July 20, 1965 L. E. WALKUP 3,196,013

XEROGRAPHIC INDUCTION RECORDING WITH MECHANICALLY DEFORMABLE IMAGE FORMATION IN A DEFORMABLE LAYER

Filed June 7, 1962 2 Sheets-Sheet 1

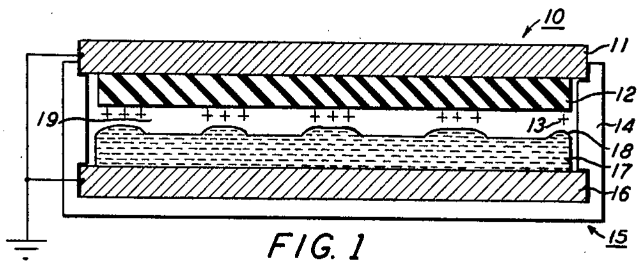

FIG. 1

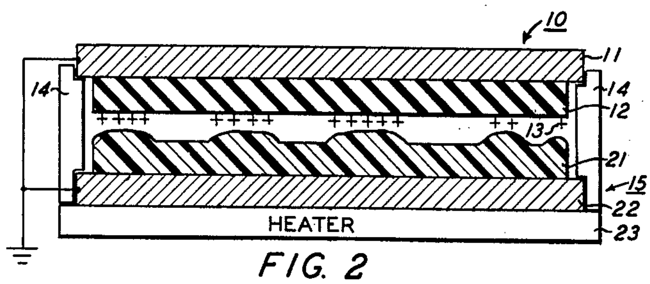

FIG. 2

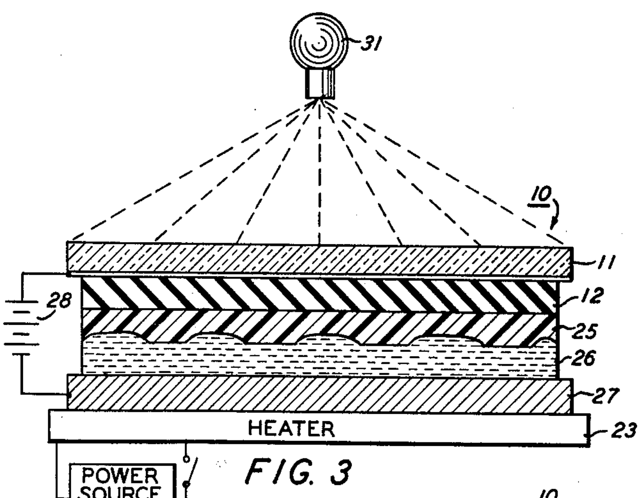

FIG. 3

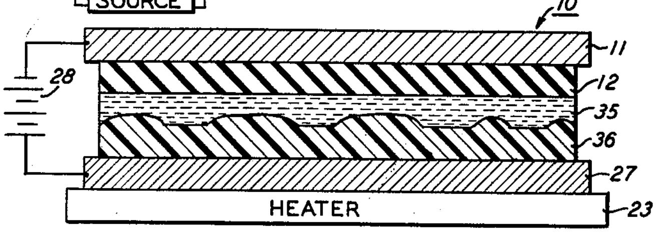

FIG. 4

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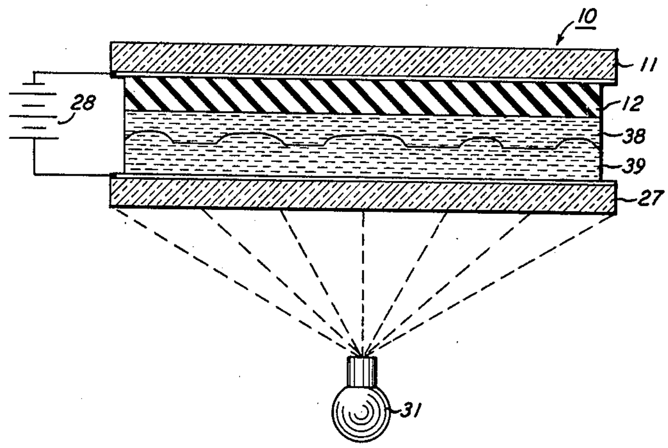

FIG. 5

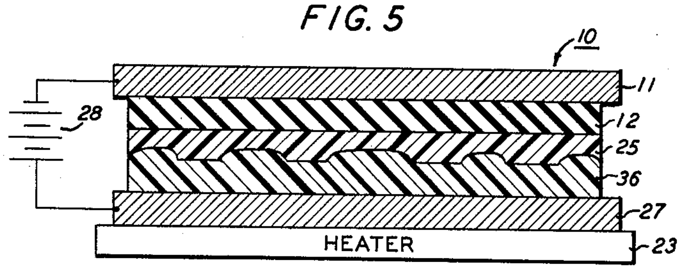

FIG. 6

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XEROGRAPHIC INDUCTION RECORDING WITH MECHANICALLY DEFORMABLE IMAGE FORMATION IN A DEFORMABLE LAYER

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This invention relates in general to xerography and in particular to deformation development of latent electrostatic images.

In conventional xerography the latent electrostatic image on a xerographic plate is developed by applying a particulate pigmented developer material characterized in that its is attracted selectively by a latent electrostatic image. Once the latent electrostatic image has been developed on a xerographic plate there is no way to re-use the xerographic plate until the developed image has been transferred and the plate cleaned of remaining developer material or the material has otherwise been cleaned off the plate. Thus, conventionally, it has been the practice to transfer the developed image from a xerographic plate to a copying paper and then by some means cleaning the remaining material off the plate. Such transfer and/or cleaning procedures necessarily introduce a considerable time factor into the operation. In some instances it has been found desirable to eliminate this time factor. Such instances occur, for example, in the cases of television, facsimile and radar applications where it is desired to display the image and then immediately replace it with further images in fairly rapid succession. It has been suggested that a liquid or thermoplastic layer over the surface of the xerographic plate may be deformed by the effects of the latent electrostatic image and may then be displayed by the use of schlieren optics or the like. In the case of the liquid layer, the image is erased by removal of the electrostatic image. In the case of the thermoplastic layer, the image is formed by softening the layer in the presence of the latent electrostatic image and is later erased by removing the electrostatic latent image and softening the thermoplastic material. It is plain, however, that with this suggestion there is also a considerable delay factor involved. Although it is not necessary to remove one developer material and add further developer material, the plate cannot be used for a second image until the first image has been displayed and erased.

Now in accordance with the present invention, it has been found that such a deformation image on a liquid or thermoplastic layer may be formed on such a layer that is spaced or separable from the xerographic plate so that the layer may be removed from proximity with the xerographic plate, displayed, erased and then returned for re-use while the xerographic plate may be re-used during the timer interval. To achieve this the present invention encompasses methods and means of deforming a separate or separable layer from the induction effects of the electrostatic latent image on xerographic plate. Thus, it is an object of the invention to define methods of deforming a deformable layer by electrostatic induction.

It is a further object to define a method of deforming a liquid layer by induction effects of a latent electrostatic image.

It is a further object to define a method of deforming a deformable plastic by induction from a latent electrostatic image.

And, it is a further object to define novel methods and means for simultaneously forming an electrostatic image and an induced deformation image.

Further objects and features of the invention will become apparent while reading the following description in connection with the drawings wherein:

FIGURE 1 is a diagrammatic illustration of induction deformation of a liquid layer.

FIGURE 2 is a diagrammatic illustration of induction deformation of a thermoplastic layer.

FIGURE 3 is a diagrammatic illustration of induction deformation of the interface between a conductive liquid layer and an insulating thermoplastic layer.

FIGURE 4 is a diagrammatic illustration of inductive deformation of the interface between an insulating liquid layer and a conductive thermoplastic layer.

FIGURE 5 is a diagrammatic illustration of inductive deformation of the interface between an insulating liquid layer and a conductive liquid layer.

FIGURE 6 is a diagrammatic illusrtation of inductive deformation of the interface between a conductive thermoplastic layer and an insulating thermoplastic layer.

The present invention utilizes the physical effects of electrical field forces for image reproduction. Thus, the fields emanating from an electrostatic latent image may be used to displace material in such a way as to form a usable image. In one embodiment of the invention, as shown in FIGURE 1, xerographic plate **10** carries latent electrostatic image **13**. This image may be previously formed in a conventional xerographic manner as by electrostatically charging photoconductive insulating layer **12** and exposing the layer to an image pattern to selectively dissipate some of the charge. The xerographic plate as shown comprises layer **12** of a photoconductive insulating material such as vitreous selenium, zinc oxide in a binder, or other known photoconductive insulators, and conductive backing **11** such as brass, aluminum, conductive paper, glass with a conductive coating of tin oxide, and the like. As illustrated, layer **12** has been charged positively and the charges have been dissipated in the areas where the layer has been illuminated. The charges remaining after forming the electrostatic latent image emanate fields or lines of force in the direction of available charges of the opposite polarity. Thus, these positive charges as illustrated will emit lines of force in the direction where there are no charges indicated on the surface of the layer or else down through the layer to the conductive layer underneath.

In accordance with the invention, xerographic plate **10** bearing the latent electrostatic image is maintained in the dark and is positioned on supports **14** immediately over the image plate **15** comprising a conductive layer **16** which may suitably be made of conductive paper, metal, or other conductive material, and a conductive liquid layer **17** such as water, alcohol, mercury, "Aquadag" (Acheson Colloids Corp.) a concentrated colloidal dispersion of pure electric furnace graphite in water with a solids content of 22%, an average particle size of 0.5 micron and a maximum particle size of 4 microns, or a liquified conductive resin material. The two plates are positioned as closely together as possible while avoiding actual physical contact. Thus, gaseous space **19** is maintained between the adjacent surface preferably with a gap width of between 1 and 5 mils. A narrower gap width presents too great a problem in precisely positioning the plates and raises the probability of dielectric breakdown which produces image defects. A gap width exceeding about 5 mils reduces the field effects obtained, lowers the quality of the reproduced image and reduces resolution and contrast. With the conductive liquid layer connected in common, through ground and conductive backing plates **11** and **16**, to the back of xerographic plate **10**, the electrical charges representing the latent electrostatic image attract charges of opposite polarity to the adjacent areas of conductive liquid **17**. As a result, the lines of force emanating from the latent electrostatic image find a proximate point of opposite polarity charges in the liquid layer 17 and exert the physical forces of attraction on those charges producing a deformation in the liquid layer. As illustrated in FIGURE 1, the surface of the liquid layer 17 is displaced in accordance with the latent electrostatic image to form a relief image 18.

An embodiment of the invention similar to that illustrated in FIGURE 1 is shown in FIGURE 2 wherein a deformable layer 21, which is a solid at normal room temperatures, is used in place of the liquid layer 17 in FIGURE 1. Thus, deformable layer 21 is appropriately a thermoplastic material such as glycerol ester of 50 percent hydrogenated rosin sold as "Staybelite" by Hercules Powder Co., styrene and styrene homologue resins and other thermoplastic materials preferably having softening temperatures between about 90° F. and 200° F. in order to maintain stability at room temperature and yet soften readily for image formation.

Such plastic materials are commonly electrically insulating but their conductivity is readily increased by appropriate additives. Thus, when there is no desire to pass light through the deformable layer, the plastic may contain carbon black or like conductivity agent such as a colloidal graphite suspension.

Where it is desirable to expose through the deformable layer, it is necessary to use an additive that will not reduce the transparency of the layer. Stannic chloride has been found suitable for this purpose.

Throughout this specification the relatively conductive deformable layer is described as "conductive." This is not intended to mean conductive in the general sense, but rather specifically to the electrophotographic art. In the general sense conductors are considered to have resistivities of less than 1 ohm-cm. Semiconductors are considered to occupy the range up to 10^9 ohm-cm. and materials with still higher resistivities are considered insulators. In electrophotography insulators are generally considered to be materials having resistivities of 10^{13} ohm-cm. and higher with materials capable of some charge retention having resistivities higher than 10^{10} ohm-cm. Thus, for electrophotographic purposes, it is conventional to speak of materials with lower resistivities than 10^{10} ohm-cm. as conductors. While no fine line can really be drawn, it is necessary for the present invention that the material used have a number of "free" charges available with sufficient mobility to neutralize induced potential differences without any substantial time lag. Accordingly, it is the intent that throughout the present disclosure, "conductive" shall be interpreted to include resistivities of 10^{10} ohm-cm. or less.

The deformable layer 21 is supported by a conductive layer 22 against which is appropriately positioned a heating element 23. After the xerographic plate carrying the latent electrostatic image is positioned adjacent to the deformable layer, the deformable layer can be liquified by energizing heating element 23. The deformable layer will deform in the image pattern as described in connection with FIGURE 1 during the liquid phase, and then upon deenergization of the heating element the deformable layer will freeze in the image pattern and may be removed from the presence of the latent electrostatic image for separate use. Re-heating in the absence of the latent electrostatic image will cause complete erasure of the image.

An embodiment of the invention for simultaneous formation of both the latent electrostatic image and the induction deformation image is illustrated in FIGURE 3. The embodiment of FIGURE 3 has the advantage of not requiring separate movement of the xerographic plate 10 and the image plate 15 during the process steps. A further advantage is that no corona charging is used, reducing the required voltage, equipment, and process steps. Also, this can work in a vacuum where corona charging is not possible. Thus, a xerographic plate 10 such as described in connection with FIGURE 1 is positioned in a sandwich with a deformable insulating layer 25 and a conductive liquid layer 26 in turn supported by a conductive backing 27. The deformable layer 25 which coats the conductive liquid layer 26 serves a dual function of providing a layer which may be frozen in a deformed condition and also providing an insulating barrier between the conductive liquid 26 and the photoconductive insulating layer 12. With this insulating barrier 25 it is possible to reduce the spacing between the photoconductive insulating layer and the conductive liquid layer down to a gap in the order of 5 microns or more. With this decrease in spacing gap as compared to the embodiment of FIGURE 1, improved image contrast and resolution is obtainable. As well as various thermoplastics listed in connection with FIGURE 2, the deformable layer 25 in FIGURE 3 is appropriately low melting point paraffin. A voltage is applied between the conductive layers 11 and 27 from a voltage source 28. While conventionally the voltage used for charging a xerographic plate is in the order of several thousand volts, in the embodiment of FIGURE 3, the desired effects may be obtained by a considerably lower potential so voltage source 28 is accordingly in about the range of 100 volts or higher. The limiting high voltage is one that would cause a dielectric breakdown in insulating layer 25 or photoconductive insulating layer 12. The sandwich of layers is heated as by a heating element 23 so as to liquify the deformable layer 25 to a highly compliant condition. The photoconductive insulating layer is exposed to a light image as by a projector 31 as illustrated in FIGURE 3. The backing layer of the xerographic plate is made of a transparent material such as glass coated with a conductive layer such as tin oxide. This permits exposure of the photoconductive insulating layer 12 through the back of the xerographic plate. Under the influence of the light image the electrical capacity of the sandwich varies in the image configuration. A greater charge density is achieved in the discrete areas of relatively greater capacity producing stronger field effects and selectively deforming both the conductive liquid layer 26 and the deformable layer 25 which yields to the forces induced in the conductive layer 26. When the heating element is disconnected, the deformable layer 25 will freeze producing a fixed deformed interface between it and the liquid layer 26. The image plate with the deformed frozen layer and the liquid layer may then be removed from the xerographic plate and an image projected from it by virtue of differences in refraction at the deformed interface. One of the advantages that is obtained in this embodiment and similar embodiments disclosed below is that when both the insulating deformable layer and the conductive deformable layer are in a liquid state the effects of surface tension and the like are greatly reduced and viscosity of the layers offers the principal resistance to deformation.

FIGURE 4 illustrates the variation of the embodiment of FIGURE 3 in which an insulating liquid layer 35 is positioned between the latent electrostatic image bearing surface and a conductive deformable layer 36. In this embodiment, layer 36 is made of a material that is solid at room temperature and readily liquifies on the application of heat. This has a slight advantage over the embodiment of FIGURE 3 in that the thermally liquifiable layer 36 is closer to the heat source 23. Thus, in FIGURE 4 the heating requirements are slightly less and there is less chance of deterioration of the xerographic plate 10 due to repeated application of heat.

The use of an insulating liquid and a conductive liquid is illustrated in FIGURE 5 in which an insulating liquid 38 is positioned in between the latent electrostatic image bearing surface and a conductive liquid layer 39. These two liquid layers must be selected so as to be non-miscible and the insulating liquid must have a lower density than the conductive liquid. For example, the conductive liquid may be water and the insulating liquid may be oil. In the embodiment of FIGURE 5 the resistance against the deformation effects of the latent electrostatic image is produced almost entirely by liquid viscosity and interfacial tension between the two liquids. Since materials may be selected to minimize interfacial tension, deformation is readily obtained enabling the use of lower voltages, thinner layers, and larger solid relief areas.

In FIGURE 6, both the insulating deformation layer and the conductive deformation layer are made of thermally liquifiable materials that are solid at normal room temperatures. With both of these layers made of a material such as thermoplastic, it is possible to strip them apart after the image has been formed and solidified so as to obtain two separate deformation images. In this embodiment the conductive layer would have a direct reading image while the insulating layer would have a mirror reverse image on its deformed surface. In FIGURE 6 as well as in FIGURE 3 it is possible to use an insulating layer that is bonded permanently to the photoconductive insulating layer of the xerographic plate. However, this would require slightly different xerographic steps from those customarily used. Thus, sensitizing the plate would have to be performed by a method such as disclosed in U.S. Patent 2,833,930 in which charge is induced to the photoconductor surface under illumination and then trapped at the surface by discontinuing the illumination.

FIGURES 3, 4, 5, and 6 are all illustrated with a voltage source **28** applied across the conductive layers **11** and **27**. However, if a latent electrostatic image is formed on xerographic plate **10** before the layers are sandwiched together, the common electrical reference connections as shown in FIGURES 1 and 2 produce the desired results. It is also possible to charge plate **10**, then sandwich the layers together, and then form the latent image by exposing with a light image through a transparent side of the sandwich. In this latter case, either a common reference as in FIGURES 1 and 2 or a voltage source **28** connected between layers **11** and **27** will establish the desired references for deformation.

The embodiments illustrated have been selected as showing the greatest number of variations within the inventive concept and it is intended that these encompass the various embodiments that would be formed by substitution between elements of the illustrated ones.

What is claimed is:

1. A method of image formation on the spaced surface of a continuous conductive liquid layer by induction from a latent electrostatic image comprising:

(a) forming latent electrostatic image on an insulating layer surface by uniformly charging and selectively discharging,

(b) positioning said conductive liquid layer with one surface spaced from said insulating layer surface a distance in the range of 5 microns to 5 mils,

(c) applying electrically conductive planes to the non-adjacent surfaces of said insulating layer and said liquid layer and providing an electrically conductive path between said conductive planes whereby electrical charges are induced into said liquid layer producing a surface deformation of said liquid in the pattern of the image.

2. A method of electrostatic induction image formation according to claim **1** in which the spacing between the conductive liquid layer and the insulating layer surface is an air space.

3. A method of inducing a relief image to form at the interface of a thermoplastic layer and a liquid layer comprising:

(a) coating a conductive surface with a conductive liquid layer,

(b) applying a thermoplastic layer having a thickness range of 5 microns to 5 mils to the surface of said liquid layer,

(c) positioning a xerographic plate having a photoconductive insulating layer with said photoconductive insulating layer in contact with the surface of said thermoplastic layer,

(d) forming a latent electrostatic image on said photoconductive insulating layer by uniformly charging and selectively discharging said photoconductive insulating layer, and

(e) heating said thermoplastic layer to a compliant state so that said liquid layer, acting in response to the electrostatic fields of said latent electrostatic image, deforms the interface between said liquid layer and said thermoplastic layer.

4. A method of electrostatic induction image formation from a latent image on a uniformly charged and selectively discharged surface comprising:

(a) coating a liquid dielectric material in a thickness range of 5 microns to 5 mils over a conductive thermoplastic layer,

(b) positioning a xerographic plate bearing a latent electrostatic image with its image bearing surface in contact with said dielectric material,

(c) connecting the conductive backing of said xerographic plate with an electrical connection to said thermoplastic layer so that electrical charges are induced into said thermoplastic layer in the pattern of the latent electrostatic image,

(d) heating said thermoplastic layer to compliancy so that the charges induced in it produce a relief image in the pattern of the latent electrostatic image,

(e) cooling said thermoplastic layer to freeze the image on the surface of the layer, and

(f) separating the thermoplastic layer bearing the relief image from the xerographic plate.

5. A method of electrostatic induction image formation from a latent image on a uniformly charged and selectively discharged surface comprising:

(a) coating a conductive plate with a conductive liquid of a first density,

(b) coating said conductive liquid with 5 microns to 5 mils of a dielectric liquid of a second density less than said first density,

(c) positioning a xerographic plate bearing a latent electrostatic image in contact with the free surface of said second liquid so that charges induced in said first liquid produce a deformation in said first liquid that is resisted substantially only by the viscosities of said first and said second liquid.

6. A method of simultaneously forming a direct reading relief image and a mirror-reverse relief image by induction from a single latent electrostatic image comprising:

(a) coating a conductive plate with first a conductive thermoplastic layer and second an insulating thermoplastic layer having a thickness range of 5 microns to 5 mils,

(b) positioning a photoconductive insulating layer, backed by a transparent conductive layer, in contact with the surface of said insulating thermoplastic layer,

(c) applying a direct current potential between said transparent conductive layer and said conductive plate,

(d) illuminating said photoconductive insulating layer through said transparent conductive layer with an image pattern of light and shadow,

(e) heating said thermoplastic insulating layer and said conductive thermoplastic layer to compliancy allowing the interface between them to deform in response to the electrostatic fields resulting from said image pattern,

(f) cooling said insulating thermoplastic layer and said conductive thermoplastic layer so that they solidify in their deformed configuration, and

(g) separating said insulating thermoplastic layer and said conductive thermoplastic layer to provide a direct reading image on the insulating thermoplastic layer and a mirror-reverse image on the conductive thermoplastic layer.

7. An image display member comprising:

(a) an electrically insulating layer, bearing on one surface a latent electrostatic image;

(b) a conductive liquid layer spaced from said insulating layer a distance in the range of 5 microns to 5 mils, the surface of said conductive liquid layer adjacent to said insulating layer being deformed in a pattern corresponding to the latent electrostatic image upon said insulating layer;

(c) a first conductive non-deformable layer positioned against that surface of said insulating layer which is non-adjacent to said conductive liquid layer;

(d) a second conductive non-deformable layer electrically connected to said first conductive layer and positioned against that surface of said conductive liquid layer which is non-adjacent to said insulating layer; and,

(e) supporting means adapted to hold the said several layers of said image display member in fixed spatial relation relative to each other.

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