claim 1 comprising providing a first insulator and a second insulator having similar electric surface characteristics.

3. A method according to claim 2 wherein the first and second insulators are electrically photosensitive papers.

4. A method according to claim 1 further comprising recharging said second photoconductive insulator to the same level and polarity as a subsequently introduced photoconductive insulator to provide reversal development of an electrostatic image upon said subsequently introduced photoconductive insulator.

5. A method according to claim 4 comprising exposing said second insulator to light prior to recharging to eliminate residual electric charge remaining from the previous cycle.

6. A method according to claim 1 further comprising subjecting said first photoconductive insulator having a latent image formed thereon and developed by applying liquid developing particles to the space between said first and second photoconductive insulators, to at least one additional application of liquid developing particles in the space between said first photoconductive insulator and a subsequent photoconductive insulator, said subsequent photoconductive insulator being charged to the same level and polarity as said first photoconductive insulator.

7. A method according to claim 6 comprising charging said subsequent insulator by direct corona discharge at a level less than that of said second insulator to compensate for the decrease of the electric potential of the electrostatic latent image developed in the previous cycle.

8. A method according to claim 6 comprising successively decreasing the charge level on subsequent insulators spaced from said first insulator to maintain a charge level on said subsequent insulators equivalent to that portion of the electrostatic latent image having a high electric potential on said first insulator, thereby controlling gradation.

9. A method for performing reversal development of an electrostatic image comprising uniformly charging a first grounded photoconductive insulating layer and an electric field controlling second photoconductive insulator to the same level and polarity; forming an electrostatic latent image upon said first grounded photoconductive insulating layer as a pattern of charged and discharged areas; positioning said imaged first photoconductive insulating layer across a gap of small fixed dimension from said second photoconductive insulator, said second photoconductive insulator and said imaged layer having an approach converging toward a line of apparent contact but spaced therefrom at passage; and applying developing particles in the gap between said insulators, said developing particles charged to the same level and polarity as the imaged first photoconductive insulating layer.

10. A method according to claim 9 comprising applying developing particles in the gap between said imaged first photoconductive insulating layer and at least one additional electric field controlling photoconductive insulator charged to the same level and polarity as the imaged first photoconductive insulating layer.

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