

March 4, 1958

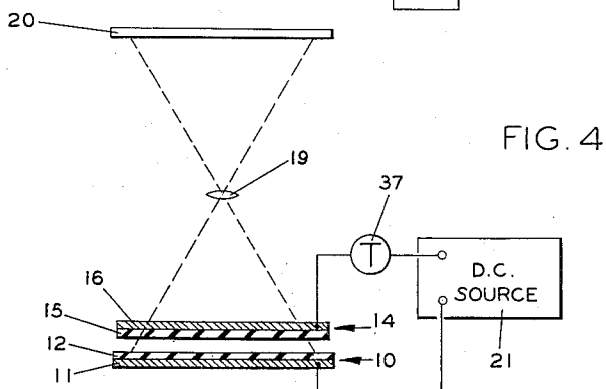
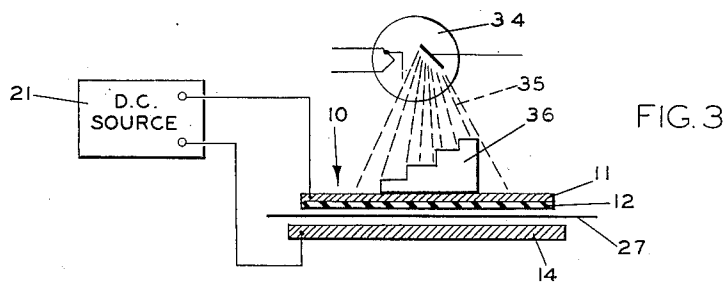
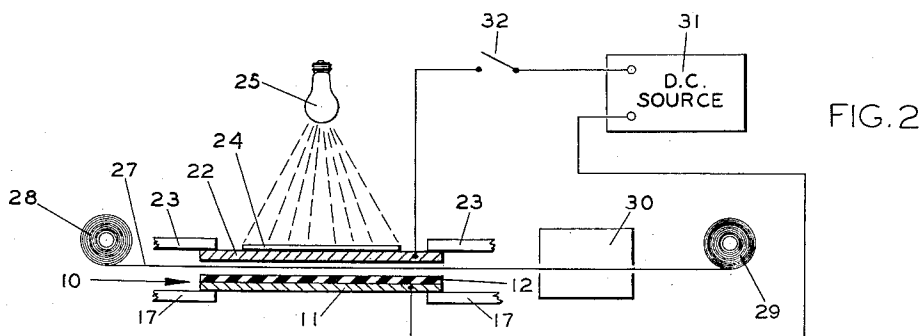
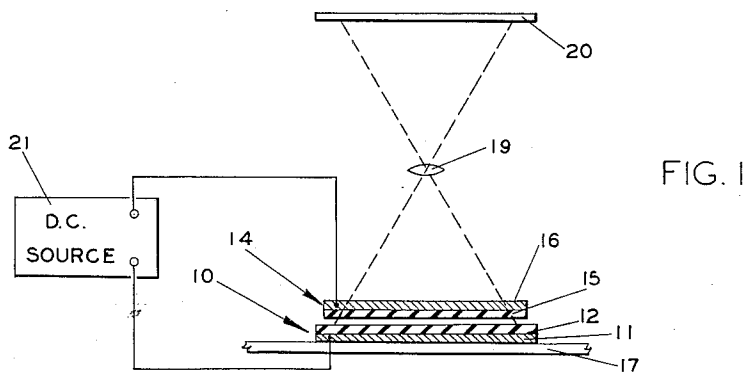
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2,825,814

XEROGRAPHIC IMAGE FORMATION

Filed June 4, 1954

3 Sheets-Sheet 1



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XEROGRAPHIC IMAGE FORMATION

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3 Sheets-Sheet 2

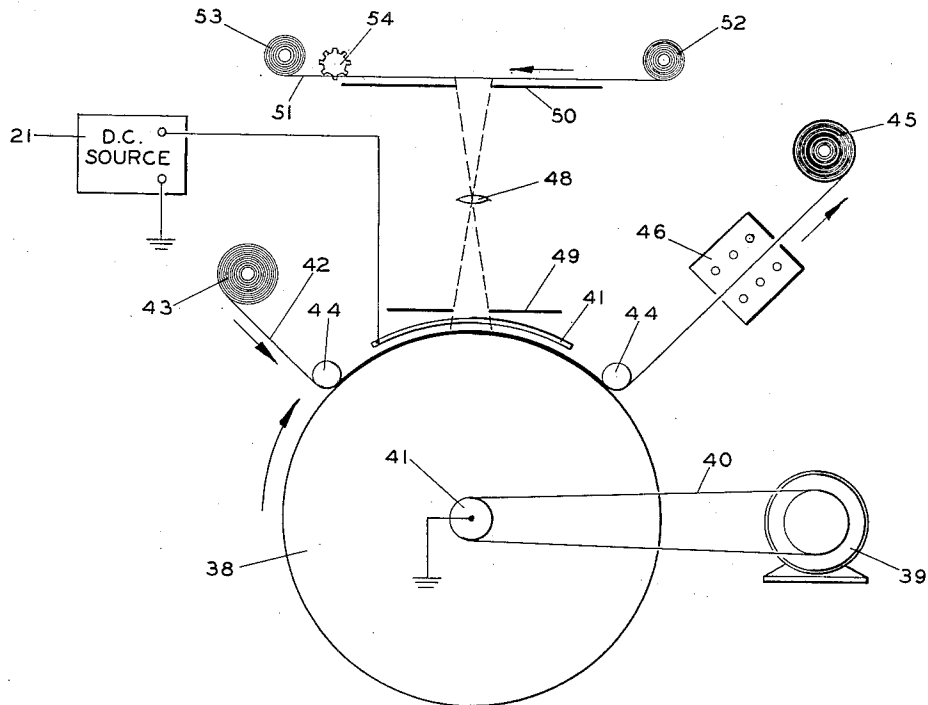


FIG. 5

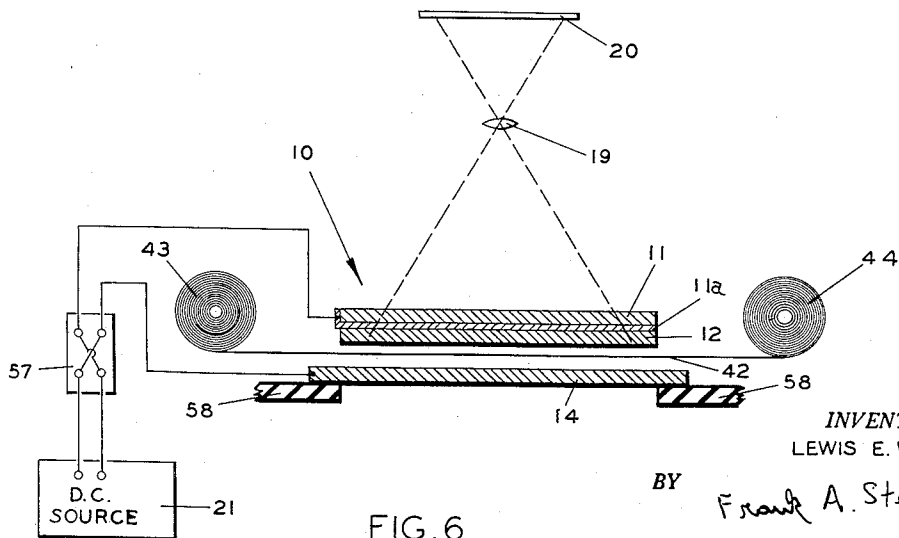


FIG. 6

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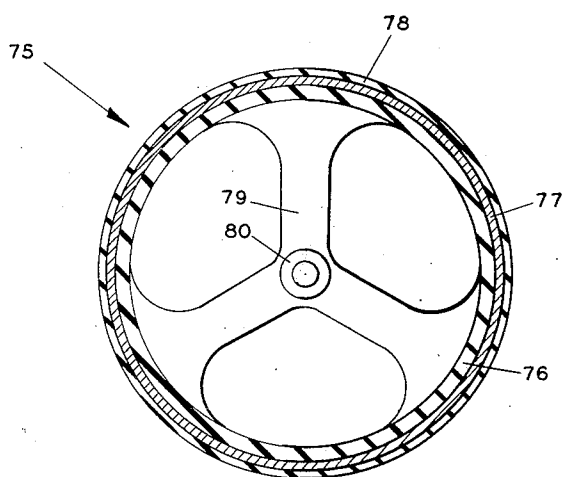
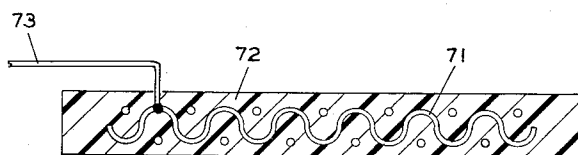
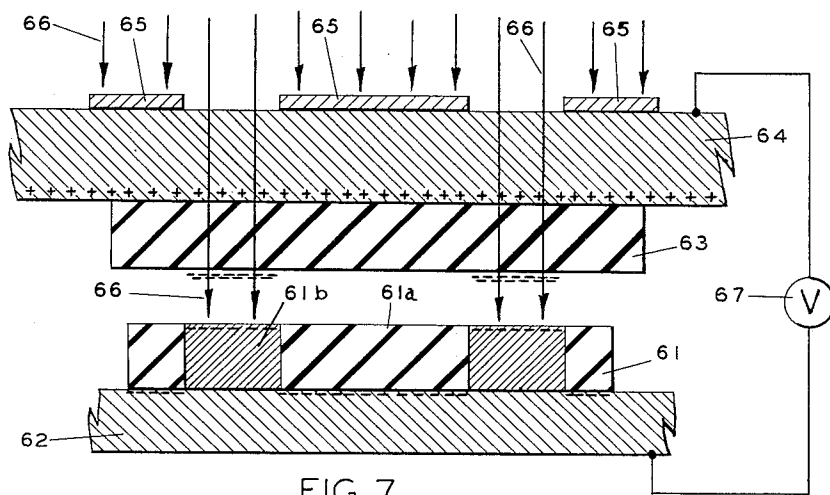
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XEROGRAPHIC IMAGE FORMATION

Filed June 4, 1954

3 Sheets-Sheet 3



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XEROGRAPHIC IMAGE FORMATION

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Application June 4, 1954, Serial No. 434,491

11 Claims. (Cl. 250—49.5)

This invention relates in general to a formation of electrostatic charge patterns such as xerographic electrostatic latent images and in particular to methods and apparatus for the formation of such charge images.

According to the invention of Carlson described in U. S. 2,297,691 there is provided a process and apparatus for electrophotography or xerography wherein an electrostatic charge is applied to the surface of a photoconductive insulating layer, and this charge is selectively dissipated by exposure to a pattern of light and shadow to be recorded. This selective charge dissipation results in an electrostatic latent image corresponding in its charge pattern to the pattern of light and shadow to which the photoconductive insulating layer was exposed. Conventionally, in the art now known as xerography, an electrostatic image may be formed in this manner and may be utilized as desired, for example, by development or deposition of finely divided material in conformity with the charge pattern, optionally, together with transfer of the developed image to a print receiving surface.

Now, in accordance with the present invention, there are provided novel methods, means and apparatus for the formation of an electrostatic charge pattern or xerographic electrostatic latent image wherein an electric field is imposed through a photoconductive layer and to a contiguous insulating layer while the photoconductive layer is subject to the action of a pattern of light and shadow of visible light or other activating radiation. The contiguous insulating surface is positioned extremely closely adjacent to the surface of the photoconductive layer and may be spaced therefrom by an extremely minute distance such as, for example, the extremely small air space existent in a condition of virtual contact of one surface with another. While it is not intended to limit the invention to any specific theory of operation it is presently believed that electric charge under the influence of the applied field through the photoconductive layer and through the insulating layer migrates through the photoconductive layer, preferentially at those areas exposed to activating radiation, and migrates to the insulating layer across the minute air gap which may exist between this insulating layer and the photoconductive surface, again under the influence of the applied field. For the sake of clarity of disclosure and simplicity of explanation the invention will hereinafter be described in terms of this theory of operation although it is to be clearly understood that the theory is illustrative only and is not intended to be interpreted in limitation of the scope of the invention.

The general nature of the invention having been set forth the invention will now be described illustratively in terms of the following specification and the drawings in which:

Fig. 1 is a diagrammatic view of apparatus according to one embodiment of the invention;

Fig. 2 is a diagrammatic view of apparatus according to another embodiment of the invention;

Fig. 3 is a diagrammatic view of an embodiment of the invention employing penetrating radiation such as X-rays;

Fig. 4 is a diagrammatic view of a further embodiment of the invention;

Fig. 5 is a diagrammatic view of a xerographic machine operating in accordance with the present invention;

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Fig. 6 is a greatly enlarged diagrammatic view of a section of apparatus according to a modification of Fig. 1;

Fig. 7 is a diagrammatic view of a further modification of the invention;

Fig. 8 is a diagrammatic cross section of an induction electrode according to a further embodiment of the invention;

Fig. 9 is a diagrammatic view of a cylindrical xerographic photosensitive plate according to another embodiment of the invention.

In Fig. 1 there is illustrated a simplified embodiment of the invention. In this figure, as in the others, the illustration is diagrammatic, largely because certain key members and certain important spacings are so extremely thin and small as to make descriptive presentation impractical. The apparatus in Fig. 1 includes a photosensitive or xerographic member or plate designated 10, combining for example a photoconductive insulating layer 12 overlying and in intimate contact with a conductive backing member 11. Positioned immediately over the surface of the electrophotographic member 10 is an induction electrode generally designated 14 comprising a thin insulating layer 15 coated on a transparent conductive backing electrode 16. Desirably, the electrophotographic member 10 is supported on a suitable support member 17 and the induction electrode 14 may rest on the surface of the electrophotographic member or plate. Members 10 and 14 are illustrated as being spaced apart. It is to be understood that this spacing is extremely minute and preferably is the almost immeasurably small space between two reasonably flat surfaces in normal surface contact. Likewise certain members and structures such as, typically layer 12 are too thin to be reasonably illustrated, and therefore are shown out of proportion and diagrammatically.

Means are supplied to impose on the photoconductive insulating layer 12 a pattern of light and shadow such as an optical image to be recorded. As illustrated in the figure, such means may include a lens 19 or other member designed to project on the layer an image of an original document 20 or other pattern of light and shadow to be recorded. Since the induction electrode 14 in this embodiment is transparent it is readily apparent that a suitable image may be projected through this transparent electrode onto the surface of a photoconductive insulating layer 12.

A source of electric potential 21 or other suitable electric field generating means is adapted to impose an electric field of desired polarity between insulating layer 15 and conductive backing member 11. This potential source is indicated in the diagram as being conventionally a battery or other source of D. C. voltage and it is to be understood that any suitable source of electric potential may be employed for this purpose. If desired, a conventional power supply may be made from transformer operated rectifier systems as are well known in the art. It is desired that there be applied between member 16 and member 11 an electric potential such as will cause between these members an electric field at least through the photoconductive insulating layer 12 and to the insulating surface 15 whereby electric charge will be induced to migrate through said first layer and to the surface of said second layer.

In Fig. 2 there is illustrated a modification of the embodiment of the invention shown in Fig. 1. According to this embodiment of this invention, an electrophotographic plate, generally designated 10, comprising a photoconductive insulating layer 12 disposed on a conductive backing member 11, is supported on a suitable support member 17. Positioned parallel to and closely adjacent to the surface of the electrophotographic plate 10 is a transparent conductive electrode 22 mounted on

support members 23 or the like. Placed on top of the electrode 22, or on the side away from the electrophotographic plate, is a document 24 or other visible or image matter which is to be reproduced according to the present invention. A light source 25 or other source of activating radiation is positioned above the assembly so as to shine visible light or other radiation through the copy 24 and onto the surface of the electrophotographic member 10.

An insulating film 27 in sheet or web form is positioned between electrode 22 and plate 10 and desirably passes from a feed roll 28 between the electrodes and ultimately to a take-up coil 29. The web or film may optionally pass through a suitable xerographic processing station 30 such as for example a developing or fixing station or a plurality of such stations whereby desired xerographic operations may be performed on an electrostatic latent image. For example, xerographic stations may include means for developing the image or making it visible by deposition of finely divided material in conformity with the image, and may include means for transferring the image to a second surface and/or fusing or fixing the image.

Electric field producing means such as an electric potential source 31 is suitably connected between the electrode 22 and the backing member 11 of the electrophotographic plate optionally being connected to a switch 32 or like control means to operate and control the electric field. In this manner electrode 22 may be raised to a desired potential either positive or negative with respect to the backing member whereby a desired electric field is imposed through the photoconductive insulating layer 12 and at least to the surface of the receiving film 27, thereby inducing electric charge to migrate to the surface of this film.

At least during the exposure operation the induction electrode and xerographic plate are generally in normal surface contact with the opposite surface of film 27. Accordingly means, either mechanical or manual, may be supplied to move electrode 22 into and out of contacting position. Conveniently this can be accomplished by manually placing the electrode on top of the film and resting the electrode on the xerographic plate.

With respect to Figs. 1 and 2, it is apparent that there are certain generalities and similarities which may be noted. For example, in each of these figures a light or radiation image is imposed on the photoconductive insulating layer 12 and it is therefore apparent that either the backing member 11 supporting this photoconductive insulating layer or the induction electrode 14 or 22 must be transparent. Thus, as shown in Figs. 1 and 2 the induction electrode is the transparent member, but it is apparent that a transparent backing member 11 would permit exposure by projection through the xerographic sensitive member itself. In any case, there is a transparent conductive member, be it member 11 or 16 of Fig. 1 or both, or member 11 or 22 of Fig. 2, or both, and this member must be sufficiently conductive to permit application of an electric field through layer 12 and through the air gap and must permit the flow of electric charge under the influence of this field and the photoconductive action from the appropriate light or image source. It is specifically understood and recommended that conductive glass members or conductively coated glass members should be so employed. In general, this conductive electrode should have a specific resistivity of less than 10^{10} ohm cms. and preferably, less than 10^5 ohm cms. Desirably, this member should be what is ordinarily considered to be conductive and should carry a substantial flow of current under only mild potential differences. In addition to conductive glass or conductively coated glass, there may be employed other conductive members such as thin, partially transparent metallic films on transparent support bases including glass, transparent plastic films and the like, and conductive transparent

members coated or impregnated with conductive materials such as metals or ionic salts or the like where sufficient moisture is present to cause the materials to be conductive. Likewise, conductive liquids or fluids may be employed, such as electrolytic salt solutions or other ionized liquids, or ionized air or other ionized gases or the like.

The photoconductive insulating layer 12 is, in the preferred embodiment of the invention, a vitreous or amorphous selenium layer, preferably deposited on the surface of the conductive backing member 11. Members of this type comprising a vitreous or amorphous selenium layer are commercially available in the art of xerography. In addition to this specifically preferred embodiment, it is to be understood that there may be employed other photoconductive members including anthracene, sulphur, and the like, coated on suitable backing members, as well as photoconductive binder layers including photoconductive materials dispersed in a suitable binder and coated on a conductive surface. These materials include, for example, crystalline materials generally available as phosphors or luminous compounds which frequently exhibit photoconductivity and which can be employed in suitable organic binders and film forming materials on the surface of photoconductive members.

In the case of photoconductive layers, according to the present invention, as distinguished from the photoconductive insulating layers preferred in the art of xerography in general, it is to be observed that the layers according to the present invention are not required to hold an electrostatic charge on their surface for similarly long periods of time, but are required on the contrary to permit migration of electric charge through the thickness of the layer at a substantially differential rate depending on activation or nonactivation by suitable radiation. Thus, while photoconductive layers for xerography in general must be capable of supporting an electric charge on the surface for appreciable periods of time to permit formation of an image and development of the image, this is not true in the case of the present invention where the electrostatic image is retained for development on the insulating layer 15 of Fig. 1, or the insulating film 27 of Fig. 2. Thus xerographic members characterized by higher dark decay or current leakage in the absence of activating radiation may be employed in the present invention.

In Fig. 3 there is illustrated a further embodiment of the invention whereby the new invention is particularly adapted to the formation of X-ray or radiographic images. As illustrated in the figure a xeroradiographic plate generally designated 10 comprising a normally insulating layer 12 and a conductive backing member 11 is disposed over an induction electrode 14 with an insulating transfer member 27 therebetween. A suitable power supply 21 is connected between conductive backing member 11 and the induction electrode 14 to apply a field from the one member to the other.

A suitable test object or other material or member to be examined by X-ray methods is placed on the conductive backing member which thereby serves the dual purpose of supporting the test object and simultaneously operating as the backing electrode for the system. Illustrated in the drawing is a step wedge 36 such as may be particularly designed for testing the radiograph operations. An X-ray source such as X-ray tube 34 is disposed and positioned to supply penetrating radiation or X-rays indicated by dotted lines 35 which are projected onto and through the test object to strike the xeroradiographic plate 10. In general the backing member 11 of the xeroradiographic plate will be a support sheet or plate of a metal or like electrical conductor which desirably may be opaque to ordinary or visible light. It is apparent, therefore, that the penetrating radiation such as X-rays striking this backing member will penetrate through it to enter into the normally insulating layer 12 disposed thereon. This

normally insulating layer is a layer of material which in the absence of activating radiation is an insulator but which, under the activating influence of X-rays or other penetrating radiation becomes substantially more conductive to electricity and it may, if desired, be a photoconductive insulator such as the photoconductive insulators employed according to the embodiments of the invention operating with visible light. Alternatively, it may be such other insulating member as is substantially insensitive to visible light but activated by penetrating radiation. Thus, for example, many insulating films and layers become conductive under the action of penetrating radiation even though they are not generally considered to be photoconductive and it is within the scope of the present invention to employ such insulating members.

In the embodiment of the invention shown in Fig. 3 it is presently preferred to employ a photosensitive xerographic plate comprising a layer of amorphous or vitreous selenium disposed on and coated on a conductive backing plate comprising a sheet of brass, aluminum, or the like.

Illustrated in Fig. 4 is a further embodiment of the invention wherein the time or duration of exposure is controlled by controlling the application of potential between the induction electrode of the system rather than by controlling the duration of exposure to light. In Fig. 4 is shown a xerographic plate and an induction electrode 14 exposed to a projected light image from an original 20 through a lens 19 or other means. The members and operations are in general the same as the members and operations according to Fig. 1.

Connected between the backing member 11 of the xerographic plate and the conductive electrode 16 is a power supply or potential source 21 which operates through a timing switch 37 which is constructed and adapted to apply a pulse of electric potential between the two electrodes for a predetermined time as may be selected by the timing switch. According to this embodiment of the invention the appropriate exposure conditions are set up by projecting the desired pattern of light and shadow through the transparent electrode 14 onto the xerographic plate 10. The timing switch is then set and energized to apply the desired potential difference between the conductive members 11 and 16 for the preselected time as controlled by the timing switch.

The embodiment of the invention shown in Fig. 4 is particularly desirable for use in conjunction with photoconductive insulating members characterized by what is known in the art as high dark decay. Members of this type are characterized by a somewhat higher conductivity in the absence of activating radiation than are members generally preferred for conventional methods of xerography. Specifically, according to prior methods of xerography, it is usual to apply an electric charge to the surface of a photoconductive insulating layer and to store this charge on the surface from the time the surface is charged until the charge is selectively dissipated by exposure to light and finally developed by deposition thereon by charged electroscopic particles. The usual operations of charging, subsequently exposing, and then developing, require a period of time varying from relatively large fractions of a second up to a time as much as several minutes and, accordingly, it is necessary that the charge be retained on the photoconductive insulating surface in the absence of radiation or exposure for a time cycle sufficient to permit the carrying out of these xerographic steps. Now, however, according to the embodiment of the invention illustrated in Fig. 4 it is not necessary to place and retain a charge on the photoconductive surface for a long time as has previously been required in xerography. It is apparent that this embodiment of the invention calls for activation of the photoconductive layer or differential conductivity through this layer during the time when the layer is both subjected to an electric field and exposed to the pattern of radiation. In the absence

of either of these conditions there is not the combination which leads to charge dissipation since the charge once deposited on the insulating layer 15 is held in its image configuration by the insulating characteristics of this insulating layer rather than by the insulating characteristics or absence thereof of the photoconductive layer 12.

It is apparent, therefore, that the photoconductive layer 12, according to this embodiment of this invention, may be somewhat more conductive in the absence of radiation than permissible according to prior inventions of xerography. Thus, according to this embodiment of the invention, both the electric image formation and other variations in electrostatic charge pattern on insulating layer 15 are substantially restricted to the period of time indicated by timing switch 37. An image thus formed is held on the insulating surface for a period of time sufficient to permit other xerographic steps such as development or the like, regardless of whether the photoconductive layer 12 has a sufficiently low dark decay to permit its use in other variations and modifications of xerography.

In Fig. 5 is illustrated diagrammatically a machine for the production of xerographic copy of suitable original material according to one embodiment of this invention. According to this figure, a xerographic cylinder 38 is adapted to be rotated by a motor or other drive means 39 optionally acting through a drive belt 40 on a pulley 41. The xerographic cylinder in general is a drum-like or cylindrical surface having at least a portion of its surface covered with a xerographic photosensitive member as in the previous figures. At one point around the circumference of the drum is a transparent induction electrode 41 fitted very closely to the drum and allowing just sufficient room for passage between the electrode and the drum of a sheet or web of an insulating film 42 which desirably passes from feed roll 43 around guide roll 44 to a take-up roll 45. During its path of travel from feed roll 43 to take-up roll 45 the film passes between the electrode 41 and the cylinder 38 and desirably passes through one or more xerographic stations or positions 46 which may be developing or fixing stations or the like.

At the exposure station, this being the location of the induction electrode adjacent to the xerographic cylinder, is suitable apparatus or means for exposing the xerographic cylinder to the pattern of light and shadow to be recorded. As illustrated there is slit exposure mechanism comprising projecting means or lens 48, an image slit 49, and a projection slit 50, the lens being adapted to project through the image slit a focused image of the projection slit. Material to be copied such as for example documentary information or the like desirably in roll or web form is adapted to be passed across the projection slit 50 for example as the web 51 of image material passing from a feed roll 52 to a take-up roll 53 and adapted to be driven at a desired rate of speed by drive means 54. Desirably this drive means will include suitable drive mechanism synchronized with the rate of travel of the xerographic cylinder. In the event that web 51 is photographic microfilm or the like the drive means may be a gear wheel 54 with teeth adapted to engage the slots of microfilm to carry the microfilm past the projection slit.

The suitable D. C. voltage source is connected to the induction electrode in such manner as to maintain a potential difference between the induction electrode and the backing member of the xerographic cylinder. This will be accomplished, of course, by means and methods similar to those described in the previous figure.

In use and operation the machine of Fig. 5 operates according to the principle of Fig. 2. Motor or drive means 39 is energized to rotate the xerographic cylinder in a clockwise direction. Image web 51 then is carried across the projection slit at a rate synchronized with the rotation of the xerographic cylinder and trans-

fer or insulating web 42 is carried along with the xerographic cylinder between the cylinder and the induction electrode. The applied potential between the induction electrode and the backing member of the xerographic cylinder causes formation of an electrostatic image on insulating web 42 and this image-bearing web is then carried to the further xerographic stations where it may be developed and fixed or otherwise treated as desired to yield a xerographic print or to yield other xerographic results as desired including, for example, a scanning electric signal of light. In the event that a xerographic print is formed the resulting print is formed into take-up roll 45.

According to a further embodiment of the invention the light image to be recorded is projected through the reverse side of the xerographic plate and further reversing means are supplied to make possible reversing the potentials applied between the conductive backing electrode 11 and the induction electrode 14. In Fig. 6 is illustrated this embodiment of the invention. As shown here, the induction electrode 14 comprises a conductive surface connected to one pole of a reversing switch 57. Desirably the conductive electrode is a support surface such as, for example, a flat metallic surface suitably supported on or comprising a support bed plate of the device. Positioned over the induction electrode 14 is a xerographic plate comprising a photoconductive insulating layer disposed on a transparent conductive backing electrode 11 such as, for example, a glass plate with a conductive coating 11-a on the surface thereof, this conductive coating being either of a transparent material or being sufficiently thin so that it is largely transparent to incident light. For example, the conductive coating may be a thin evaporated film of aluminum or other metal on the surface of the glass plate, or the glass may be a conductive or conductively coated glass as is readily commercially available. Coated on the layer surface, or conductive surface, of the glass is a photoconductive insulating layer 12 such as the layer 12 of Fig. 1.

A sheet of an insulating material is positioned between electrode 14 and plate 10 or desirably a web 42 of insulating material is passed between said members passing from feed roll 43 to take-up roll 44. The conductive backing member 11 and the induction electrode 14 are connected to the output poles of reversing switch 67, and the input poles are connected to a D. C. potential source 21. By throwing reversing switch 57 in either direction, the potential or field between member 11 and member 14 may be made positive in either direction as desired. In the event that induction electrode 14 is to be raised to a potential other than ground it generally is desirable that this electrode be supported on insulating supports 58.

In operation, the device shown in Fig. 6 is energized by exposing the photoconductive insulating layer 12 to the projected image of object 20 while a potential difference is applied between backing electrode 11 and induction electrode 14. If desired, greater intensification can be achieved by first reversing the polarity of the potential or field through reversal of switch 57 and subsequent exposure and application of the desired potential or field. Alternatively, the electrostatic image placed on sheet or web 42 may be transferred to the xerographic plate after formation of the image by reversal of the polarity such as to drive the electrostatic charge back across the air gap to deposit the charge on the surface of layer 12. In this manner the electrostatic charge image can be placed either on insulating film 42 or on the photoconductive layer 12 as desired, and may be transferred from one to the other after its formation. Thus, the electrostatic latent image may be developed or otherwise utilized on insulating film 42 or it may if desired be developed or otherwise utilized on the xerographic plate.

In Fig. 7 there is illustrated in greatly enlarged form a diagrammatic representation of the formation of images according to one embodiment of this invention. It is to

be understood that this illustration is presented in an effort to describe the operation of the invention in accordance with one theory of mechanism which is believed to explain this image formation. It is to be realized, however, that other mechanisms of image formation may also be in accord with experimentally determined fact and that the present explanation is presented as one theoretical possibility and the invention is not to be limited to this expression of theory.

In Fig. 7 is a photoconductive insulating layer 61 disposed on a conductive backing member 62. Spaced therefrom by a minute air gap is an insulating layer 63 disposed on a conductive backing layer 64. This conductive backing layer 64 is transparent and on the back surface thereof is an image layer 65 adapted to interrupt the passage of light through the layer and to cause a light image to be projected onto the surface of the photoconductive insulating layer 61 as indicated by arrow 66. It is understood that image 65 is a diagrammatic representation of any means by projection or contact to control, in image configuration, the exposure to activating radiation. Thus, as illustrated, certain portions of the photoconductive insulating layer indicated as blocks 61-b are struck by light and become conductive whereas other portions 61-a are not struck by light and remain insulating.

A suitable voltage source or voltage supply 67 is operatively connected between conductive backing member 64 and conductive backing member 62 whereby a field or potential difference is applied between these two members. In the regions of the insulating portions 61-a of the photoconductive insulating layer this field is represented by plus signs in the induction electrode backing member 64 and by minus signs in the conductive backing member 62 of the xerographic plate, these plus and minus signs representing positive polarity and negative polarity charge or potential. In the regions of light activation, however, the selenium layer becomes conductive and, therefore, the charge or potential migrates through the layer and can be represented as being at the surface of the layer in the areas 61-b which are conductive due to the action of light. It is to be understood, however, that the air gap between layer 61 and layer 63 is extremely small and that the application of the relatively high potential between the surface of layer 61 and the conductive backing member 64 of the induction electrode will cause charge to migrate from the surface of layer 61 to the surface of layer 63. This charge, once deposited on the surface of layer 63, becomes trapped there because the layer is an insulator either in the presence of light or in its absence. The result is an electrostatic latent image on the surface of layer 63 corresponding to the areas which are illuminated in layer 61.

For simplicity of explanation in connection with the current theory of field emission, the formation of a negative polarity image has been illustrated in Fig. 7. In order to explain the formation of this image and to analyze it mathematically certain assumptions are taken with respect to voltages, thicknesses, and distances as well as dielectric constants. For the purposes of a mathematical interpretation it is therefore assumed that a potential difference of 1000 volts is applied between electrode 64 and electrode 62 and that the surfaces of layer 61 and 63 are separated by a distance of 2 microns. In practice a separation of this order of distance can be achieved by placing solid particles of the desired diameter between the surfaces. Layer 61 is assumed to be a layer of vitreous or amorphous selenium about 20 microns thick and for the purposes herein it is assumed that the dielectric constant of this layer is about 6. It is understood, of course, that this is a reasonable approximation of the dielectric constant of selenium, but that the exact figure is selected arbitrarily because of the fact that the dielectric constant of selenium varies depending on its allotropic form and perhaps also depending upon the conditions such as field or potential gradient and the like. It is also assumed

for the purposes of simplicity that layer 63 is an insulating layer of the same thickness, namely 20 microns, and also has the same arbitrarily assumed dielectric constant of 6. In this situation, then, when a 1000 volt potential difference is applied between the conductive backing electrodes in the areas of nonillumination, there will be a field of approximately 385 volts through the selenium layer 61 and through insulator layer 63, and a potential difference of about 230 volts across the air gap. In the other areas 61-b there will be substantially no field or potential difference through layer 61 and the field then will be such that about 375 volts will be across the air gap and about 625 volts through insulating layer 63. These voltages and fields are calculated in the assumption that the air gap is substantially a perfect insulator and this, of course, is not the fact.

The next approximation introduced into the figures is the arbitrary assumption that a potential gradient in the order of about 10^6 volts/cm. will cause the phenomenon known as field emission in air. It has been known for some time that a particularly high potential gradient adjacent to a surface of a solid will cause electrons to be torn from or emitted from the surface. This is the phenomenon known to the art as field emission and measurements have indicated that this phenomenon comes about at a potential which is generally in the order of 10^6 volts/cm. Accordingly, this value, as selected here arbitrarily, is a reasonable representation of the fact. Referring now to the previous figures, it is observed that when a potential difference of 375 volts is applied across an air gap of 2 microns thickness, the potential gradient across this air gap becomes a little less than 2×10^6 volts/cm., or a little less than 20 times the potential gradient required for field emission. Accordingly, it is apparent that under the conditions illustrated here, field emission or other mechanism of charge transfer will occur. To put the same facts differently, field emission or other transfer of charge must occur when the potential gradient in the air space above this surface exceeds about 10^6 volts/cm. and for a distance of 2 microns through air the total potential difference will not exceed about 20 volts.

It follows that in the embodiment shown in Fig. 7 charge will migrate from conductive backing member 62, through the conductive areas 61-b of the selenium photoconductive insulating layer, and across the air gap, to be deposited on the surface of layer 63 until a deposit of charge on this layer builds up to a charge density such as to reduce the potential gradient across the air gap to a value no higher than that required for field emission or namely about 20 volts. This will result in the formation of a substantial charge density in the image areas on the insulating layer 63. It is seen that for the nonconductive area 61-a of insulating layer 61 there cannot be the formation of an equal charge density in these nonimage areas of the insulating layer 63. The migration of charge across the air gap by field emission or other mechanism in the insulating area 61-a will build up a reverse potential gradient across this area rapidly. When charge potential to the amount of 105 volts has migrated to areas 61-a, these areas become 105 volts more negative, the background areas on layer 63 become only 105 volts more positive and the potential across the air gap here again becomes the 20 volt threshold for field emission. Using the figures presented herein, it is seen that the image corresponding to area 61-b will be a negative polarity image on the surface of layer 63, the potential of which will be equal to the applied potential of 355 volts minus the potential of about 20 volts needed for field emission or a negative polarity image of about 355 volts against a background potential of 105 volts. Layer 63, therefore, has on it image areas charged to a potential of about 355 volts negative polarity with background areas at a potential of about 105 volts negative polarity leaving a potential difference between image and

background areas of about 250 volts. An image of this potential difference can be developed by the methods and materials of Walkup and Wise, U. S. Patent 2,638,416, wherein a composition of powder particles and granular bead carrier material with the powder particles being charged by triboelectric relationship with the beads is rolled or cascaded across the electrostatic latent image-bearing surface to deposit the powder particles on the surface.

In carrying out the present invention care is to be taken to employ a good electrical insulator as the image surface or film on which the electrostatic latent image is formed. Similarly extreme care is to be taken to place this image surface in very close proximity to the photoconductive layer. In this connection it is to be observed that the present invention differs from certain prior art methods of treating electric charges wherein it has been attempted to induce an electrostatic charge or charge pattern to a surface which is conductive or which is temporarily made conductive. Thus, for example, it may be possible to form an electrostatic image of relatively low potential on the photoconductive insulating surface 12. According to the present invention, however, it is on the adjacent insulating surface and not on the photoconductive surface that the electrostatic latent image is to be formed and the invention includes the migration of charge from one surface to a second surface, with image formation on that second surface.

A brief examination of the mechanism of operation and the geometry of the members in terms of capacitance will illustrate the advantages that call for such charge transfer. In the first place, in Fig. 1, if the induction electrode 14 is spaced at even a moderate distance from the xerographic plate 10, there is a relatively low maximum potential which can be formed on the photoconductive surface. For example, in Fig. 8 of Carlson U. S. 2,297,691 there is an illustration of a system in which a substantial air gap exists between the members and in which there is formation of an electrostatic latent image on the photoconductive surface. However, as was done hereinbefore for the present invention, an analysis on a mathematical basis can be made of this prior disclosure. For clarity, referring to Fig. 7 herein, it is assumed that layer 63 again is a 20 micron insulating layer having a dielectric constant of 6, and in this case it is assumed that the air gap between layer 63 and layer 61 is $\frac{1}{40}$ inch air gap having a dielectric constant of 1. Layer 61 is again assumed to be a 20 micron layer of selenium also having a dielectric constant of 6. If in this case a potential of 1,000 volts is placed between electrode 64 and 62 and areas 61-b are made conductive by light to induce charge to the surface of layer 61 and then the light is cut off and electrode 64 removed, there will result a very small charge potential on these areas 61-b. Because of the air gap between layers 61 and 63 of $\frac{1}{40}$ inch or approximately 100 times the thickness of layer 61 itself, with the air gap having the dielectric constant of one as against the dielectric constant of 6 for the layer 61, it is seen that a potential of 1,000 volts through this air dielectric can induce to the surface of the conductive areas a total charge in coulombs which, after removal of electrode 64, will result in a potential difference of only a few volts between the surface of layer 61 and the surface of conductive electrode 62. Therefore, the prior procedure of image formation on the photoconductor can produce an electrostatic latent image on the photoconductive insulating surface, but this image will be only a few volts in magnitude. When electrode 64 is at a positive polarity, this is a negative polarity image on layer 61.

As was seen earlier, if these two members are brought closer and closer together there becomes finally a maximum potential in the order of about 20 volts for a 2 or 3 micron spacing which can be produced on the photo-

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conductive insulating surface by induction methods. This potential, however, will be comparatively less than a potential that might be left on the background areas by charge migration away from said areas and it is apparent that direct induction techniques are not the major cause of image formation in that case. It is apparent therefore that the electrostatic image which may be formed on the xerographic plate will be an image of comparatively low potential and that the purpose of the present invention is to form images of substantially higher potentials and to form such images on the adjacent insulating layer rather than on a photoconductive insulating layer.

Whether the mechanism of operation of the present invention is according to field emission or other phenomena such as air ionization or other methods of charge migration across the air gap, extremely close spacing is necessary between the two surfaces. It has been found that for most materials and surfaces the methods and apparatus of the invention operate at near optimum conditions when the two surfaces such as layers 12 and 15 of Fig. 1 are placed in nominal contact. Thus for materials such as a selenium surface of a xerographic plate and a polystyrene film disposed directly on a metallic backing member the condition of normal surface contact has been found to be extremely desirable. It is understood, of course, that in this condition there are a relatively few points of actual surface contact between the two surfaces, and at most points there are air gaps in the order of about a micron. A second system of somewhat preferable spacing for the surfaces described and other surfaces is a spacing system wherein a predetermined distance of several microns is maintained between the two surfaces. This distance is achieved by any of several methods and the following is recommended as a preferred method. A hard, relatively clear, transparent material such as a plastic or resin is ground to a relatively uniform particle size in the order of the size of spacing desired between the two members. A small quantity of the powdered material is dusted onto one of the surfaces in an amount to be almost invisible on the surface. The second surface then is placed on top of the dusted surface and the charging and exposing operations carried out as hereinbefore described. The presence of the powder particles scattered over the surface maintains between the two members a spacing in the general order of the same size as the particle diameter. In this manner distances between the two surfaces in the order of about 2 to 5 microns have been found nearly optimum and it is generally preferred that the two surfaces be spaced apart by a distance of less than about 10 microns. Somewhat greater spacing may be usable and operable under certain conditions and it is generally understood that the two surfaces according to the present invention should be spaced apart by a distance no greater than about 20 microns. It is observed that as the spacing between the surfaces increases two characteristics of the image result. In the first place the image becomes somewhat less dense and in the second place the resolution of the image decreases sharply. Such decrease is significant when the two surfaces are spaced apart by as much as 10 microns. Other impaired effects of lesser significance are apparent as spacing is increased. As a further observation it is pointed out that extremely good surface contact is not to be sought after since there can, under conditions of actual contact, be substantial transfer of charge or potential in the background areas and this transfer by contact frequently will result in a mottled background.

In Figs. 8 and 9 are illustrated two further embodiments of induction electrodes which may be employed according to the present invention. According to the embodiment of Fig. 8 a suitable induction electrode may comprise a very fine metallic or wire screen having a plastic coating on at least one surface thereof. Desirably,

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the working surface of this electrode should be substantially smooth and uniform. The electrode therefore comprises a conductive metal screen consisting of interwoven wires 71 imbedded in insulating plastic body 72. A conductive lead 73 is connected to the wire screen to form a means for applying a suitable potential to the electrode. Desirably the lead 73 is connected to a suitable wire mesh or the like and the electrode is formed by spraying, dipping, or painting the insulating film material onto the screen or mesh. It is desirable that the wires be relatively fine and the screen be substantially transparent to transmitted light, and be extremely fine and uniform. A fine screen such as a 200 mesh or finer sieving screen is excellent for the purpose, so that the screen or mesh pattern does not become significant as part of the electrostatic latent image, and so that the screen or mesh pattern does not unduly affect the transmission of a projected light image to the electrode.

In Fig. 9 is illustrated a cylindrical induction electrode designated 75. The electrode comprises a glass or other transparent support cylinder 76 having a coating 77 on its surface comprising a thin layer of metal such as aluminum deposited in a uniform film, for example, by evaporation on to the glass surface. Positioned on the metal film is a layer of an insulating material 78. Suitable support means are provided such as, for example, spokes 79 connecting the cylinder to a hub 80 which is adapted to be rotated around a shaft or axle or the like. As is apparent the electrode of the type described herein is particularly adapted to be used in conjunction with a continuous machine such as is disclosed in Fig. 5. If desired suitable image sources such as a light source or a reflecting mirror, prism, lens, or the like, may be mounted within the cylindrical induction electrode so that the induction electrode operates as a combination of the electrode 41 and lense or image member 48 of Fig. 5.

It is to be understood that variations and modifications may be made without departing from the scope of the invention, and that the disclosure herein is to be taken as being illustrative of the invention and not in limitation thereof.

This is a continuation-in-part of copending application Serial No. 368,408, filed July 16, 1953.

What is claimed is:

1. The method of forming an electrostatic image comprising varying electric charges on an insulating surface said method comprising positioning an insulating surface over a conductive electrode and in virtual contact with the surface of a normally insulating layer disposed on a conductive backing support, said insulating surface being positioned in face-to-face relationship with the surface of the normally insulating layer and separated therefrom by a minute gas gap, applying an electric field above the threshold of field discharge for the particular gap distance involved between the surfaces in virtual contact through said normally insulating layer and to the insulating surface to bring about electric breakdown of the gas gap between the surface of the normally insulating layer and the insulating surface to cause ionic movement in the gap for charge deposition, as controlled by the electric fields, on the insulating surface in conformity with a pattern of penetrating radiation being recorded while exposing the normally insulating layer to said pattern of penetrating radiation, said applied electric field being of a sufficient intensity in the absence of photo-emission for charge deposition on the insulating surface.

2. The method of forming an electrostatic image comprising varying electric charges on an insulating surface over a conductive electrode and spaced from the surface of an insulating layer carrying an electrostatic image, the insulating layer being disposed on a conductive backing support, the insulating surface and the image bearing insulating layer being spaced apart by a minute gas gap while in face-to-face relationship, said method comprising applying a high enough electric field through the

insulating image bearing layer and to the insulating surface for the particular spacing involved between the insulating surfaces to bring about electric breakdown of the gas gap between the surface of the insulating image bearing layer and the insulating surface to cause ionic movement in the gap for charge deposition as controlled by the electric fields and electrostatic image formation on the insulating surface in conformity with the electrostatic image of the insulating image bearing layer, said applied electric field being of a sufficient intensity in the absence of photo-emission for electrostatic image formation on the insulating surface.

3. The method of forming an electric image, comprising varying electric charges, on a first insulating surface in virtual contact with an electrostatic image bearing second insulating surface and in face-to-face relationship thereto, said method comprising applying an electric field above the threshold of field discharge between the two insulating surfaces to cause electric breakdown of the gap between the surfaces in virtual contact to create ionic movement for charge deposition as controlled by the electric fields and electrostatic image formation on the first insulating surface in conformity with the electrostatic image on the second insulating surface, said applied electric field being of sufficient intensity in the absence of photoemission for electrostatic image formation on the first insulating surface.

4. The method of forming an electrostatic latent image comprising varying electric charges on an insulating surface said method comprising positioning an insulating surface in virtual contact with the surface of a photoconductive insulating layer disposed on a conductive backing support, said surface being disposed and positioned in face-to-face relationship with the surface of the photoconductive insulating layer, applying a high enough electric field through said photoconductive insulating layer and to the insulating surface to bring about electric breakdown of the gap between the surface of the photoconductive insulating layer and the insulating surface to cause ionic movement in the gap for charge deposition, as controlled by the electric fields on the insulating surface in conformity with a pattern of activating radiation being recorded while exposing the photoconductive insulating layer to said pattern of activating radiation, said applied electric field being of a sufficient intensity in the absence of photoemission for charge deposition on the insulating surface.

5. The method of forming an electrostatic latent image comprising varying electric charges on an insulating surface comprising positioning said surface over a conductive electrode and in virtual contact with the surface of a photoconductive insulating layer disposed on a conductive backing support, said surface being positioned in face-to-face relationship with the surface of the photoconductive insulating layer and spaced apart therefrom by a minute gas gap, applying an electric field above the threshold of field discharge through said photoconductive layer and to the insulating surface while exposing the photoconductive layer to a pattern of radiation to be recorded to cause electric breakdown of the gas gap between the surfaces in virtual contact to create ionic movement in the gap for charge deposition on the insulating surface, as controlled by the electric fields, in conformity with the pattern being recorded, said applied electric field being of sufficient intensity in the absence of photoemission for charge deposition on the insulating surface.

6. The method of claim 5 in which the insulating surface and the surface of the photoconductive layer are spaced apart by a gap distance of up to about 20 microns.

7. The method of claim 5 in which at least one of the two paths to the photoconductive insulating layer, namely through the conductive electrode and the insulating surface or through the conductive backing support, is transparent and in which the pattern of light and shadow to be recorded is directed through the transparent path.

8. The method of claim 5 in which the photoconductive insulating layer subjected to exposure comprises photoconductive insulating selenium.

9. The method of forming an electrostatic latent image comprising varying electric charges on an insulating surface, said method comprising positioning the insulating surface in virtual contact with the surface of a photoconductive insulating layer and in face-to-face relationship thereto while spaced apart therefrom by a minute gap, applying an electric field above the threshold of field discharge through said photoconductive insulating layer and to the insulating surface while exposing the photoconductive layer to a pattern of activating radiation to be recorded, said electric field being sufficient in the absence of photoemission to cause electric breakdown of the gap between the surfaces in virtual contact to create ionic movement in the gap for charge deposition on the insulating surface, as controlled by the electric fields, in conformity with the pattern being recorded.

10. The method of forming an electrostatic image comprising varying electric charges on an insulating surface overlying a conductive electrode and spaced from the surface of an insulating layer carrying an electrostatic image, the insulating layer being disposed on a conductive backing support, the insulating surface and the image bearing insulating layer being spaced apart by a minute gas gap while in face-to-face relationship, said method comprising applying an intense electric field through the insulating image bearing layer and to the insulating surface, and while the field continues to be applied separating the insulating surface from the insulating layer, said applied electric field being above the threshold of field discharge and of a sufficient intensity to cause electric breakdown of the gap between the insulating surface and the image bearing insulating layer to create ionic movement and charge deposition as controlled by the electric fields to form, in the absence of photoemission, an electrostatic image on the insulating surface in true conformity with the electrostatic image on the insulating layer.

11. The method of forming an electrostatic latent image comprising varying electric charges on an insulating surface said method comprising positioning an insulating surface in virtual contact with the surface of a photoconductive insulating layer disposed on a conductive backing support, said surface being disposed and positioned in face to face relationship with the surface of the photoconductive insulating layer, applying an intense electric field through said photoconductive insulating layer and to the insulating surface while simultaneously exposing the photoconductive insulating layer to a pattern of activating radiation, and while the field continues to be applied separating the insulating surface from the photoconductive insulating layer, said applied electric field being above the threshold of field discharge and of a sufficient intensity to cause electric breakdown of the gap between the insulating surface and the image bearing insulating layer to create ionic movement and charge deposition as controlled by the electric fields to form, in the absence of photoemission, an electrostatic image on the insulating surface in true conformity with the radiation pattern to which the photoconductive insulating layer was exposed.

References Cited in the file of this patent

UNITED STATES PATENTS

2,221,776	Carlson	Nov. 19, 1940
2,277,013	Carlson	Mar. 17, 1942
2,297,691	Carlson	Oct. 6, 1942
2,357,809	Carlson	Sept. 12, 1944
2,666,144	Schaffert et al.	Jan. 12, 1954
2,693,416	Butterfield	Nov. 2, 1954
2,701,764	Carlson	Feb. 8, 1955

FOREIGN PATENTS

188,030	Great Britain	Oct. 23, 1922
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