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3,333,958

ELECTROPHOTOGRAPHIC DEVELOPING

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Fig. 1.

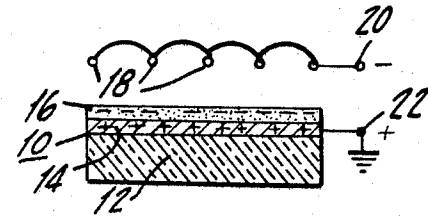
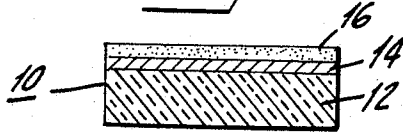


Fig. 2.

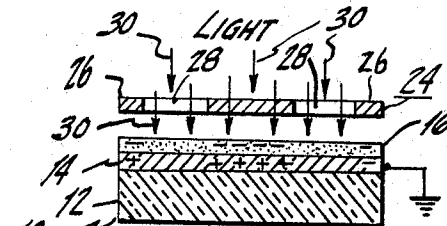


Fig. 3.

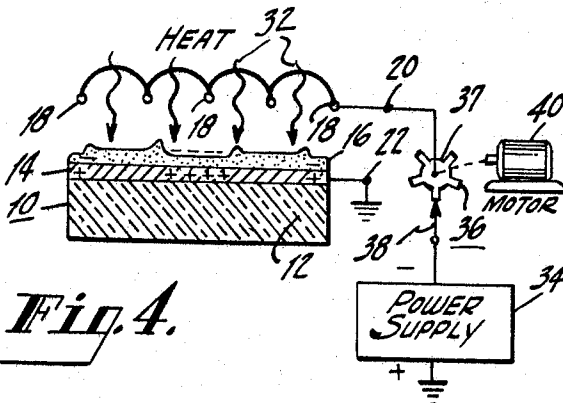


Fig. 4.

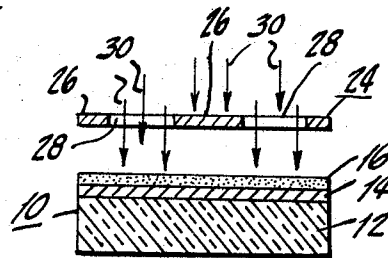


Fig. 5.

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ELECTROPHOTOGRAPHIC DEVELOPING

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This invention relates generally to the art of electrophotographic reproduction, and more particularly to an improved method of developing electrophotographic record elements of the type having a thermoplastic photoconductive layer. The improved method of the present invention is particularly, but not exclusively, useful for providing ripple images in electrophotographic record elements.

It has been proposed to form a ripple image in a thermoplastic photoconductive layer, hereinafter called "layer," of an electrophotographic record element by a developing process wherein the layer is first charged electrostatically and then exposed to a light image to discharge it selectively. Next, the record element is heated until the layer is softened. Then the electrostatic forces on the layer produce a ripple image of the latent image thereon. The record element is cooled, fixing, that is, freezing, the ripple image in the thermoplastic photoconductive layer.

It has been observed that the rate of decay of the electrostatic charge on the layer is markedly increased after the record element has been exposed to the light image and also during the heating process. Under these conditions, the retention of the electrostatic forces remaining on the layer, after the latter has been softened by heat, is desirably greater than is presently available in order to produce better ripple images, that is, images with better relief in the layer.

It is an object of the present invention to provide an improved method of producing ripple images of good relief in an electrophotographic record element.

Another object of the present invention is to provide an improved method of producing ripple images in electrophotographic record elements wherein an electrostatic charge which may have leaked off during the process is replenished.

Still another object of the present invention is to provide an improved method of developing an electrophotographic record element that is relatively easy to carry out and is highly efficient in producing ripple images of good relief.

Briefly stated, these and other objects and advantages of the present invention are accomplished by an improved method comprising the steps of (1) producing a light conductivity pattern in the thermoplastic photoconductive layer of a record element by exposing the layer to a light image, (2) heating the layer to soften it, and (3) charging the layer with an electrostatic charge periodically prior to and/or during at least a portion of the time the layer is being heated. The layer may, if desired, be charged with a uniform electrostatic charge before it is exposed to produce the conductivity pattern in it, but electrostatically charging the layer prior to producing the conductivity pattern is not necessary because the layer is charged electrostatically just prior to, and/or during the heating step in the improved developing method.

The novel features of the present invention, both as to its organization and operation, as well as additional objects and advantages thereof, will be more readily under-

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stood from the following description, when read in connection with the accompanying drawing, in which similar reference characters refer to similar parts throughout, and in which:

FIG. 1 is a cross-sectional view of an electrophotographic record element of the type used in the improved method of the present invention; and

FIGS. 2, 3, 4, and 5 are cross-sectional views of the electrophotographic record element in different stages of the improved method of the present invention for producing a ripple image in the thermoplastic photoconductive layer of the record element.

Referring, now, particularly to FIG. 1 of the drawing, there is shown an electrophotographic record element 10 having either a flexible or a rigid substrate 12, such as "Mylar" or glass, a transparent or reflective conductive layer 14, such as tin oxide or aluminum, and an essentially transparent, thermoplastic photoconductive layer 16. The photoconductive layer 16 may comprise a solid solution of a leucobase dye intermediate, such as the leucobase of malachite green, in a thermoplastic resin, such as styrene. The photoconductive layer should be heat deformable over a relatively narrow range of temperatures.

A ripple image may be formed in the layer 16 of the record element 10 by one embodiment of the improved method of the present invention, the steps of which are illustrated in FIGS. 2, 3, and 4. The layer 16 is charged electrostatically with a uniform electrostatic charge by any suitable means, as by a corona discharge device, known in the art. Referring to FIG. 2, there is shown a plurality of interconnected wires 18, in cross-section, from which a corona discharge may be produced. The interconnected wires 18 are connected to a voltage terminal 20, and the conductive layer 14 is connected to a voltage terminal 22, the latter being connected to a common terminal, such as ground. A source of unidirectional high voltage of about 6,000 volts (not shown) may be connected between the terminals 20 and 22 to provide the corona discharge. When the negative terminal of the power supply is connected to the terminal 20, the layer 16 is charged negatively, as indicated in FIG. 2.

The record element 10 is now exposed by a light image to produce a conductivity pattern, as well as an electrostatic latent image in the layer 16. The layer 16 may be exposed to the light image through a mask 24 having dark areas 26 opaque or partially opaque to light and light transmitting areas 28. Light, illustrated by the arrows 30, passing through the light transmitting areas 28 of the mask 24 discharges the photoconductive layer 16 selectively in accordance with the intensity of the light impinging thereon, as illustrated in FIG. 3. The portions of the layer 16 beneath the dark areas 26 retain their electrostatic charges.

It has been found that a previous exposure of the photoconductive layer 16 to light as well as the subjection of the charged layer 16 to heat causes a marked increase in the decay rate of the charges on the layer 16, especially the charges in the dark areas of the layer 16.

Means to replenish the electrostatic charges on the layer 16 that may be lost upon heating and/or that may have been lost as a result of the increased decay rate caused by the previous light exposure are shown in the arrangement of apparatus illustrated in FIG. 4. The layer 16 is exposed to heat of a temperature sufficient to soften it so that the electrostatic charges remaining on it may de-

form it. Preferably, to accomplish such heating, a hot gas, such as hot air, illustrated by the arrows 32, is blown onto the surface of the layer 16 by any suitable means (not shown), such as a hot air blower. Means are also provided to charge the layer 16 electrostatically either immediately prior to or during at least a portion of the time that the layer 16 is being heated. To this end, there is provided a high voltage unidirectional power supply 34 having its positive terminal connected to the common connection, ground, and its negative terminal connected to the voltage terminal 20 through a switch 36. The power supply 34 is capable of supplying a sufficient voltage (for example, 6,000 volts) between the wires 18 and ground to charge the layer 16 electrostatically.

The switch 36 may be any suitable switching means to interrupt the power supply 34 periodically. As shown in FIG. 4, the switch 36 comprises a rotary contact wheel 37 having a plurality of contacts that are adapted to engage a fixed contact 38 when the rotary contact wheel 37 is driven by a motor 40. Thus, the layer 16 may be charged periodically with a suitable charge, depending upon the polarity connections of the power supply 34, at a frequency depending upon the speed at which the switch 36 is driven. Although the switch 36 is shown as a mechanical switch herein, it may instead be an electronic switching circuit, whose frequency may be varied at will, in a manner known in the art. The frequency of charging is not critical and may vary from 60 c.p.s. to 2000 c.p.s.

The latent image produced on the layer 16 can now be developed by heating the layer 16, as shown in FIG. 4, until the layer 16 softens sufficiently so that electrostatic charges on the layer 16 can deform it to produce the ripple image. The layer 16 should be charged either immediately before heat is applied to it, or during at least a portion of the heat application step. Although the electrostatic charges may be deposited continuously upon the layer 16 to produce the ripple image, it is preferable to apply the electrostatic charges repeatedly, and preferably periodically to provide better control of the charging process. The layer 16 is then allowed to cool, freezing the ripple image in the layer 16.

Preferably, the charging pulse duration should be less than the time required for the layer 16 to reach its saturation voltage value. Thus, the shorter the pulse time, the finer is the control of the charging process to arrive at a desired voltage level on the layer 16.

In another embodiment of the method of the present invention, the layer 16 of the record element 10 need not be charged electrostatically prior to exposing the layer 16 to a light image. The conductivity pattern, which is in fact a latent image, can be produced in the layer 16 by exposing the uncharged layer 16 to a light image by any suitable means. Thus, as shown in FIG. 5, a conductivity pattern is produced in the layer 16 by directing light 30 through the light portions 28 of the mask 24. The mask 24 may also be a photographic negative or positive, for example.

A ripple image of the latent conductivity pattern in the layer 16 can now be formed by heating the layer 16 and applying an electrostatic charge thereto either continuously or periodically, as shown in FIG. 4, during at least a portion of the time the layer 16 is being heated. The layer 16 may also be charged electrostatically, either periodically or continuously, immediately preceding the heating of the layer 16.

From the foregoing description, it is apparent that there has been provided improved methods of forming ripple images of good relief in thermoplastic photoconductive layers of electrophotographic record elements. While only two embodiments of the improved method of the present invention have been described, variations in the method, all coming within the spirit of this invention, will, no doubt, readily suggest themselves to those skilled in the art. Hence, it is desired that the foregoing shall be considered as illustrative and not in a limiting sense.

What is claimed is:

1. In a method of developing an electrophotographic record element of the type comprising an electrically conductive layer and a thermoplastic photoconductive layer thereon, and wherein a conductivity pattern is produced in said photoconductive layer, the improvement comprising

- (a) applying heat to said photoconductive layer having said conductivity pattern therein, and
- (b) charging said photoconductive layer periodically with an electrostatic charge in pulses during at least a portion of the time said heat is applied to said photoconductive layer to replenish any electrostatic charge dissipated by said heat, whereby to allow electrostatic charges to deform said layer and to produce a ripple image therein.

2. A method of developing an electrophotographic record element of the type comprising a thermoplastic photoconductive layer, said method comprising the steps of

- (a) charging said layer with a uniform electrostatic charge,
- (b) exposing said layer to a light image to discharge it selectively,
- (c) heating said exposed layer, whereby to soften said layer so that the electrostatic forces thereon form a ripple image therein, and
- (d) applying a further replenishing electrostatic charge to said layer in pulses during at least a portion of the time said layer is being heated.

3. In a method of developing an electrophotographic record element of the type comprising an electrical conductive coating and a thermoplastic photoconductive layer thereon, wherein said layer is uniformly charged with an electrostatic charge, and wherein said charged layer is exposed to a light image to discharge said layer selectively, the improvement comprising

- (a) heating said exposed layer, whereby to soften it and to allow electrostatic charges thereon to deform said layer to produce a ripple image therein, and
- (b) further charging said layer in pulses periodically just prior to and during at least a portion of the time said layer is being heated to replenish any charge dissipated during said heating.

4. In a method of forming a ripple image in an electrophotographic record element of the type comprising a substrate, an electrical conductive coating on said substrate, and a thermoplastic photoconductive layer on said coating, wherein said layer is uniformly charged with an electrostatic charge, and wherein said charged layer is exposed to a light image to discharge said layer selectively and to produce a latent image, the improvement comprising

- (a) directing a stream of hot air onto said exposed layer from one side of said layer to heat said layer first, whereby to soften said layer and to allow electrostatic charges thereon to deform said layer and to produce a ripple image therein,
- (b) applying a further replenishing electrostatic charge to said layer in pulses periodically during at least a portion of the time said stream of hot air is directed onto said layer, and
- (c) cooling said record element.

5. A method of developing an electrophotographic record element of the type comprising a thermoplastic photoconductive layer, said method comprising the steps of

- (a) exposing said layer to a light image to produce a conductivity pattern thereon,
- (b) heating said exposed layer, whereby to soften said layer,
- (c) charging said layer in pulses periodically during at least a portion of the time said layer is being heated to replenish any charge dissipated during said heating, and
- (d) cooling said layer when a ripple image correspond-

ing to the light of said conductivity pattern has formed in said layer.

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