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[54] ELECTROPHOTOGRAPHY WITH A PHOTOCONDUCTOR COATED FINE MESH

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[51] Int. Cl. G03g 13/22
[58] Field of Search .... 96/1 R, 1 E, 1.1, 1.4, 96/1 TE; 355/3 R

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[57] ABSTRACT

The use of a photoconductor coated electrically conducting mesh for forming a latent electrostatic image in conformance with an optical image in an apparatus in which the photoconductor is placed in physical contact with an insulating member while a potential is applied between the conducting mesh and a conductive layer adjacent said insulating member.

4 Claims, 5 Drawing Figures

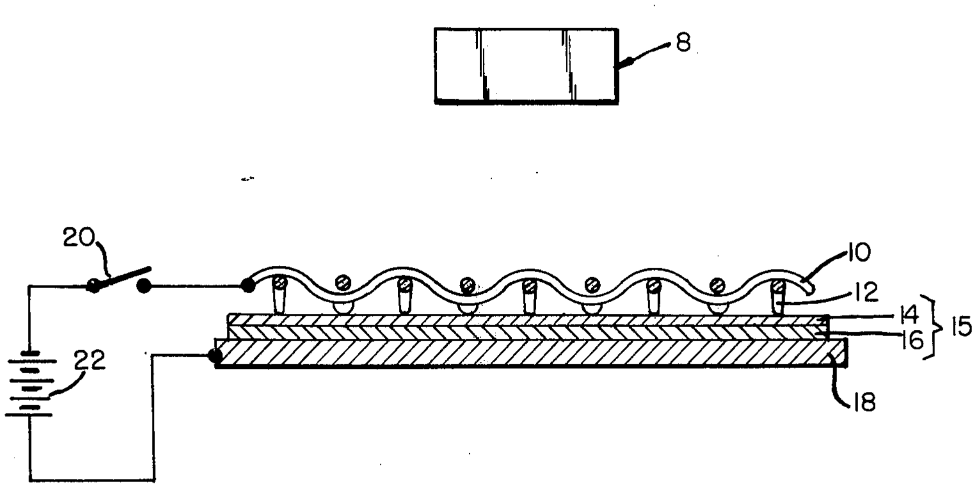


FIG. 1.

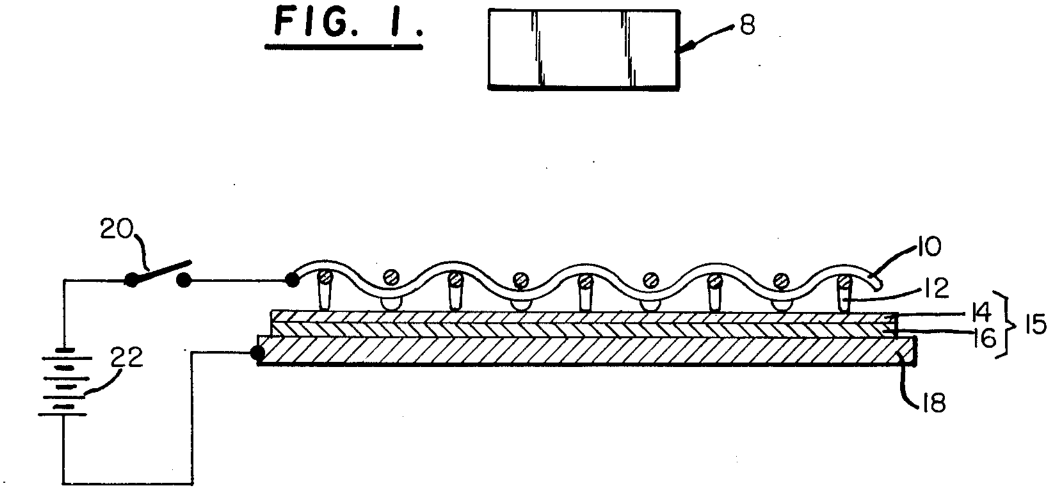


FIG. 2.

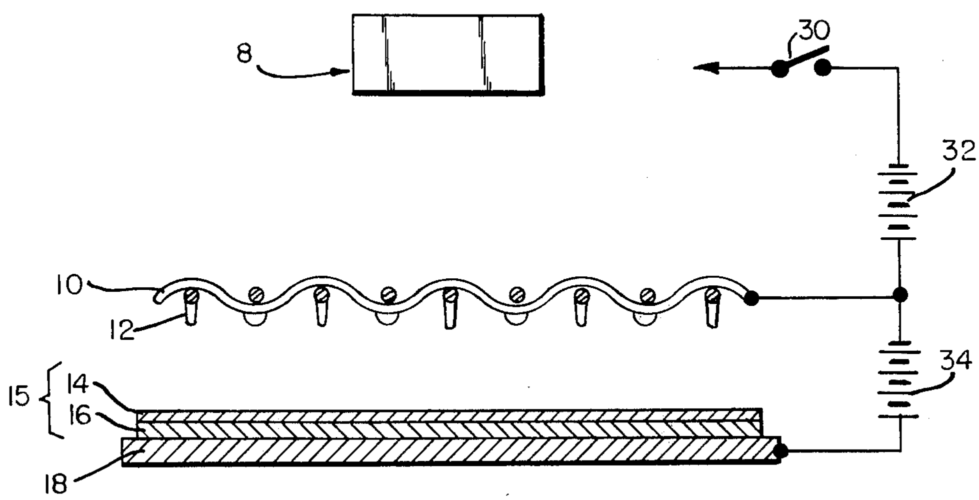


FIG. 3.

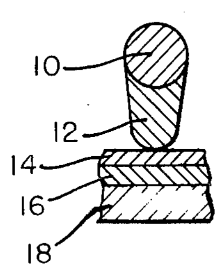


FIG. 5.

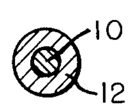
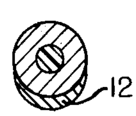


FIG. 4.



ELECTROPHOTOGRAPHY WITH A PHOTOCONDUCTOR COATED FINE MESH

SPECIFICATION

This invention relates to forming a latent electrostatic image upon a suitable receptor sheet, the invention residing in both the apparatus and its use in forming such a latent image.

BACKGROUND OF INVENTION

One known means of forming a latent electrostatic image upon a charge receptor sheet such as dielectric (electrographic) paper or a thin insulating plastic film involves the use of a transparent substrate coated with a semiconducting transparent layer over which is deposited a photoconductive layer. The photoconductor layer surface is placed in contact with the insulating charge receptor member and a potential is applied between the semiconductive transparent film and a conducting substrate supporting the charge receptor member. An optical image is projected onto the photoconductor simultaneously with the application of the electric field. This process is described by Walkup in U.S. Pat. No. 2,825,814 and in subsequently issued U.S. Pat. Nos. including 2,833,648; 2,937,943; 3,635,556; 3,649,261 and 3,653,890 and others. This known method of forming a latent electrostatic image does not, in general, provide full continuous-tone renditions. Furthermore, difficulties are encountered in establishing the proper spacing or degree of contact required between the photoconductor and the insulating charge receptor member; thus leading to nonuniform or blotchy image charge transfer.

Another known method of forming an electrostatic latent image on a charge receptor member, in accordance with an optical image, involves the use of a multiapertured member either directly adjacent to the charge receptor member or spaced a small distance away and employed in such a manner that the optical image controls the flow of ions through the apertures onto the dielectric receptor sheet. Processes of this type are described in U.S. Pat. Nos. 3,220,324; 3,220,833; 3,532,422; 3,582,206; 3,603,790; 3,645,614; 3,647,291; 3,680,954; 3,697,164; and in British Specification Nos. 1,149,901 1,152,308 1,173,427 and also in my copending applications Ser. No. 178,521 filed July 24, 1972; 275,674 filed Aug. 2, 1972; and 279,205 filed Aug. 14, 1972 now issued as U.S. Pat. Nos. 3,797,926; 3,761,173 and 3,843,250 respectively.

DESCRIPTION OF INVENTION

This invention relates to an invention in the formation of an electrostatic latent image upon a chargesupporting member in conformance with an optical image. The electrostatic latent image may be subsequently toned with any of a variety of conventional toning means such as cascade development, liquid electrostatic toning, magnetic brush, or powder cloud development to yield a visible image which may then be rendered permanent through fixing by any conventional fixing or fusing process known in the art of electrophotography.

One object of the invention is to provide an image forming process and apparatus which avoids the disadvantages of the prior art processes and apparatuses described in the patents noted above.

A further objective of this invention is to provide an electrophotographic process having extreme simplicity with resultant low cost, low maintenance, and associated advantages.

Still another objective of the present invention is to provide a capability for forming high quality, continuous-tone visible images in accordance with an optical image.

These and other objects of the invention will become apparent from the description which follows taken with the drawings in which:

FIG. **1** is a schematic drawing indicating one apparatus for the practice of the invention;

FIG. **2** is a schematic drawing showing a modification of FIG. **1**; and

FIGS. **3**, **4** and **5** are cross sectional views showing various strand configurations.

As shown in FIG. **1**, the apparatus comprises a fine mesh screen coated with a photoconductive material **12**. Screen **10** is placed in contact with a charge receptor member **15**. This charge receptor member consists of a thin insulating film **14** deposited over a semiconducting support base **16**. The charge receptor member **15** is in contact with an electrically conducting support plate **18**. Means for applying potential between the conducting screen **10** and the metal support plate **18** are provided by leads connecting a source of potential **22** in series with switch **20**, and with plate **18** and screen **10**.

Fine mesh screen **10** may be formed of any suitable metals or alloys. Typical electrically conducting materials which have been found suitable include brass, stainless steel, aluminum or phosphor bronze. The mesh count, i.e. the number of wires per linear inch, may range from 100 to 1,000; the finer mesh screens providing highest resolution. Or, the fine mesh may be fabricated from a woven synthetic resin monofilament such as polypropylene, polyester or polyamide. Such woven polymer screens are available in mesh sizes to over 325, are extremely strong, and somewhat less expensive than corresponding screens woven from metal wires. When an insulating plastic monofilament screen is employed, a conductive coating must be supplied to the surface of the monofilament. A convenient means of applying such a conductive coating involves vapor vacuum deposition of a thin layer of a conductor, such as aluminum, over the surface of the screen. Other means of providing conductivity, such as electroless plating, may also be employed. The photoconductive coating **12** should possess a high resistivity in the dark, typically in excess of 10^{12} ohm-centimeters.

A wide variety of photoconductors are effective for this process, including selenium, selenium-arsenic alloys, selenium-arsenic-antimony alloys, selenium-antimon-bismuth alloys, zinc oxide, cadmium sulfide, cadmium selenide, zinc sulfide, and solid solution combinations of the latter three photoconductors. In addition, a variety of organic photoconductors may be employed. In the case of zinc oxide and organic photoconductors, appropriate sensitizing dyes may be employed to modify and extend the spectral sensitivity in the manner well known to those skilled in the art. The photoconductive layer may be formed on woven mesh **10** in any of a number of ways such as vapor vacuum deposition, spraying, or settling of powders, and is not critical in the practice of the invention.

The charge receptor sheet, composed of insulating layer **14** and partially conducting layer **16**, many conveniently be a dielectric paper (also known as electrographic paper). Such papers comprise a partially conducting paper base layer coated with a very thin insulating polymer layer. The insulating polymer layer normally includes a well dispersed white pigment to provide good feel and surface characteristics. The thickness of the insulating dielectric coating is normally in the range of 1/5 to 1 mil. Such papers are commercially available from a number of sources. If a transparency is desired, the dielectric paper may be replaced with a thin polymer film such as acetate, polyester or polystyrene, having a transparent or semitransparent conductor on the back. Such transparent conducting layers may be formed in a variety of ways. One typical method of forming such a layer consisting of copper iodide involves vapor depositing a thin layer of copper onto the film surface and subsequently treating the copper layer with iodine vapors. The thickness of the plastic insulating layer is preferably not over 3 mils, and is typically in the region of 1 mil. If it is desired to have a thicker transparency for ease of handling, then a three layer charge receptor member may be constructed of a relatively thick film base which is coated with a transparent conducting layer and over which is coated a thin insulating layer. Such a member may be composed, for example, of a 5 mil polyester base upon which is placed a semiconducting transparent copper iodide layer, over which is next placed a ½ to 1 mil thick coating of a thermoplastic such as polystyrene.

The source of potential **22** is only required to supply currents in the range of microamperes for very short times. This source of potential may comprise batteries or conventional DC power supplies capable of providing potentials in the region of 500 to 1,000 volts.

In carrying out the process of this invention, the assembly of FIG. **1** is formed by laying the charge receptor sheet on conducting platen **18**. The photoconductor coated fine mesh screen is then laid over the charge receptor sheet so that the photoconductor is in gentle contact with dielectric layer **14** at the many thousands of high spots (crossover point areas) of the screen. The photoconductor is thus in uniform contact with the dielectric receptor layer only in those areas where the wire mesh forms a point of contact. No pressure is applied between the screen and the dielectric receptor member other than the electrostatic forces generated as a consequence of the application of the potential between the metal screen and the semiconducting member **16**.

A latent electrostatic charge image is formed by closing switch **20** while simultaneously providing an optical image at the fine mesh screen. This optical image may be generated by any of a variety of means. A projector or enlarger may provide the image or a transparency may be laid directly on the screen to provide a contact print. Alternately, a cathode-tube display may be optically imaged or a scanning laser beam caused to traverse the screen to form the optical image. Thus, this image may be formed either uniformly over the whole surface of the fine mesh screen or the image may be formed in a point by point scanning manner.

When a paper-base or other semiopaque or opaque receptor sheet is employed in this process, the incident exposing illumination is preferably directed onto the screen from the uncoated side of the screen. In carrying

out the process using a transparent or semitransparent receptor sheet, the illumination may be incident upon either side of the screen. For illumination which passes through the charge receptor sheet, conducting platen **18** must be transparent to the illumination also. Conducting glass is effective in this event.

In illuminated areas of the screen, the resistivity of the photoconductor is reduced, thus permitting charge to transfer to the dielectric receptor sheet. The process, when operated in this manner, is negative-working. The image as generated in this manner is in the form of a dot or half-tone screen; a 400 mesh screen providing a dot pattern having a count of 280 dots per linear inch. The size of the dot is dependent upon the exposure level at the photoconductor. Thus, a screened half-tone image capable of faithful tone rendition is obtained. It has also been found that the density of the toned image in the dot is somewhat dependent upon the exposure, thus providing a true continuous-tone effect. Since the image is inherently screened, any conventional electrostatic toning method provides excellent solid area coverage without the necessity for employing a development counterelectric. Since the screen has a modest degree of flexibility, intimate contact between high points on the screen and the dielectric receptor member is assured as a consequence of the flexibility of screen and receptor sheet members and the high electrostatic force generated between these members during the application of potential. Furthermore, the presence of the many small apertures in a typical coated screen allows air to escape between the screen and charge receptor member as these members are electrostatically drawn together thus providing uniform contact over large areas.

After the latent image has been formed on the dielectric charge receptor sheet, this sheet may be electrostatically toned and fixed. Alternately, a thermoplastic recording receptor member may be employed as a charge receptor. In this case, heating of the thermoplastic member provides a relief image which, being self-screened, is suitable for scattering illumination in formerly charged areas in a manner similar to frost image thermoplastic recording.

This process may also be employed to provide positive images. In order to generate a positive image, i.e. an electrostatic charge on the dielectric receptor sheet in nonilluminated areas, it is necessary to first charge the dielectric receptor sheet using a blanket exposure of illumination and next, reverse polarity of potential source **22**, and then expose the photoconductor screen to the image to be copied. This second step discharges those areas of the dielectric paper which were previously charged in the first step, thus providing an electrostatic charge image in non-illuminated areas of the image-wise exposure.

The following examples illustrate variations in the process described in this disclosure. These examples are not meant to limit the invention in any way.

EXAMPLE 1

A plain square weave, 400 mesh, stainless steel, woven wire screen was stretched over a square aluminum frame whose inside dimension was 12 inches on a side and whose outside dimension was 13 inches. The stainless steel screen was fastened to the frame with epoxy cement. The frame-screen assembly thus prepared was mounted in a vacuum vapor coater an average distance of 24 inches from a quartz crucible mounted in a tantalum heater. A charge of 100 grams of high purity selenium was placed in the evaporation crucible. The vacuum coater was evacuated to a pressure of 10^{-5} torr and the selenium evaporated from the boat onto the screen over a period of 1 hour. During the evaporation, the screen was maintained at an elevated temperature, employing an electrical heater, of 70°C. The resultant selenium coating thickness was found to be approximately 1 mil.

A sheet of Weyerhaeuser Company dielectric coated (electrographic) paper was placed, dielectric coating side up, on an 8 × 10 inch aluminum plate. The selenium coated wire mesh screen was placed (selenium coated side down) over the dielectric paper. A power supply providing 800 volts was connected in series with a switch between the conducting fine mesh screen and the aluminum platen.

The image of a negative was projected onto the screen, the high-light brightness in the image being approximately 100 foot-candles. During the time the image was projected (a period of approximately 1 second), switch **20** was closed. At the end of this exposure, the dielectric paper was removed and developed in an Addressograph Multigraph Corporation magnetic brush dry toner unit. The developed image was then fixed employing a Sun Chemical Corporation Model 120 radiant fusing unit.

EXAMPLE 2

The process of Example 1 was repeated; however, this time a contact print was made by laying a continuous-tone transparency directly over the photoconductive screen. The exposure was made employing as a light source a single pulse from a General Radio Type 1538-A electronic stroboscope, the pulse duration being 3 microsecond. After development, a high quality image was obtained. This short exposure time formation of the latent image illustrates the extremely rapid response of this process.

EXAMPLE 3

The process of Example 1 was repeated except that the image was formed by scanning the screen with a 1 mw output helium-neon laser whose output beam was focused, with the aid of a Galilean telescope, to a diameter of 0.010 inch. Satisfactory high density traces of the scanning laser beam were obtained after magnetic brush toning of the latent image.

EXAMPLE 4

A P-4 phosphor faceplate of a cathode-ray tube was imaged onto the photoconductive screen using an f/4.5, 6 inch focal length lens. A high density image corresponding to the cathode-ray tube display was obtained at scanning velocities of 50 inches per second.

With the use of the screen described in Examples 1–4, the resultant sensitivity depends on the applied potential. At voltages much in excess of 900 volts, background density appears as charge is transferred in non-illuminated areas of the screen. It was also found that the equivalent results were obtained independent of the polarity of the power supply. It was necessary, however, to employ toners which provided different charged pigment development particles in accordance with the sign of the charge transported onto the dielectric coated paper. For example, when the polarity of power supply **22** was such that the screen was maintained positive with respect to the paper backing platen, then positive charge was transferred to the surface of the dielectric paper. In this case it is necessary to develop with a magnetic carrier toner system in which the toner particles acquire a negative charge with respect to the magnetic carrier.

EXAMPLE 5

The process of Example **1** was repeated except that a positive image was formed from a positive transparency which was projected to form a positive optical image at the photoconductor coated screen. The potential was connected such that the screen was 900 volts positive with respect to conducting platen **18.** The switch was closed for a period of 2 seconds while the screen was uniformly flooded with 50 foot candles of tungsten illumination. Next, the power supply polarity was reversed and the potential lowered so that the screen was at a potential of −700 volts with respect to conducting platen **18.** A projected positive transparency, having a high-light brightness near 100-foot-candles, was projected onto the screen, while the potential was applied, for a period of 1 second. The image receptor sheet was then removed from the sandwich-like array and toned using the magnetic brush toning apparatus. A high density positive image was formed.

EXAMPLE 6

A plain, square weave, 400 mesh, stainless steel, woven wire screen was stretched over an aluminum frame and the screen fastened to the frame with epoxy cement. The frame-screen assembly thus prepared was supported in a horizontal plane at the bottom of a large beaker. The beaker was filled with methylethylketone, in which was dissolved a chlorinated rubber. Copper and chlorine-activated cadmium sulfide powder was dispersed in the solution and allowed to settle under gravity onto the wires of the fine mesh screen. After the cadmium sulfide powder had settled, the liquid was decanted from the beaker and the screen removed and dried.

This screen was employed to form visible images, corresponding to the negative of a projected image, in the manner of Example 1. Increased sensitivity was observed; satisfactory images being obtained with an exposure period of 1 second at a high-light brightness of 5 foot-candles.

EXAMPLE 7

The process of Example **1** was carried out with the exception that the dielectric paper was replaced with a transparent receptor sheet. This transparent receptor sheet was prepared by first vapor depositing a thin layer of copper onto a clean 5 mil thick polyester film base. The copper was then converted to copper iodide by holding the copper coated film in a stream of iodine vapor. Finally, a thin dielectric film was provided over the now transparent semiconductive copper iodide layer by employing a draw-down coating procedure, using a Bird applicator, and a 10 percent solution of polystyrene in a 50:50 benzene-toluene solvent. The dry coating thickness of the polystyrene layer was very close to one-half mil. The same procedures were employed as in Example 1 with approximately equivalent results, except the image could not be viewed by transillumination.

TWO STEP METHOD

The process of this invention may also be carried out in a less direct manner. In this method of operation two steps are employed to obtain an electrostatic latent image upon a charge receptor sheet. The first step is identical to that described above, that is a latent charge image is formed not only on the dielectric charge receptor sheet but also on the surface of the photoconductor. Thus, in illuminated areas, a surface charge will reside on the photoconductor while in non-illuminated areas no such charge exists.

If the photoconductor coated screen, bearing the latent image charge is separated from the dielectric receptor sheet and a second dielectric receptor sheet placed under the screen (as shown in FIG. 2), then it is found possible to provide an electrostatic latent image on the second charge receptor sheet by employing the latent image on the photoconductor to control the flow of ions from an ion source onto this second receptor sheet.

In FIG. **2**, which illustrates the manner of carrying out the second step of this indirect operating mode, the conducting screen **10** and photoconductor **12** are shown positioned either in contact with or within a distance of 1 inch above a second dielectric receptor sheet having a dielectric coating **14** and a semiconducting support **16**. This receptor sheet is also supported on a conducting platen **18**. A corona wire **30** is shown in FIG. **2** as providing the source of ions. The ions are generated upon providing a potential from source **32** that maintains the corona wire potential at a voltage of at least 6 kv and more preferably 10 to 15 kv positive with respect to conducting screen **10.** A second source of potential **34** is employed to maintain conducting screen **10** positive with respect to conducting base plate **18.** This second source of potential serves to maintain the collimation of any ion beams passing through the apertures in conducting screen **10** to preserve the resolution of the latent charge image deposited upon dielectric layer **14.** The corona wire **30**, preferably fabricated from 0.002 to 0.005 inch diameter platinum alloy or tungsten wire is caused to mechanically move across screen **10** as indicated in FIG. **2.** Alternately, an array of corona wires may be positioned above screen **10** so as to provide a uniform corona current to the screen. Although the corona wire may be operated at a negative potential with respect to the screen, a positive potential is preferred since a more uniform corona distribution is obtained and since lower quantities of ozone are evolved in the formation of an effective corona current to the screen.

The required potential of power source **34** depends upon the spacing between photoconductor coated screen **10** and the dielectric receptor sheet **14.** If the spacing is very close, i.e. less than 0.01 inch, this potential may be very low or, in fact, equal to zero. For spacings as great as one-half inch, a potential of 8 to 10 kv is required to maintain collimation of the ion beam.

In carrying out this indirect method of operation, the original dielectric receptor sheet which assisted in the formation of a latent charge image upon the photoconductor surface may be reused by merely erasing its latent charge image through the use of an AC corona or by wiping the surface of said sheet with a conductor to substantially discharge the surface potential at the sheet.

The photoconductor coated screen containing the latent image may be employed to control the flow of charged toner particles through the apertures in the screen in a manner similar to that described in U.S. Pat. Nos. 3,220,833; 3,582,206 and 3,647,291. In this event, the toned image is generated directly upon the receptor sheet and, in fact, the charge receptor sheet may be replaced with any conventional paper since in this event it is not necessary that the dielectric receptor sheet be capable of supporting an electrostatic latent image.

One method of operation in the "indirect" mode as well as the principles of operation may be better understood from the following example.

EXAMPLE 8

The screen of Example 1 was employed in the same manner as indicated in Example 1 to provide an electrostatic latent image on the surface of the photoconductor coating the conducting mesh screen. A positive projected image was focused on the screen and a potential of +800 volts, with respect to the conducting platen **18,** applied to the screen for a period of 2 seconds. At the end of this period, the potential was removed and the illumination extinguished. While in the dark, the screen was raised one-quarter inch, the initial charge receptor sheet removed, and a second sheet inserted into position as shown in FIG. **2.** The screen was next maintained at a potential of +6000 volts with respect to conducting platen **18** while corona wire **30,** a 2 mil diameter tungsten wire supported one-half inch above the screen, was maintained at a potential of 12 kv positive with respect to conducting screen **10.** While in the dark, the corona wire was caused to traverse over the screen at a velocity of 2 inches per second.

In areas which had been previously exposed, no ion current was observed to pass through the apertures in the screen and hence onto the dielectric receptor sheet. In previously nonilluminated areas, on the other hand, corona current did pass through the screen apertures to form a latent image on the dielectric receptor sheet in those areas corresponding to nonilluminated areas in the original exposure; thus providing a positive-working rendition after the dielectric receptor sheet had been electrostatically toned.

It was found that multiple copies could be prepared by repeating the second step in this process. After each traversal of the corona wire, the latent image-containing receptor sheet was removed and replaced with a fresh receptor sheet which, in turn, was charged with a latent image as the corona wire was caused to again traverse the length of the previously charged screen.

The operation in this mode depends on establishing a retarding field for the positively charged ions at those apertures which are surrounded by photoconductor having a positive electrostatic surface charge. This retarding potential prevents ions from passing through the screen, and such ions are collected at the top surface of the conducting metal screen. Where there is no retarding potential, a portion of the incident ions pass through the screen onto the dielectric receptor sheet.

EXAMPLE 9

The indirect manner may be carried out in such a way as to enhance the contrast over that obtained from the previous example. In this case, a method similar to that of Example 2 was utilized to obtain a latent image on the surface of the photoconductor. This was accomplished by first providing a blanket exposure of the screen, the screen being maintained at a potential of −900 volts with respect to support plate **18.** The polarity was then reversed and applied between screen and conducting platen **18** simultaneously with projection of a positive image onto the screen. The screen was then raised, the dielectric receptor sheets changed, as in Example 4, and the corona and screen maintained at the same potentials as in the previous example while the corona was scanned across the surface of the wire mesh screen.

The higher contrast image results since, in those areas of the photoconductor which are charged positively, a retarding potential is present which prevents the passage of ions while in areas of the screen which were previously in nonilluminated areas, an accelerating field is present due to the presence of negative charge on the surface of the photoconductor; this negative charge being generated as a consequence of the initial blanket exposure.

The indirect process may be employed to form negative copies by reversing the polarities employed during the blanket exposure and the image-wise exposure.

FIGS. **3** and **4** show in greater detail the configuration of the mesh with photoconductor **12** deposited only on the side adjacent to the image forming layer **14.** Although FIGS. **1-4** show the photoconductor deposited upon only one side of the screen, effective operation is also observed when the photoconductor completely surrounds the wires of the mesh as shown in FIG. **5** or when the photoconductor is coated asymmetrically. The only requirement of the coating geometry is that the photoconductor be present between mesh **10** and insulating layer **14** so that the mesh is not in direct contact with this insulating layer.

What is claimed is:

1. A process for forming a latent electrostatic image on a dielectric sheet in conformance with an optical image which comprises:

disposing an opaque electrically conductive mesh a portion of which is coated with a photoconductor in physical contact with an opaque record sheet consisting of an electroconductive paper base coated with a charge supporting insulating layer, that portion of said mesh which is in physical contact with said record sheet being coated with said photoconductor;

applying an electrical potential between said electrically conducting mesh and a conductive layer adjacent to said insulating layer; and

projecting an optical image on that side of said coated mesh which is opposite to the side disposed on said record sheet, simultaneously with said application of potential, whereby a latent electrostatic image is formed on said record sheet.

2. The process of claim **1** including in addition the step of developing a visible image from said latent electrostatic image by application of a toner to said record sheet.

3. The process of claim **2** including in addition transfer of said visible image to a permanent record medium.

4. A process for forming a latent electrostatic image on a dielectric sheet in conformance with an optical image which comprises:

disposing an opaque electrically conductive mesh, a portion of which is coated with a photoconductor, in physical contact with an opaque record sheet consisting of an electroconductive paper base coated with a charge supporting insulating layer, that portion of said mesh which is in physical contact with said record sheet being coated with said photoconductor;

applying an electrical potential between said electrically conducting mesh and a conductive layer adjacent to said insulating layer;

projecting uniform illumination on said photoconductor mesh simultaneously with said application of potential;

and then reversing the potential between said electrically conducting mesh and a conductive layer adjacent to said insulating layer;

and projecting an optical image on that side of said coated mesh which is opposite to the side disposed on said record sheet simultaneously with said second application of potential whereby a latent electrostatic image is formed on said record sheet.

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