United States Patent

[11] **3,615,387**

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[21] Appl. No. **193,129**
[22] Filed **May 8, 1962**
[45] Patented **Oct. 26, 1971**
[73] Assignee **Xerox Corporation**
Rochester, N.Y.

[54] **STRIPPABLE LAYER RELIEF IMAGING PROCESS**
6 Claims, 11 Drawing Figs.

[52] **U.S. Cl.** ..... **96/1.1,** 96/1.5, 117/201, 117/218, 178/6.6 TP, 340/173 TP, 346/74 TP, 355/9
[51] **Int. Cl.** **B41m 5/20**
[50] **Field of Search** ..... 96/1, 1.1, 1.5; 340/173 TP, 173 R; 346/74 PC, 74 TP; 178/6.6 TP, 6.6 R; 117/201, 218; 355/9

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ABSTRACT: Thermoplastic deformation images are produced by xerographically deforming softenable films temporarily overcoated on conventional xerographic sensitive members. By the use of appropriate support layers for the softenable films, the deformed films can be readily separated from the sensitive member while preserving the image.

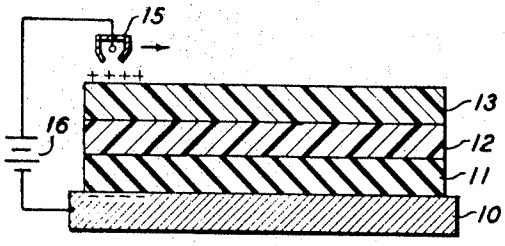


FIG. 1

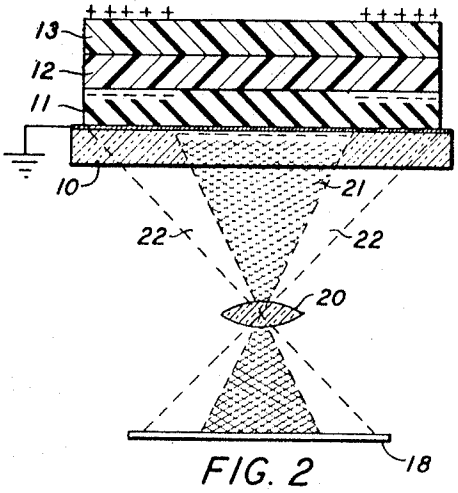


FIG. 2

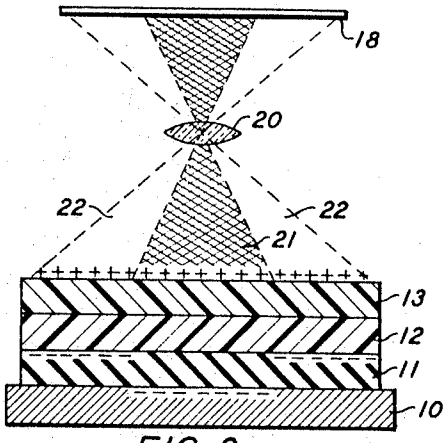


FIG. 3

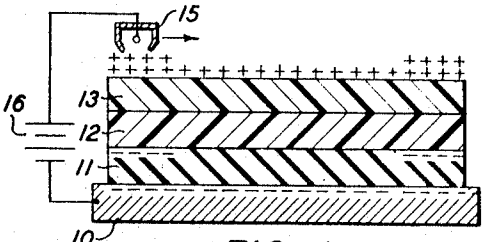


FIG. 4

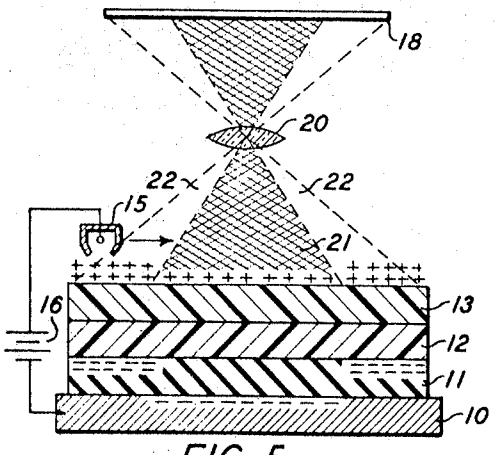


FIG. 5

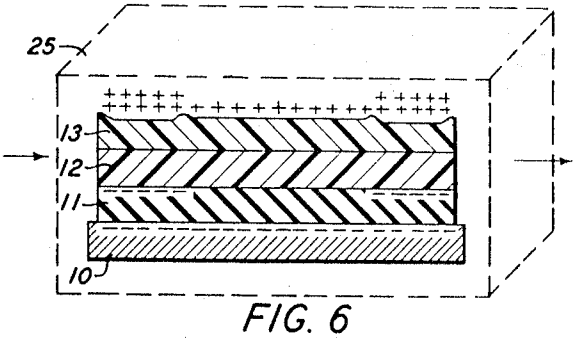


FIG. 6

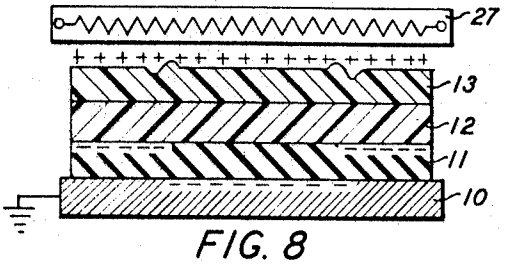


FIG. 8

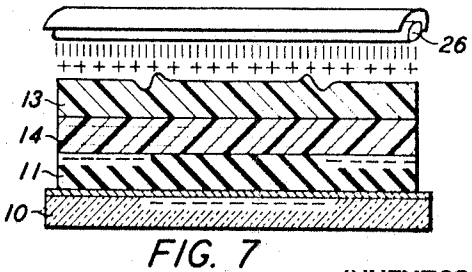


FIG. 7

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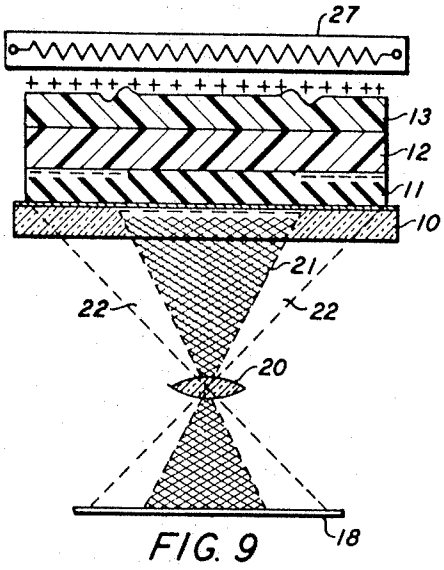


FIG. 9

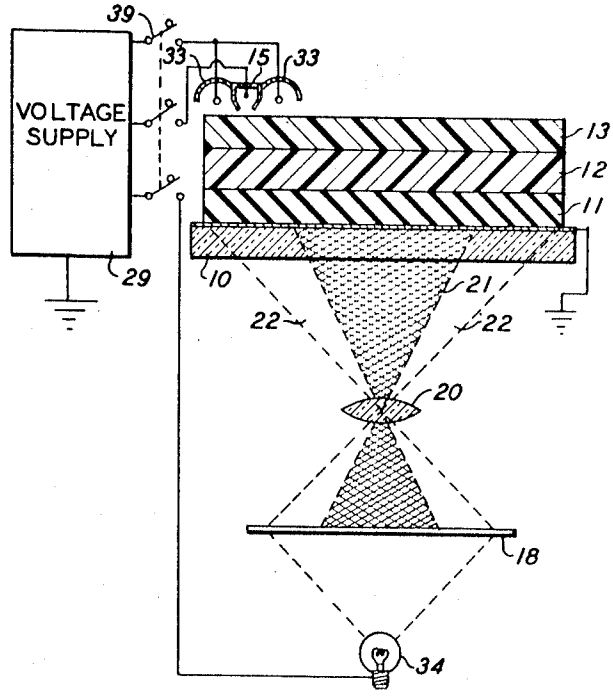


FIG. 10

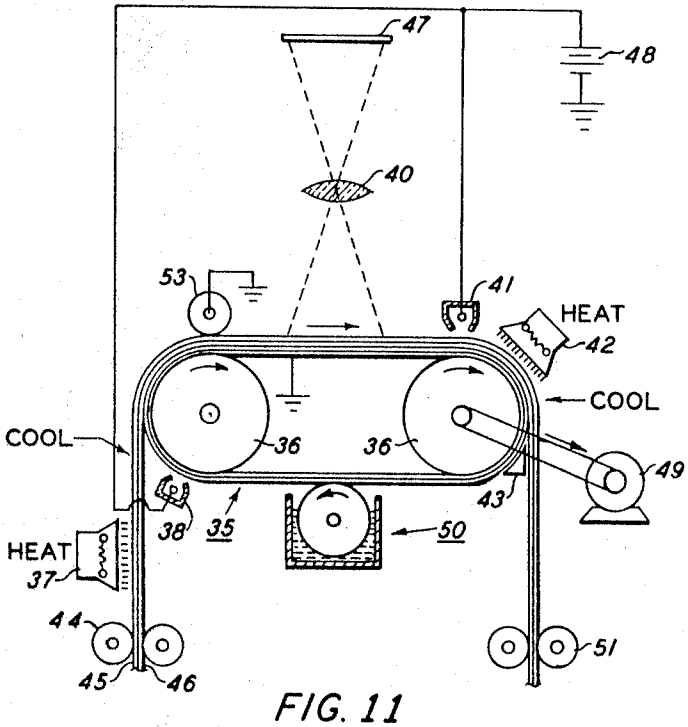


FIG. 11

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STRIPPABLE LAYER RELIEF IMAGING PROCESS

This invention relates to electrostatic printing and, in particular, to forms of electrostatic printing in which the latent electrostatic image is made visible by the deformation of a compliant layer. In xerography, as it was taught for example by Carlson in U.S. Pat. No. 2,297,691, as insulating photoconductive layer was sensitized by charging to an electrostatic potential and then the latent electrostatic image was formed by exposing the layer to an image pattern of light and shadow to selectively dissipate the electrostatic charge. The latent electrostatic image thus formed has been conventionally developed by means of an electroscopic pigmented powder. The powder image then must be fixed to a second layer or transfer sheet in order to prevent disturbance of the powder image. These steps of development and fixing of the image are time consuming and require considerable complexity in the apparatus. More recently, attempts have been made to develop latent electrostatic images by deformation of compliant layers as produced by the electrostatic forces of the image. This eliminates the necessity of a developer material, reduces the development time, and the complexity of the equipment. However, conventional xerographic materials and methods have not been found to lend themselves readily to this type of deformation imaging and attempts to make use of the more obvious methods have produced weak and impermanent images. Attempts to provide adequate deformation images have led to systems of increasing complexity. For example, systems operating in a vacuum and systems using a deformable liquid with a further development or transfer step to render it permanent. In some instances, it is particularly desirable to produce high resolution images so that large quantities of image data may be stored in a relatively small space or on a relatively small amount of recording material. Thus, for example, when recording equipment is used in different types of missiles and space vehicles, it is desirable that the amount of recording material needed to store a given amount of information be relatively small and that the equipment necessary to produce the image be likewise small without unnecessary operative stages. The necessity in conventional xerography of a bulky development stage and of relatively high heat fixing with its attendant high power consumption has ruled it out in the past for purposes of this nature.

Now in accordance with the present invention, it has been discovered that deformation images can be produced by xerographically deforming softenable films temporarily overcoated on conventional xerographic sensitive members. It has further been discovered that the use of appropriate support layers for said films enables the deformed films to be readily separated from the sensitive member while preserving the image. Thus it is an object of the invention to define self-supporting deformable overlayers for xerographic imaging.

It is an additional object of the invention to define methods for deformation printing using a photoconductive insulating layer coated with a separable deformable member.

It is an additional object of the present invention to define apparatus for xerographically deforming a separable member.

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

FIG. 1 is a diagrammatic illustration of charging a thermoplastic coated xerographic plate;

FIG. 2 is a diagrammatic illustration of exposing a sensitized thermoplastic coated xerographic plate;

FIG. 3 is a diagrammatic illustration of a second method of exposing a sensitized thermoplastic coated xerographic plate;

FIG. 4 is a diagrammatic illustration of a second charging step employed in accordance with an embodiment of the present invention;

FIG. 5 is a diagrammatic illustration of simultaneous charging and exposing of a thermoplastic coated xerographic plate;

FIG. 6 is a diagrammatic illustration of vapor development of a deformation image;

FIG. 7 is a diagrammatic illustration of heat development of a deformation image;

FIG. 8 is a further embodiment of heat development of a deformation image;

FIG. 9 is a diagrammatic illustration of simultaneous exposure and development of a thermoplastic coated xerographic plate;

FIG. 10 is a diagrammatic illustration of an embodiment using a colored thermoplastic layer in accordance with the present invention; and,

FIG. 11 is a diagrammatic illustration of apparatus for forming deformation images on a separable thermoplastic layer.

Some thermoplastic materials have been found to deform readily when softened while under the influence of a latent electrostatic image. An assembly of a xerographic plate carrying a layer of such a thermoplastic material is illustrated in FIG. 1. This arrangement is adapted in accordance with the invention to sustain either voltage gradients or electrostatic charge density gradients on a surface which is then deformable in accordance with such gradients. The plate is shown as comprising conductive substrate 10 coated with photoconductive insulating layer 11 as is conventional. Over the photoconductive insulating layer is interlayer 12 which is, in turn, coated with compliant thermoplastic 13. Substrate 10 may be any conventional conductive backing as used in conventional xerography. Thus, it may be brass, aluminum, or other metal or it may be a flexible conductive material such as conductive paper or a plastic material coated with a conductive coating such as tin oxide or copper iodide or it may be a transparent material such as glass or clear plastic with a conductive coating of tin oxide, copper iodide, or the like for transparency. Any conventional photoconductive insulator such as vitreous selenium, anthracene, sulfur, zinc oxide in a binder material, or other photoconductors may be used in insulating binders. However, as will be disclosed below, photoconductors adapted to forming uniform homogeneous layers have been found preferable for high resolution purposes. Interlayer 12 serves as a barrier layer between the thermoplastic and the photoconductive insulating layer and also serves other important functions. It protects the photoconductor from any interaction with the particular thermoplastic used. It serves as an isolation layer during development to protect the photoconductor from the effects of the solvent vapor or the effects of the heat and at the same time, helps to maintain electrical insulation between the thermoplastic layer and the photoconductive layer. A further function of interlayer 12 is in separable deformation layers in which case the interlayer serves as a separation support. This is essential since suitable compliant layers such as the various insulating thermoplastics have inadequate dimensional stability as self-supporting layers to maintain an undistorted image during separation. Since some photoconductive materials such as many of the organic photoconductors show no deleterious reaction to most thermoplastic materials or to temperatures used for softening such materials, the use of interlayers with them serves no purpose unless separation is required. Many of the high melting point plastics are suitable for use as interlayer 12. They are preferably tough, electrically insulating, and highly transparent. High dimensional stability is required where used for separable layers. In some embodiments of the invention, as will be seen below, however, the interlayer need not be transparent. One preferred material is "Vinylite" (trademark of Carbide and Carbon Chemical Company, New York, N.Y.) polyvinyl chloride. This has been found preferably because of its high insulating qualities, low reactive effects, high tensile strength, and a softening point above the temperatures necessary for deforming low melting point thermoplastic materials as found suitable for use with the present invention. Also suitable for interlayer 12 are other polyvinyl chloride or polyvinyl acetate resins, or mixtures thereof, as well as polyethylene terephthalate and other plastics having the desired characteristics set forth above. Thermoplastic layer 13, in accordance with the present invention, must be

adequately insulating to support an electrostatic charge on its surface and is preferably selected to be capable of maintaining such a charge while it is softened by heat or vapor to a point where deformation can occur. It is further preferable that the thermoplastic have a low softening temperature so that it will be deformed from the effects of a latent electrostatic image at temperatures below about 140° F. It is further desirable that the thermoplastic be free from flow effects at normal room temperatures, that is, below about 90° F. A preferred material has been found to be "Staybelite" (trademark of Hercules Powder Company, Wilmington Del.) Ester No. 10. This material has been found preferable due to longer term storage characteristics for preserving the image than has been found in other thermoplastics having similar electrical resistance and softening temperatures. Other suitable materials are "Piccolastic" (trademark of Pennsylvania Industrial Chemical Corporation, Clairton, Pa.), Type A with melting point from 50°–75 C.; "Nevillac" soft (trademark of Neville Company, Pittsburgh, Pa.); and other transparent thermoplastic resins having a melting point generally between 40° and 80° C. and electrical resistivity of at least 10^{12} ohm-centimeters at 30° C. The thermoplastic layer and interlayer are preferably kept thin for high resolution and in the case where the layers are permanently bonded, the interlayer may be as thin as one-tenth of a micron. Where separable layers are used, the interlayer must be thick enough to provide the necessary strength and dimensional stability for separation. Thus, for separable layers interlayer 12 may vary between a few microns and about 1 mil depending on the strength of the material used. The thinner layers may be applied to the photoconductive insulating layer by permanently bonding in a dip, spray, or whirl-coating procedure or by vacuum evaporation. For dip, spray or whirl-coating the plastic is dissolved in a solvent and applied to the photoconductive layer in a liquid form and then hardened by evaporation of the solvent. The thermoplastic layer may be coated over the interlayer in a similar manner. Where separable layers are used, the interlayer is preferably in the form of a self-supporting web which is coated with the thermoplastic layer by one of the procedures suggested above.

The process steps to form the image reproduction in accordance with the invention are capable of various manipulations which are generally selected in accordance with the particular conditions and desired results. FIG. 1 shows a conventional preliminary charging step that may be used to sensitize the thermoplastic coated plate of the invention. Corona charging device 15 connected to potential source 16 is arranged to apply a voltage of between approximately 100 and 1,000 volts to the surface of thermoplastic layer 13. While either positive or negative charging may be used, positive charging is illustrated as indicated by the plus signs shown at the surface of the thermoplastic with matching negative charges shown by minus signs in the substrate 10.

FIG. 2 illustrates exposure to an image pattern of light and shadow. The thermoplastic layer need not be transparent in which case, exposure is made through substrate 10. Substrate 10 in FIG. 2 is illustrated as a transparent glass or plastic layer with transparent conductive coating 17 to enable exposure of the xerographic plate through the back. This type of exposure has the advantage in the present invention in that the interlayer 12 and the thermoplastic layer 13 may have poor optical qualities and may be colored to the extent of being opaque if desired. It has been found generally preferable to obtain opacity of the plastic coated side of the plate by coloring interlayer 12. Thus, interlayer 12 may be colored by nigrosine dye, for example, which will produce adequate opacity in a 10-micron layer of polyvinyl chloride if added in the proportion of about 10 to 20 percent weight by volume of nigrosine to plastic. Addition of most colorants in sufficient strength to produce opacity in the deformable layer has generally been found to reduce the bulk resistivity to an excessive degree. If the thermoplastic layer and the interlayer are opaque, the development step is simplified as will be seen below. In FIG. 2, an image 18 is projected through an optical system 20 onto the xerographic plate. The crosshatched section 21 of the projected image indicates a dark section with little or no illumination while the uncrosshatched section of the projected image 22 is a light or high illumination portion of the image. Where illumination reaches the photoconductive layer 11, the resistance of the layer decreases so that negative charges in the substrate pass up through the photoconductor to the interface between the photoconductor and interlayer 12. Where the photoconductor is illuminated, the electrical capacity between the surfaces bearing the opposite electrical charges is increased due to the decrease in spacing between the charge carrying surfaces. Increasing the capacity in this way without changing the charge quantity decreases the voltage of the charged surface in accordance with the formula $Q=CE$. Q represents the quantity of electric charge in coulombs, C equals capacity in farads, and E represents voltage. It will be seen that when the capacity (C) is increased while the charge quantity (Q) is maintained constant, that the voltage (E) will be reduced. Thus, the measurable potential on the surface of the thermoplastic becomes less over the illuminated areas than over the dark areas.

FIG. 3 is an alternative embodiment of the exposure step in which the image pattern of light and shadow is projected onto the photoconductor through the thermoplastic layer. As is obvious, this requires a high degree of transparency in the thermoplastic layer and in any interlayer that exists. After exposure, the image may be developed immediately or the voltage differentials existing on the surface of the thermoplastic layer can first be changed to variations in charge density.

FIG. 4 illustrates a procedure for changing the voltage gradients into variations in charge density. This is done by repeating the charging step as performed in the first sensitization of the plate. Since the charging devices conventionally used in xerographic processes are voltage responsive, the charging device sees the reduced voltage over the illuminated areas and applies more charge as indicated by the double row of plus signs over the previously exposed areas of the plate. In the areas where the plate was dark during exposure, the charging device sees the original voltage and applies no additional charge. Thus, the charge quantity is increased only in the areas that were illuminated during the exposure step. There is a significant difference between the forces present after a second charging as in FIG. 4 compared with those present immediately after the exposure step. With just the voltage gradients on the surface, only an edge effect image can be produced while after the second charging, it is possible to produce effects on larger areas. This will be described in more detail in connection with image development illustrated in FIGS. 7–10.

It is possible to simultaneously charge and expose a thermoplastic coated xerographic plate as illustrated in FIG. 5. This produces the same effect as shown in FIG. 4 to a pronounced degree. Thus, since the exposure is going on continuously during charging, charges of one polarity in the substrate may continuously drift up through the photoconductive layer in the illuminated areas permitting increased charging in the respective thermoplastic surface areas. This permits greater relative charge density in the illuminated areas as compared to processes described in connection with FIG. 4 in which the conductivity of the photoconductor is shut off during the second charging. While in FIG. 5, the image is illustrated as projected from the same side of the coated xerographic plate as that on which the charge is applied, it is, of course, possible to project the image through a transparent substrate in the manner of FIG. 2 while simultaneously charging the surface of the thermoplastic layer.

Deformation of the thermoplastic layer in the image pattern can be produced by two general methods. One is to soften it by heating and the other is to apply a solvent preferably in a vapor form to soften the layer. Heat is considered preferable since it is more readily controlled and its action can be stopped more rapidly than that of the solvent. Following exposure as in FIGS. 2 and 3, deformation development must be

performed with the photoconductor shielded from light. If exposure has been made through a transparent substrate and an opaque plastic layer shields the photoconductor on the side of the deformable layer as has been suggested above, thermoplastic layer 13 may be developed by heat or vapor while under illumination. Also where recharging has produced charge density variations on the deformable surface, development may be carried out under normal illumination.

FIG. 6 illustrates the use of the solvent vapor. The plate carrying the thermoplastic layer can be passed into chamber 25 containing a solvent vapor for the thermoplastic. With a thermoplastic layer of "Staybelite," suitable solvents are ethylene dichloride, carbon tetrachloride, hexane, trichloroethylene, or the like.

FIGS. 7 and 8 show development by means of heat. The heat source in FIG. 7 is indicated as an infrared lamp 26 and the heat source in FIG. 8 is illustrated as an electrical resistance heating element 27. The infrared heat source is particularly suitable when one of the plastic layers is colored and exposure is made through a transparent substrate. The coloring absorbs the infrared radiation giving preferential heating. Accordingly, interlayer 14 in FIG. 7 is illustrated as an opaque layer.

It is also possible to develop an image by softening the thermoplastic layer during the exposure step. This is illustrated in FIG. 9 in which exposure from image 18 is made through transparent substrate 10 while an electrical resistance heating element 27 applies softening heat to the surface of the thermoplastic layer.

The amount of heat or solvent to be applied will depend upon the characteristics of the thermoplastic layer and of thickness. "Staybelite," by way of example, should generally be heated to a surface temperature of about 45°–70° C. In any case, the viscosity of the material should be reduced to between about 10^4 to 10^6 poises. A viscosity below this range generally produces a loss of surface charge which may be due to mobility of ions in the material as it becomes more fluid. A viscosity above this range will still permit deformation, however the time required will run into several seconds or even minutes which is generally excessive for practical use. It should also be noted in this connection that repeated heating of vitreous selenium to temperatures above 50° C. will lower its electrical resistance. However, with other photoconductors, such as the organic photoconductors, the repeated use of high temperatures has no significant effect on electrical characteristics. In at least one embodiment of the invention, a lower electrical resistance in selenium is not necessarily harmful as will be seen below.

In a particularly compact embodiment of the invention, the process steps of charging, exposure and development are carried out simultaneously as illustrated in FIG. 10. A further discussion of this embodiment is given in connection with techniques for enhancing image visibility.

After the material has been exposed as illustrated in FIG. 2 or 3 and then developed as illustrated in FIGS. 7 and 8, or if it is simultaneously exposed and developed as illustrated in FIG. 9, deformation can take place in accordance with the following theory which is presented by way of explanation but not intended to be limiting:

After electrostatic charging and before exposure, large fields exist in both the overcoating and the photoconductor in amounts inversely proportional to the dielectric constant. That is,

$$\frac{E_{ph}}{E_{th}}=\frac{K_{th}}{K_{ph}}$$

and

$$E_{ph}=\frac{4\pi Q/A}{K_{ph}}=\frac{V_{ph}}{d_{ph}}$$

where E is the field, Q/A the charge per unit area, K the dielectric constant, d the layer thickness, and ph and th the subscripts for the photoconductive and thermoplastic layers.

For typical xerographic use, the potential across a 20-micron selenium plate is about 600 volts, so that

$$E_{ph}=\frac{600}{2\times10^{-3}}=300{,}000 \text{ volts/cm.}$$

and across the thermoplastic with about one-third the dielectric constant,

$$E_{th}=900{,}000 \text{ volts/cm.}$$

After exposure, the field in the photoconductor would be reduced to a value proportional to the induced charge remaining on the substrate, so that a fully exposed area will have zero field within it. On the other hand, the field across the thermoplastic does not change (in large uniform areas). What does change is the potential. The potential of the free surface is given by

$V_{surface}=4\pi\sigma_{th}\, d_{th}+4\pi\sigma_{ph}\, d_{ph}$ where $\sigma_{th}=\sigma_o$, the initial charge and σ_{ph} = charge remaining on the substrate after exposure. If now the plastic is softened, nothing will happen in large exposed areas, because there has been no change in electrostatic stress. However, at the boundary between a region of higher potential (unexposed) and lower potential (exposed) an additional electrostatic field will be generated on both sides of the edge.

This will create additional electrical and mechanical stress at the exposed edge and reduced stress on the dark side of the edge, to give deformation in the softened film as shown, for example, in FIG. 7.

As part of an extensive computer analysis of fields above electrostatic surfaces, a calculation yields a value of 6×10^5 volts/meter for the normal components of the field at an edge between charged and discharged portions of the plate. For such a field and a charge density of 1.4×10^{17} coulombs/cm^2, the deforming pressure is

$P=6\times10^5\times1.4\times10^{13}=800$ newtons/$m^2=8000$ dynes/cm^2.

For a line electrostatic image 1.0 cm. long and 0.1 cm. wide, this yields a force of 80 dynes.

It should be noted that when a simultaneous development and exposure is used as in FIG. 9, a slightly enhanced image is produced since the first displacement of the surface during development produces additional variations in the layer capacity at the image edge increasing the contrast effected by the exposure and thus permitting a greater deformation.

As implied by the above theory of operation, in FIGS. 7, 8 and 9 as illustrated, an edge deformation of the image occurs at the position of the potential gradients 28. While this method will not reproduce solid areas, this edge effect type of image is capable of very high resolution and can be readily projected by the use of Schlieren optics or the like.

Where solid area reproduction is desired, a modification of the reproduction process has been found to permit limited solid area deformation. An example of this modification is the second charging step as illustrated in FIG. 4, or in a simultaneous charge and expose method as in FIG. 5. Thus, if the exposed material is recharged to bring it to uniform potential, the field produced by the charge density is increased in the exposed area. The image response of the softened plastic is generally to depress and create large thinner areas whose surfaces are parallel to the original surface. The image on such a layer yields phase differences which can be observed by a phase contrast method, however the ability of the material to squeezed out of an area by the image-dependent electrostatic force is greatly influenced by the conditions in the surrounding areas and accordingly this method is most useful where the areas to be depressed are relatively small. In reproducing continuous tones or large solid areas, a screening process is preferred to break the large solid image areas into readily deformed small areas.

With increased charge density in the exposed areas, a solid area deformation can be produced as indicated by the depressed areas 30 in FIG. 6. While development of the solid area deformation is illustrated in FIG. 6 by solvent vapor and while the edge deformation development has been illustrated in FIGS. 7, 8 and 9 by heat, it is completely a matter of choice which form of development is used for either the solid area

deformation or the edge deformation. As has been previously stated, heat development is generally preferable in both instances since it is more readily controlled.

The solid area deformation produced by differences in charge density produces an image of plane parallel areas at different levels. This type of an image is not readily observable and requires a phase-sensitive imaging system for display purposes. Several techniques for enhancing visibility of the deformed image have been found, however, that permit ready observation of such an image. FIG. **10** shows an example of this in which deformable thermoplastic coating **32** is of contrasting color or of highly differentiated color density relative to interlayer **31**. Thus, for example, layer **31** may be transparent while layer **32** is colored as by the addition of a small amount of nigrosine. These layers can be readily applied to the plate by dip coating steps in which layer **31** is permitted to harden and dry before the application of layer **32**. Upon forming and developing a solid area image of different charge densities, the exposed areas of the uppermost layer **32** are depressed and thus thinned out to the point where it is virtually invisible and the lower layer **31** is exposed to observation. This produces an immediate viewable image. It is also possible with separable layers to obtain a transparency. The deformable thermoplastic layer colored by some colorant such as nigrosine dye is coated on a separable interlayer that is highly transparent. After image formation and development, the depressed areas of the thermoplastic layer being relatively thin contain relatively less dye and transmit more light than the areas that are not depressed. Accordingly, the interlayer can be stripped off the plate carrying the deformed, dyed, thermoplastic layer and utilized in a conventional projector. Due to the effect of the usual colorants in lowering the resistivity of the thermoplastic it has been found desirable when using dyed deformable layers to charge, expose and develop simultaneously. Since this requires minimum storage time for the electrostatic charges on the deformable surface, a substantially lower bulk resistivity is compatible. With this simultaneous processing, resistivities as low as 10^{10} ohm-cm in the deformable layer have still permitted image deformation. The illustrated embodiment, FIG. **10**, is arranged to provide exposure through substrate **10** while charging and developing from the opposite side of the layered assembly. While this embodiment has been chosen for ease of illustration, it is just as suitable to use an opaque substrate and expose, charge and develop simultaneously from the side facing the deformable surface. Substrate **10** and photoconductive layer **11** are the same as described in previously disclosed embodiments. Interlayer **32** is preferably a clear plastic and layer **31** is a thermoplastic having a lower softening temperature than layer **31**. For example, layer **32** can be polyvinyl chloride and layer **31** can be "Piccolastic" A–75. Layer **31** contains a dye such as nigrosine. Effective coloring in a 5-micron layer of thermoplastic is provided by about 10 percent by weight of nigrosine base per volume of thermoplastic (CGS units.) Thinner layers require higher percentages of nigrosine and thicker layers require lower percentages of nigrosine to obtain the same maximum image density.

Heating elements **33** are shown in association with charging device **15**. As the charging device is operated to apply an electrostatic charge, the heating elements function to heat the same area to the deformation temperature of deformable layer **32**. Source of illumination **34** is operative in conjunction with optical system **20** to project a light and shadow pattern of image subject **18** onto photoconductive layer **11**. Voltage source **29** applies operating potentials to charging device **15**, heating elements **33**, and source of illumination **34** simultaneously by a ganged switch **39**. This simultaneous method has been found to be fast and is adapted to compact systems.

A method that avoids the use of colored layers requires an extra development step. By this method, a depressed area image is formed by any of the processes previously discussed and then a high viscosity or pastelike pigmented material is wiped over the surface of the deformed plastic so that it fills in the depressions. Pigmented materials that have been found useful for this purpose include printers' ink and many of the graphite dispersions sold under the trademark "Dag" such as "Aquadag" by Acheson Colloids Corporation of Port Huron, Mich.

A reusable temporary overcoating system is illustrated in FIG. **11**. This figure shows the continuously operable apparatus for producing deformed thermoplastic images on a thermoplastic layer overlying a continuous photoconductor web. The photoconductive web **35** comprises a photoconductive insulating layer on a conductive backing material which is carried onto rotatable cylinders **36**. Cylinders **36** are connected for rotation to a drive means **49**. Arranged in sequence in the direction of rotation of the photoconductive web is erasing station **37**, charging station **38**, exposure station **40**, recharging station **41**, development station **42** and separating station **43**. The thermoplastic layer **45** coated on a heat resistance transparent plastic support member **46** is fed through the erasing station **37** and into traveling contact with the photoconductive web by feed means **44**. The surface of photoconductive web **35** is precharged at electrostatic charging station **38** before contacting plastic support member **46**. At erasing station **37**, heat or solvent vapor is applied to smooth out the surface of the thermoplastic and erase any images on it that may remain from previous use. This erasing station may also suitably include cooling or drying means so that the thermoplastic layer will be more highly insulating when advanced over photoconductive web **35**. The plastic support **46** carrying thermoplastic coating **45** is transported along with the movement of the photoconductive insulating layer under pressure roller **53**. Pressure roller **53** is a conductive roller with or without an insulating surface layer and having an electrical connection to reference potential. The electrical reference permits the roller to apply electrostatic pressure as well as mechanical pressure to assure a uniform contact between member **46** and web **35**. The layers are then transported together past the exposure station **40** which suitably employs a conventional moving slit exposure means operating in synchronization with the movement of the layers. The exposure station projects a pattern of light and shadow through the thermoplastic and its support onto the photoconductive insulating layer **35** in accordance with an image subject **47**. The latent electrostatic image thus formed appears as voltage gradients on the surface of the thermoplastic insulating layer. The combined layers then pass through the second charging station **41** where residual conductivity in the previously illuminated areas of the photoconductive layer permits enhanced variations in the charge density produced by the voltage sensitive charging device. After the second charging, a development station **42** using heat or a solvent vapor develops the charge density variations on the thermoplastic layer. As in the case of erasure station **37**, development station **42** suitably includes cooling or drying means to harden or "fix" the thermoplastic layer so that the deformation image will remain after removal of the electrostatic image-forming field. The thermoplastic layer along with its support layer have been separated from the photoconductive insulating layer and utilized as by a Schlieren optical system for projection of the image. When the deformable layer is not permanently bonded to the xerographic member, as in FIG. **11**, it is preferred to wet the surface of the xerographic member before applying the plastic layer. Such wetting helps to eliminate air bubbles and may be added in a washing process that reduces dust or lint buildup on the xerographic plate. Silicone oil such as type DC–200–20CS (Dow Corning), other light oil or any electrically insulating low viscosity liquid that does not chemically react with the xerographic plate or the plastic layer can be used. FIG. **11** shows bath **50** for applying a liquid film to xerographic web plate **35**.

The present invention has a particular advantage in high resolution reproduction for high density image storage and the like. Resolutions greater than 115 line pairs per millimeter have been obtained. For optimum resolution, certain materi-

als and processes are preferred. The photoconductive material, itself, is preferably selected to have a smooth homogenous surface when coated on a substrate. Suitable photoconductive coatings are vacuum evaporated vitreous selenium or organic photoconductors dissolved in a solvent with an organic resin material. The organic solution provides a smooth homogenous coating by spray, whirl or dip coating procedures. Organic photoconductors for this purpose include 2.5 bis (4' diethyl aminophenyl) 1,3,4 oxadiazole; 2.5-bis-(P-aminophenyl)-1,3,4-triazoles and other 1,3,4 oxadiazole and 1,3,4-triazole compounds. One commercially available example in Kalle To 1920, available from Kalle and Co., Wiesbaden-Biebrich, Germany.

The thickness of the layers is a significant factor in high resolution embodiments. The thickness of the photoconductive layer is not as critical as the thickness of the overcoatings, but with vitreous selenium the best resolutions have been obtained with a vitreous selenium layer of about 50 microns. Layers from about 20 to 80 microns of vitreous selenium also produced good results. With other homogenous photoconductive layers such as organic photoconductive layers, high resolutions have been obtained with layers as thin as about three microns.

Of greater significance for high resolution considerations is the thickness of material between the photoconductive surface and the deformable surface. Empirically it has been found that the maximum resolution that can be obtained is generally limited by the thickness of such material in accordance with the relationship $R = k/4d$ where R represents the resolution in line pairs per millimeter, K is the dielectric constant of the material and d is the thickness in millimeter. Thus, it has been found for resolutions of better than 100-line pairs per mm., the thickness of material between the photoconductive surface and the deformable surface must be less than ten microns thick assuming a dielectric constant of about 4. With the thickness of an interlayer added to the thickness of the deformable thermoplastic between the photoconductive surface and the deformable surface, the dielectric constant must be adjusted accordingly.

While the present invention has been described as carried out in specific embodiment thereof, there is no desire to be limited thereby, but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. A method of image reproduction comprising:
   a. applying a thin film of electrically insulating low viscosity oil to the photoconductive surface of a xerographic plate,
   b. covering the oiled surface of said plate with a double electrically insulating plastic overlay in which the layer nonadjacent the photoconductive surface is a thermoplastic having a lower softening temperature than the layer adjacent the photoconductive surface,
   c. electrostatically charging the surface of the thermoplastic layer,
   d. exposing said plate to an image pattern to be reproduced,
   e. electrostatically charging the surface of the thermoplastic layer a second time,
   f. softening the thermoplastic layer until it deforms in correspondence to the image pattern,
   g. hardening said thermoplastic layer, and
   h. peeling said plastic overlay from said plate.

2. A method of image reproduction comprising:
   a. coating the photoconductive surface of a xerographic plate with a double electrically insulating plastic overlay in which the layer nonadjacent the photoconductive surface is a thermoplastic having a softening temperature between about 40° and 80° centigrade, and the layer adjacent the photoconductive surface is a dimensionally stable plastic between a few microns and one mil thick,
   b. electrostatically charging the surface of the thermoplastic layer,
   c. exposing said plate to an image pattern to be reproduced,
   d. electrostatically charging the surface of the thermoplastic layer a second time,
   e. softening the thermoplastic layer until it deforms in correspondence to the image pattern, and
   f. stripping the double plastic overlay from said photoconductive surface.

3. A method image reproduction according to claim 2 in which said softening is produced by application of a solvent vapor.

4. A method of deformation printing comprising:
   a. coating a xerographic plate having a transparent supporting substrate with a dimensionally stable deeply colored plastic layer between a few microns and 1 mil. thick,
   b. permanently coating said colored plastic with a transparent plastic layer having a melting temperature between 40° C. and 80° C. and a bulk resistivity at 30° C. of at least 10^{13} ohm-cm.,
   c. applying an electrostatic charge to the surface of said transparent plastic layer,
   d. projecting an image pattern of light and shadow through said substrate to expose said xerographic plate,
   e. softening said second plastic layer with infrared radiation until it deforms in accordance with the image pattern,
   f. cooling said transparent plastic layer, and
   g. separating said colored plastic layer supporting said transparent plastic layer from said plate.

5. A process for forming a relief pattern by electrostatic deformation of a thermoplastic surface comprising:
   a. coating a photoconductive layer supported on a conductive substrate with a double plastic overlay in which the layer nonadjacent the photoconductive surface is a thermoplastic layer having a melting temperature of about 40° C. to 80° C.,
   b. electrostatically charging the surface of said thermoplastic layer with respect to said conductive substrate,
   c. simultaneously with said charging, heating said thermoplastic layer to soften it to a viscosity of about 10^4 to 10^6 poises,
   d. while charging and softening said thermoplastic layer, exposing said photoconductive layer to an image pattern so that said thermoplastic layer deforms in accordance with said image pattern,
   e. cooling said thermoplastic layer until it hardens, and
   f. stripping said double plastic overlay from said photoconductive surface.

6. A method of image reproduction comprising:
   a. applying a transparent plastic layer to a xerographic plate,
   b. applying a colored thermoplastic layer having a melting temperature of about 40° to 80° C. to said plastic layer,
   c. applying an electrostatic charge to the surface of said thermoplastic layer while simultaneously softening said thermoplastic layer and exposing said xerographic plate to an image pattern of light and shadow to be reproduced,
   d. hardening said thermoplastic layer, and
   e. stripping said transparent plastic layer carrying said colored thermoplastic layer from the surface of said xerographic plate to obtain an image reproduction of relatively transparent and colored areas.