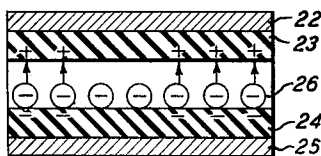
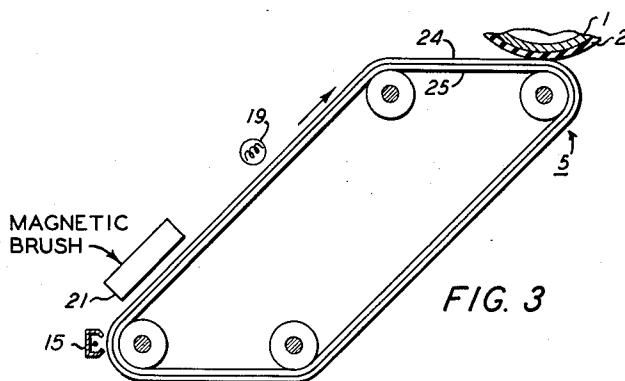
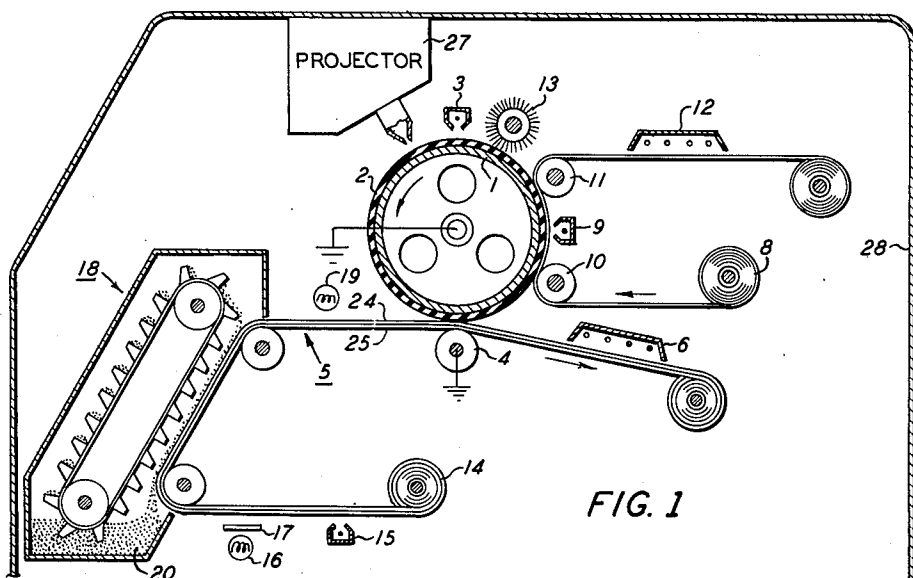


Nov. 9, 1965

P. F. KING
METHOD OF DEVELOPING ELECTROSTATIC IMAGE
WITH PHOTOCONDUCTIVE DONOR MEMBER
Filed March 2, 1962

3,216,844



INVENTOR.
PAUL F. KING

BY

Stanley Z Cole

ATTORNEY

1

3,216,844

METHOD OF DEVELOPING ELECTROSTATIC IMAGE WITH PHOTOCONDUCTIVE DONOR MEMBER

Paul F. King, Webster, N.Y., assignor to Xerox Corporation, Rochester, N.Y., a corporation of New York
Filed Mar. 2, 1962, Ser. No. 176,996
3 Claims. (Cl. 117—17.5)

This invention relates in general to the development of latent electrostatic images and in particular to the use of a photoconductive insulating layer as a carrier for bringing developer to the surface bearing the image to be developed.

In the art of xerography as originally disclosed in U.S. Patent 2,297,691 to Carlson and later patents in the art of electrophotography, an electrostatic latent image is formed on a photoconductive insulating layer generally overlying a conductive backing and is developed through the deposition thereon of charged, finely-divided material. According to these inventions a photoconductive insulating layer with a relatively conductive backing in the form of a flat plate or cylindrical drum is first charged by rubbing with cotton, silk, or fur, by corona discharge as taught for example by U.S. Patent 2,588,699 to Carlson or by other methods well known to those skilled in the art. The charged plate is then exposed to the image or pattern to be reproduced. This exposure renders the illuminated areas of the photoconductor more conductive allowing the charge in those areas to become dissipated while the charge in the non-illuminated areas is retained. Since there is very little lateral conduction in the non-illuminated area of the photoconductor, the charge is retained in image pattern. The image is then developed with electroscopic particles hereinafter referred to as toner. After the image is developed it is generally transferred to a copy sheet or web and fixed by heating, by subjection to the fumes of a solvent or by other methods known to those skilled in the art.

A method of development now known involves bringing a carrier such as a sheet or web that has been uniformly coated with toner to the surface of a charged and exposed xerographic plate or drum. This carrier is known as the "donor." Upon contact of the toner in a sandwich relationship between the donor and the surface to be developed, toner is selectively transferred from the donor to the xerographic plate or drum, thus developing the charge pattern or latent electrostatic image. Aspects of this process are more fully explained in U.S. Patent 2,895,847 to Mayo.

Although the donor sheet may be of almost any material such as paper, plastic, etc., certain problems have been encountered in its use. For example, it is difficult to consistently obtain a uniform coating of developer to a uniform amount on known donors. Difficulties are also encountered when developing large charged solid areas since the lines of force of the resultant electric field in the center zone of the large solid areas for the most part extend inwardly to the conductive plate backing member since they are attracted to the nearest opposite pole and thus do not attract developing particles. The fringing field at the edges of these charged areas cause development of these edges without development of this center zone.

It is accordingly an object of this invention to define a novel donor member.

It is another object of this invention to define novel methods to uniformly coat donor members.

It is an additional objective of this invention to provide a new method and novel apparatus for improved development of electrostatic images.

2

It is a further objective of this invention to define novel method and apparatus for development in xerography employing a donor in which charge is induced by the image thereby aiding transfer of toner from the donor to image surfaces and producing an improved developed image.

It is an additional objective of the invention to provide novel apparatus to produce improved solid area coverage of developed images in xerography.

For a better understanding of this invention, together with other further objects thereof, reference is now had to the following description taken in connection with the accompanying drawings, and the scope of the invention will be pointed out in the appended claims.

FIGURE 1 is an embodiment of a xerographic device in accordance with this invention.

FIGURE 2 shows a small segment of the xerographic drum and toner covered donor indicating toner transfer.

FIGURE 3 is a view of the donor loading device in accordance with a second embodiment of the invention.

The apparatus shown in FIGURE 1 comprises one embodiment for carrying out the invention wherein a conductive drum 1 bears a photoconductive insulating layer such as vitreous selenium 2 on its outer periphery. As shown in FIGURE 1 the conductive portion of this drum is grounded. The outer drum surface is charged by corona discharge from a charging electrode 3 which is connected to a source of high voltage not shown. After charging, the drum is exposed to the image to be reproduced by an exposing means 27 which might be any conventional projection means. The drum then rotates to a position above grounded conductive roller 4 where it picks up charged developer or toner from web 5 which has previously been uniformly coated in a manner which will be explained later. This roller 4 serves as a path to ground for the conductive web backing as will be discussed more fully hereinafter. The developing powder or toner is transferred to the drum in accordance with the charge which has been left on the drum after selected areas of the drum have been discharged due to light impinging on its surface in accordance with the exposure. This results in a positive image on the drum and a negative image on the donor or vice versa depending on the polarity of the charge on the toner and drum and the bias potential from the conductive backing of the donor to that of the drum as will later be more fully explained. Web 5 then moves away from the drum whereupon the powder remaining on the web may be fixed to it by heat fuser 6 as shown in this figure, a solvent fixer or other fixing devices known to those skilled in the art. If it is desired to use only the image on the drum, fixer 6 may be omitted, and the web may be reloaded for reuse. The drum then continues to rotate to a point where it contacts a continuous web of copy paper 7 which is fed towards the drum from a roll 8. The powder image formed on the drum from web 5 is then transferred to copy paper 7 by means of a corona discharge device 9 hereinafter referred to as a transfer corotron connected to a source of high voltage. This corotron is placed between two rollers 10 and 11 which hold the copy sheet close to the drum during the transfer step. This transferred image may then be fused on the copy sheet by any one of several means such as fixer 12. The drum then continues to rotate to a position where rotating brush 13 removes any remaining developer from the drum surface. The whole device is enclosed in a light-tight cabinet. It should be noted that the elements in this embodiment are exemplary only and any one of many other well known sensitizing, exposing, cleaning, transfer and fixing means may be used. The drum then begins a new cycle of operation.

Web 5 in accordance with this invention comprises

3

a photoconductive insulating layer 24 preferably overlying a conductive backing 25 although other backing materials may be used. Preferably, the web is made of flexible material and the photoconductive insulator is of the type which takes a charge opposite in polarity to that on the drum. The photoconductive insulating material of web 5 is selected so that the image bearing surface to be developed may induce a charge of a polarity opposite to its own on the web surface during the development step. Since it is general practice in xerographic development to use developing particles carrying a charge opposite in polarity to that remaining on the xerographic plate or drum after it has been exposed so that these particles will be attracted to the charge retaining areas on the plate or drum, the charge induced in the web by the drum will aid in the developer material transfer since this induced charge will be of the same polarity as the developer material.

This effect is more clearly shown in FIGURE 2 which represents a cross section of a xerographic drum and the donor web covered with electroscopic developer material or toner at the point of toner transfer. Thus layer 23 represents the photoconductive insulating layer on the conductive drum 22 while layers 24 and 25 represent the photoconductive insulating and conductive layers respectively of the donor while 26 represents the charged and loaded toner or developer material.

For exemplary purposes the photoconductive layer 23 of the xerographic drum is shown as carrying a positive charge in this instance. As shown in the figure this charge is retained only in those areas of the drum which have not been subjected to illumination so that the latent electrostatic charge on the drum is retained in image configuration. The positive charge on the drum has induced a negative charge in the photoconductive layer 24 of the donor. Since negatively charged toner 26 was used here to develop the remaining positive charge on the drum, transfer of these particles to the drum will be aided by the repelling force of the induced negative charge in the donor. Thus the charge on the drum will attract the toner while the induced charge on the donor will repel the toner.

The donor web is fed from the roll 14 and passes under a charging corotron 15 from which it receives a uniform electrostatic charge across its surface. According to a preferred embodiment of the present invention the web may then be exposed to a light source 16 through a half tone screen 17, a number of transparent fibers spaced in an opaque base or any other device for breaking up the impinging radiation and consequently breaking up the uniform charge into small areas of charge and no charge. When this exposure takes place during donor movement, a halftone dot pattern must move at the same peripheral speed as the donor web and thus is made in the form of a driven endless belt. Alternatively a line pattern made up of alternating light and dark strips, running in the direction of donor travel, may be used in a stationary screen. The screen may be of the type which produces small light areas on a dark surface or small dark areas on a light surface. The charge placed on the photoconductive insulating web 5 is thus dissipated through its conductive backing in those areas which have been exposed to the light pattern coming through the screen since the insulating photoconductor becomes conductive in its lighted areas. The web then passes to a loading station 18 where any one of the number of dusting methods may be used to deposit developer 20 on the exposed web in accordance with the latent electrostatic charges left on the web after exposure through the half tone screen. In this instance a cascade developing method of the type taught by U.S. Patent 2,618,552 to Wise is shown. As the web moves away from the development station 18 the whole of its surface is exposed to a strong light source 19 which penetrates even that web portion which is covered by developer, thus

4

dissipating most or all of the electrostatic charge on the web while leaving the developing powder charged. Alternatively, the backing on the web 5 may be a transparent material such as a clear plastic with a thin conductive tin oxide coating and the photoconductor may be exposed through the backing. The powder is retained on the web by Van der Waals forces even though most or all of the electrostatic attracting forces have been dissipated. It has been found that there is very little lateral shifting of the developer material on the web when the material is retained by these forces. Thus as the web passes between the drum and conductive roller 4 the powder is only held against the web by very weak forces which are not sufficient to counteract the attractive force of the latent electrostatic image on the drum and the repelling force of the opposite polarity electrostatic image induced in the web at the transfer point and the transfer of developer to the drum is easily accomplished. The developing material which is transferred from the donor to the drum and thence to the copy paper retains its half tone pattern superimposed on the developed image. This is due to the fact that the donor is very close to (i.e., normal physical contact) or touching the drum at the time the toner is selectively transferred to the drum in accordance with its latent electrostatic image and that the toner is moved by forces emanating from the donor and the drum resulting in particle movement substantially normal to the drum and donor surface.

FIGURE 3 shows a second embodiment of the invention in which the donor 5 is charged by a corotron 15 in the same manner as it was in the first embodiment. In this case, however, the donor is in the form of an endless belt rather than a continuous web. The charged donor then passes under a magnetic brush developer 21 and finally under the strong light source 19 where it is completely discharged. It should be noted at this point that any method for developing the donor which gives desirable coverage may be used since the desirable results will be carried over to the image which is later developed with the donor and to the complementary image which is left on the donor.

Magnetic brush development or electrode development as taught by U.S. Patent 2,784,109 may also be used to load the donor since they result in good solid area coverage of the donor even without half tone exposure. Thus by using a photoconductive donor it may be "loaded" in a number of advantageous ways without the disadvantages that would accrue if these methods were used directly on the drum and by using a donor of a type which would take an induced charge opposite to that on the xerographic drum advantage may be taken of the induced repelling charge in the donor to aid in the transfer of toner to the drum. Owing to the high uniformity of donor loading this type of donor may be advantageously used to develop various types of images, such as line copy, continuous tone and large solid dark areas. When the backing of the donor web is a fairly good conductor this backing effectively acts as a development electrode when the donor is used to develop the xerographic drum. As explained in U.S. Patent 2,784,109 this type of development electrode greatly enhances the development of large solid latent electrostatic images.

The photoconductive insulating layer of the donor should be of the type which will accept an induced negative charge if the image to be developed is positive and should be of the type which will accept an induced positive charge if the image to be developed is negative. For this reason an N type material would be selected to develop a positive charge and a P type material would be selected to develop a negative charge. A material is referred to as being of the P type when the majority charge carriers are holes and of the N type when the majority charge carriers are electrons. If the material has no preferential conductivity for either polarity of charge carriers

5

6

it may be made either P type or N type by doping with small amounts of impurities as is well known in the transistor art. It is also possible to render a commercial selenium xerographic plate which is only slightly P type, strongly P type by placing a rectifying layer between the conductive backing and the insulating photoconductive selenium layer. A rectifying layer such as copper oxide which is a barrier to electrons but not to holes would be used in this case. This would make the selenium more P type because although both holes and electrons would be injected through the conductive backing of the donor 5 the electrons would be stopped by the copper oxide layer while the holes would continue on to the surface of the selenium to set up a positive charge in opposition to the negative charge on the image to be developed. Since rectification is utilized to impart an electrostatic charge to the insulating layer, photoconductive insulators which are themselves strongly P type or strongly N type may be used per se. For example, zinc oxide is strongly N type so that modification of the material either by doping or by the interposition of a barrier layer of the rectifying type between the zinc oxide and the conductive backing is unnecessary. Since vitreous selenium as used in commercial xerographic plates is only slightly P type, it must be modified either by the interposition of a barrier layer as explained above or by doping of the selenium itself. When doped with arsenic trisulfide or tellurium etc., the vitreous selenium layer is rendered more highly N type. The selenium may also be rendered more highly P type by the inclusion of very minor amounts of a halogen.

Substantially all known photoconductive insulating layers can be employed in connection with this invention, either intrinsically or as modified according to the teaching herein. An N type material on a conductive backing is used as a donor to develop a positive electrostatic image because although hole-electron pairs are injected through the conductive backing, only the electrons are free to travel through the N type material so as to set up a negative charge on the surface of the donor in opposition to the positive charge on the image to be developed as shown in the FIGURE 2 example. A P type material such as dope selenium on a conductive backing is used as the donor member for developing a negative image on the drum because although hole-electron pairs are injected through the conductive backing only the holes are free to travel to the surface of the selenium to set up a positive charge in opposition to the negative image to be developed. Since the use of these P or N type materials enhances developer transfer and allows for the use of preferred donor loading techniques their use constitutes a large step forward in the art of developing latent electrostatic images.

EXAMPLE

A drum for operation in accordance with this invention was prepared by coating vitreous selenium onto an aluminum drum. It should be recognized, however, that any one of a number of conductive materials such as brass, steel, etc., would be suitable for the drum base and any one of a number of insulating photoconductors such as certain sulfides, oxides and selenides, of zinc, cadmium, calcium, lead, and other elements would make suitable photoconductive insulating layers for the drum coating. The web was made up of a thin base layer of aluminum coated with zinc oxide in a vinylite VYNS resin believed to be vinyl chloride acetate copolymer binder. Other insulating binders which could be used are Lucite 46 (a copolymer of N-butyl and isobutyl methacrylates), Silicone SR-82, a polysiloxane resin or Cycopul S-101 (a styrene-alkyd copolymer resin). It should be recognized that other photoconductive insulators or insulating mixtures, as well as other conductive backings could be used for the web similar to the alternative drum materials set out above providing only that the web appears conductive to the image on the drum so that an image of opposite polarity may be induced in the web. This par-

ticular web construction was chosen because it takes and holds a negative charge well as opposed to selenium which usually holds a positive charge as well and it is an easily made, flexible photoconductive insulating material. The zinc oxide binder web was negatively charged and exposed through a half tone screen of the type which produced small dark areas on the web surface constituting about 10% of its area. The web was then cascade developed with a carrier-toner mixture of the type which imparts negative polarity to the toner. Suitable cascade materials are well known in the art and are more fully described in Walkup U.S. Patent 2,618,552 and Walkup and Wise U.S. Patent 2,638,416. Since the charge was drained from the exposed portion of the web and remained on the unexposed portion leaving the exposed portion positive relative to the unexposed portion the negative toner was attracted to the relatively positive exposed area and repelled by the unexposed negative areas on the web. The web then passed under a very strong light source which discharged the whole surface of the web including it is believed even those areas which were covered by toner. This substantially eliminated the electrostatic attractive forces between the web and the toner. The selenium drum was positively charged and exposed to the image to be reproduced. Thus, the non-image areas on the selenium drum were discharged by the light from the projection source. When the donor web came very close to or in contact with the selenium drum the positive image areas on the drum were developed and a negative image resulted on the web. The web had been loaded only to a sufficient extent to produce a developed image on the plate. The transferred powder thus formed an image pattern of powder on the web. The image on the web then passed under a heating device where it was fixed to the web. The image on the drum was transferred to a sheet of copy paper by means of a transfer corotron and was then fixed by a heat fusing device.

As explained above the zinc oxide donor web gives a negative picture on the web when loaded properly for a donor when the input is also positive it is necessary to positive input. Should a positive print be desired on the perform development with a positive bias potential on the donor which equals the maximum potential found on the selenium plate after the plate has been charged. It is also necessary to load the donor with positively charged doner for this particular operation.

A test was conducted using combinations of (1) a positively and negatively charged selenium plate, (2) positively and negatively charged toner, and (3) a bias sensitized plate, and (4) a zero bias on the donor (grounded). The results of this test are shown in the tentinal on the ZnO donor equal to the potential of the table below. As used throughout the term "no bias" includes potentials from ground to about the residual potential left on exposed areas of the plate, since any potential in this general range is operative in accordance with this invention.

Table of results on plate of various operating conditions

	No Bias Potential		Bias Potential on Donor	
	+Toner	-Toner	+Toner	-Toner
Selenium Plate charged positively.	No image.	Positive image.	Negative image.	No image.
Selenium Plate charged negatively.	Positive image.	No image.	No image.	Negative image.

Good transfer of toner to the plate occurred in each case when the direction of the electric field was favorable to the polarity of the charged toner. That is, transfer did not occur regardless of the field direction. It was therefore, concluded that transfer of toner was a result of the triboelectric charges on the toner and the direction of the electric field.

Thus, it is seen that by varying bias potential, toner polarity and the polarity of charging used on the selenium plate or drum, the type of image on the drum and donor may be controlled although they will always be complementary. When a negative charge is selected for the drum it may, in fact, be preferable to use a zinc oxide insulating binder disposed on a conductive backing as the drum or plate as well as for the donor, since this material is better suited for holding a negative charge.

When using half tone exposure plus cascade development of the donor sheet the toner is deposited on the donor sheet in a half tone pattern so that the image which is left on the donor web is a half tone even though the original was not exposed through a half tone screen. This results in a good image being left on the donor sheet after the drum was removed the toner material representing the positive or vice versa if the positive is left on the donor.

A number of tests were made with Rose Bengal dye sensitizer mixed in with the zinc oxide which increased its speed. However, the zinc oxide was also used without the sensitizing dye so that better white areas might be attained in the copies.

It should also be noted that the peripheral speeds of the loaded donor and the image being developed may be different. This results in "Skid" development as more fully explained in U.S. Patent 2,895,847 to Mayo.

In addition to developing latent electrostatic images on photoconductive insulating materials with conductive backings, the developing method of this invention may be used to develop electrostatic images produced by other methods and on other materials. For example, it may be used to develop a latent electrostatic image produced on an insulator such as insulating paper or Mylar by TESI as explained in U.S. Patent 2,825,814 to Walkup.

In connection with procedures described in carrying out the instant invention, insulating toner particles have been employed throughout the discussion. However, it should be realized that conductive toner particles are also effective in image development in accordance with this invention. Their effect is dependent on certain conditions. Conductive toner particles may be loaded in accordance with the loading procedures previously described. If the photoconductive layer of the donor member is discharged prior to development, conductive particles on the surface of the donor member will also discharge. However, if charges are allowed to migrate through the photoconductive layer of the donor member during the development process because the photoconductive layer has the proper polarity of majority charge carriers, then charge will migrate to the toner particles and into the toner particles because the toner particles themselves are conductive. These particles will then move to the surface being developed. In this connection it is noted that the particles will move to the image bearing surface with a force which is equivalent to approximately the square of the field from the image to the donor member. Such a development results in a high quality continuous tone type image if a continuous tone charge pattern is being developed. This may be compared to image development employing insulating particles in the same arrangement where the particles move to the surface being developed directly in proportion to the fields involved. Thus, in the single instance of developing continuous tone type reproductions, particularly valuable reproductions are produced if a proper photoconductive layer is chosen to allow charges to flow through as controlled and called for by charges on the surface being developed and if conductive

toner particles are employed as to the toner particles across the donor member.

It is also noted in connection with the use of conductive particles that if the particles are uncharged while on the donor and if the donor includes a photoconductive layer which will not allow charges to migrate through then development of the latent charge pattern will not occur.

The particular apparatus described in this specification is intended as illustrative only. Various modifications will occur to those skilled in the art and are intended to be encompassed within the following claims.

What is claimed is:

1. A method of developing a latent electrostatic image of positive polarity on a member, comprising:
 - loading the surface of the photoconductive insulating layer of a donor member comprising an N type photoconductive insulating layer overlying a conductive backing with a layer of finely divided marking particles carrying a negative electrostatic charge;
 - bringing the loaded donor member into contiguous relationship with the image bearing member with said particles between said members; and,
 - separating the donor member from the image bearing member whereby the positively charged areas of said latent electrostatic image simultaneously attract marking particles opposite them on the surface of said donor member and induce negative charge in said donor member thereby causing said donor member to repel the particles in area corresponding to the charged areas of said latent electrostatic image.
2. A method of developing a latent electrostatic image of negative polarity on a member, comprising:
 - loading the surface of the photoconductive insulating layer of a donor member comprising a P type photoconductive insulating layer overlying a conductive backing with a layer of finely divided marking particles carrying a positive electrostatic charge;
 - bringing the loaded donor member into contiguous relationship with the image bearing member with said particles between said members; and,
 - separating the donor member from the image bearing member whereby the negatively charged areas of said latent electrostatic image simultaneously attract marking particles opposite them on the surface of said donor member and induce positive charge in said donor member thereby causing said donor member to repel the particles in areas corresponding to the charged areas of said latent electrostatic image.
3. The method of claim 2 wherein said P type photoconductive insulating layer comprises vitreous selenium.

References Cited by the Examiner

UNITED STATES PATENTS

2,829,025	4/58	Clemens et al.	
2,890,968	6/59	Gaiamo	117—17.5
2,895,847	7/59	Mayo	117—17.5
2,901,348	8/59	Dessauer et al.	96—1
2,901,374	8/59	Gundlach	117—17.5
2,968,552	1/61	Gundlach	117—17.5 X
2,976,144	3/61	Rose	117—17.5 X
2,996,400	8/61	Rudd et al.	117—17.5
3,015,304	1/62	Carlson et al.	118—637
3,041,166	6/62	Bardeen	96—1
3,052,540	9/62	Greig	96—1

WILLIAM D. MARTIN, *Primary Examiner.*