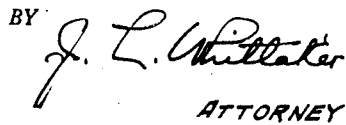


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Fig. 2.



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ELECTROSTATIC PRINTING

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This invention relates generally to improved methods and apparatus for producing latent electrostatic charge patterns and for electrostatic printing.

An electrostatic printing process is that type of process for producing a visible record, reproduction or copy which includes as an intermediate step, converting a light image or electric signal to a latent electrostatic charge pattern on an electrically-insulating substrate. The process may also include converting the charge pattern into a visible image which may be a substantially faithful reproduction of the original except that it may be different in size, color or contrast value.

An object of the invention is to provide improved methods and means of electrostatic printing.

Another object is to provide improved methods and apparatus for producing latent electrostatic images and electrostatic charge patterns.

Another object is to provide improved methods and means for producing latent electrostatic images of a desired strength and polarity from an original latent electrostatic image.

A further object is to provide improved methods and means for producing a reverse electrostatic image of an existing physical or electrostatic image.

In general, the electrostatic printing processes and apparatus of the invention comprise steps of and means for producing a powder image in a desired configuration upon a surface of a material having charge storage properties and then exposing said surface to a discharge of electrically-charged particles whereby areas of said surface not covered by said powder image become electrostatically charged. The original powder image may be produced, for example, by depositing powder through a stencil or by an electrophotographic process. The deposited powder image and its background are exposed, for example, to a corona discharge of the desired polarity until an electrostatic image of the desired strength is produced in the unmasked areas of the supporting surface. The electrostatic image produced thereby may then be used for any desired purpose, for example, it may be developed to a visible image. The practice of the invention permits the production of electrostatic images of a desired strength and polarity utilizing as a masking medium a powder image laid down by any method and from other latent electrostatic images.

The foregoing objects and other advantages will be described in greater detail in the following description when read in conjunction with the accompanying drawings in which:

Figure 1(a), (b), (c), (d) and (e) are partially-sectional, partially-schematic views of a first apparatus illustrating the steps for carrying out the improved processes of the invention, and

Figure 2 is a partially-sectional, partially-schematic view of a second apparatus for carrying out the improved processes of the invention.

Similar reference characters are applied to similar elements throughout the drawing.

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Referring to Figure 1, a typical embodiment of the invention includes a sheet 19 having a surface 21 which has charge storage properties. Such a sheet may comprise a single electrically-insulating material such as cellophane, glass, tetrafluoroethylene resin or mica. Alternatively, the sheet may comprise a relatively conducting material having a coating thereon of a material which is electrically-insulating, such as aluminum foil having a coating of polystyrene or copper having a coating of a cellulose acetate resin. For purposes of illustration, sheet 19 comprises a sheet of tetrafluoroethylene resin.

A powder image 23 is produced upon the electrically-insulating surface of the sheet 19. For purposes of illustration, such a powder image may be produced by placing a stencil upon the electrically-insulating surface 21, dusting a powder thereon and then removing the stencil with the excess powder. Such a powder image 23 may also be produced by discharging electricity upon predetermined portions of the surface 21 to form electrostatically-charged areas of a desired configuration, and then applying thereto an electroscopic powder in the manner for producing Lichtenburg figures.

The electrically-insulating surface 21 with the powder image 23 thereon is then exposed to a uniform discharge of electrically-charged particles. For this purpose, a unit comprising a plurality of three mil corona discharge wires 27 spaced about 0.5 inch from each other and from the electrically-insulating surface 21 is connected to a voltage source V (not shown) of the desired polarity and voltage. As an example, a negative voltage of 6400 volts is applied to the wires 27 producing a corona discharge therefrom which is attracted to a grounded backing plate 25 upon which the sheet 19 rests. The wires 27 are moved across the surface 21 producing a substantially uniform electrostatic charge on the surface 21 of the sheet 19. It may be desirable for the wires 27 to make several passes over the surface 21 although one slow pass usually will suffice. Electrically-charged particles may also be produced from radio-active sources of a desired type or from thermionic sources.

The corona discharge from the wires 27 produces a substantially uniform electrostatic charge across the surface 21 bearing the powder image 23. A portion of the charge resides upon the powder image 23 and a portion resides upon the electrically, insulating surface 21 not covered by the powder image 23. The powder image 23 therefore masks the electrically-insulating surface 21 beneath it from the electrostatically-charged particles emanating from the corona discharge wires 27.

The sheet 19 is preferably removed from the backing plate 25, although it may be permitted to rest thereon. A nozzle 29 directs a stream of air upon the surface 21 to blow away the powder image 23 leaving only the electrically-insulating surface 21 having electrostatically-charged areas thereon in the areas not masked by the powder image 23. A perforated container 31 may then be used to deposit a developer powder 23 by sprinkling it upon the electrically-insulating surface 21 where it deposits upon the charged areas to develop the latent electrostatic image to a visible image 35.

In another embodiment of the invention shown in Figure 2, a paper substrate 53 having a photoconducting coating 51 on one surface thereof passes between and over pulleys 47 and 49. A series of stations for producing visible images by an electrostatic printing process are disposed along the path of said sheet between said pulleys 47 and 49. The photoconducting coating 51 is preferably a photoconductive zinc oxide dispersed in a silicone resin. A preferred photoconducting coating may be prepared as follows: a mixture of 65 grams of a 60% solution of a silicone resin dispersed in xylene (a com-

mercially available product is GE SR-82 marketed by The General Electric Company, Silicone Products Division, Waterford, New York), 85 grams of toluene and 100 grams of zinc oxide having a high value of surface photoconductivity are ball milled together to a smooth uniform consistency. The mixture is applied to one surface of a paper web 53 by any standard coating technique, for example, flowing, spraying, dipping, whirling or brushing on, and then dried. Upon drying the coated paper is ready for use. Other photoconducting coatings such as an evaporated selenium or sublimed anthracene or lead iodide dispersed in cellulose acetate may be used. Similarly, other substrates such as brass, zinc, treated paper or aluminum may be used.

The photoconducting coating 51 is provided with a uniform electrostatic charge on the surface thereof. For this purpose, a plurality of three mil corona discharge wires, disposed together and spaced 0.5 inch from each other and from the photoconducting coating 51, are connected to a voltage source V (not shown) of the desired polarity and voltage. As an example, a negative voltage of 6400 volts produces a corona discharge which will deposit a negative electrostatic charge upon the surface of the photoconducting coating 51. As the photoconducting coating 51 passes beneath the wires 57, a corona discharge issuing therefrom is attracted to a grounded backing plate 55 placed behind the paper substrate 53 and deposits upon the surface of the coating 51. A positive electrostatic charge may be produced on the coating 51 by applying a positive voltage to the wires 57.

The electrostatically-charged photoconductive coating 51 now passes to a station where it is exposed to an incident electromagnetic radiation image, for example, a light image from a projector 59. The electromagnetic radiation may be derived by any of the methods well known in the photographic art, for example, by projection from a photographic transparency. The electromagnetic radiation image may be infrared, visible, ultraviolet or X-rays for example and should be a type of radiation to which the photoconducting coating 51 is sensitive. Upon exposure to the electromagnetic radiation image, the illuminated areas of the photoconducting coating 23 discharge the charge stored on the surface thereof leaving the non-illuminated areas charged, thus producing a first latent electrostatic image substantially corresponding to the electromagnetic radiation image.

The first latent electrostatic image is developed to a visible image according to any of the methods well known in the electrostatic printing art. For example, a grounded rotary pole piece 61 of a magnetic structure having spaced parallel inclined elliptical discs 63 along its length faces the photoconductive coating 51 and a fixed magnetic pole piece 65 faces the substrate side of the sheet opposite the rotary magnetic pole piece 63. A magnetic field is maintained therebetween through an enclosed magnetic field path and across the gap therebetween through which the sheet passes. A trough 67 holds a quantity of developer mix which comprises developer powder particles and magnetic carrier particles in contact with the discs 63 such that, if the discs are rotated in a clockwise position, as viewed in Figure 2, a quantity 69 of developer mix is carried upwardly and swept across the surface of the photoconducting coating 23, depositing developer powder particles in selected areas thereby producing a developed powder image 23 on the surface of the photoconductive coating 51 corresponding to the first latent electrostatic image.

A preferred carrier material for the developer mix consists of "alcoholized iron," that is, iron particles free from grease and other impurities soluble in alcohol. These iron particles are preferably relatively small in size, being in their largest dimensions from about 0.003 inch minimum to 0.008 inch maximum. Satisfactory results are also obtained using carriers consisting of iron particles of somewhat wider ranges up to about 0.001 to 0.020 inch.

A preferred developer powder may be prepared as follows: a mixture comprising 200 grams of 200 mesh piccolastic resin 4358 (an elastic thermoplastic resin composed of polymers of styrene, substituted styrene and its homologs) marketed by the Pennsylvania Industrial Company, Clairton, Pa., and 12 grams of carbon black G marketed by the Eimer and Amend Company, New York, N.Y., are thoroughly mixed in a stainless steel beaker at about 200° C. The mixing and heating should be done in as short a time as possible. The melt is poured upon a brass tray and allowed to cool and harden. The hardened mix is then broken up and ball milled for about 20 hours. The powder is screened through a 200 mesh screen and is then ready for use as a developer powder. This powder takes on a positive electrostatic charge when mixed with iron powder. It therefore will develop the negatively charged areas of an electrostatic image. About 2 to 10 grams, preferably 4 grams, of the developer powder and about 100 grams of the magnetic carrier material are blended together giving the preferred developer mix. Other ratios of developer powder to magnetic carrier material may be used.

The photoconducting coating 51 now passes to a station where it is exposed to blanket illumination from a source 71 in a shield 73 for the purpose of discharging the electrostatic charges on the surface of the photoconducting coating 51. The electromagnetic radiation for this purpose is most conveniently derived from an incandescent or a fluorescent lamp and is of the type to which the photoconducting coating 51 is sensitive.

The photoconducting coating 51 now passes to a station where the photoconducting coating with the developed powder image is exposed to a uniform discharge of electrostatically-charged particles in the same manner as heretofore described. For this purpose a grounded backing plate 25 placed behind the paper substrate 53 and corona discharge wires 27 spaced from one another and from the photoconducting coating by about 0.5 inch are connected to a voltage source V (not shown). A negative voltage of about 6400 volts, for example, is applied to the corona discharge wires 27 causing a uniform discharge therefrom. The discharge from the wires 27 is attracted to the grounded backing plate 25, producing a negative charge upon the powder image 23 and the areas of the photoconducting coating not covered by the powder image 23 passing below. The voltage and the speed of advance of the photoconducting coating 51 is adjusted so that the desired magnitude of charge may be formed on the coating 51. A positive charge may be produced by applying a positive voltage to the wires 27. Thus, the first latent electrostatic image is utilized by the invention to produce a second latent electrostatic image having areas of a desired polarity and magnitude of charge. In the example of Figure 2, the negatively-charged areas of the first latent electrostatic image are those areas covered by the powder image 23. The negatively-charged areas of the second latent electrostatic image correspond to the areas not covered by the powder image 23. Thus, by the method of the invention, the latent electrostatic image is reversed, that is, negative areas of a first latent electrostatic image are now positively-charged and positively charged areas of the first latent electrostatic images are now negatively-charged. The foregoing example describes a process wherein a negative voltage is applied to both sets of corona discharge wires 57 and 27. Similar results are obtained where a positive voltage is applied to both sets of corona discharge wires 57 and 27. Where a positive voltage is applied, it is preferred to utilize developing substances that have a greater affinity for positively-charged areas of a latent electrostatic image.

Where a negative voltage is applied to the first corona wires 57 and a positive voltage is applied to the second corona wires 27, the latent electrostatic image is not reversed. However, a second latent electrostatic image

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substantially identical to the first latent electrostatic images is produced except that the electric fields emanating therefrom may be either stronger or weaker than the fields emanating from the first electrostatic image. The process of the invention therefore, may be used to strengthen or weaken a latent electrostatic image.

The same condition holds where a positive voltage is applied to the first corona wires 57 and a negative voltage is applied to the second corona wires 27. Again, the latent electrostatic image is not reversed, although it may be strengthened or weakened as desired.

The photoconductive coating 51 bearing the first developed image 23 and the second latent electrostatic image now passes to a station which removes the first developed image and develops the second latent electrostatic image. The developing station has a grounded rotary pole piece 75 of a magnetic structure with spaced parallel inclined elliptical discs 77 along its length facing the photoconductive layer 51 and a fixed magnetic pole piece 79 facing the paper substrate 53. A magnetic field is maintained between the fixed magnetic pole piece 79 and the elliptical discs 77 through an enclosed magnetic field path and across the gap between the discs 77 and the fixed pole piece 79. A trough 81 holds a quantity of magnetic developer mix in contact with the discs 77 such that, as the discs are rotated in a clockwise direction as viewed in Figure 2, a quantity 83 of the developer mix is carried upwardly and swept across the surface of the photoconductive coating 51 wiping away the first developed image 23 and depositing developer powder particles in selected areas thereby producing a second developed image upon the surface of the photoconductive coating 51 corresponding to the second latent electrostatic image.

The photoconductive coating 51 now passes to a station where the second developed image is fixed to the photoconductive coating 51. For this purpose an electric resistance element 87 is connected to a voltage source V—V (not shown) which radiates heat sufficient to fuse the powder image 85 to the photoconductive coating 51 fixing the developed image thereto. Other methods of fixing such as spraying with an adhesive or solvent vapors and/or pressure may be used.

There have been described improved methods and means for producing latent electrostatic charge patterns and for electrostatic printing. According to the invention one may produce latent electrostatic images of a desired strength and polarity from powder images disposed on an electrically-insulating substrate and formed by physical means or electrophotographic means.

What is claimed is:

1. A method of electrostatic printing comprising the steps of producing a first latent electrostatic image on a photoconducting insulating surface, developing said first latent electrostatic image with a finely-divided developer powder thereby forming a first visible powder image on said surface, uniformly exposing said surface bearing said first visible powder image to light to which said surface is sensitive to substantially discharge the electrostatic charges remaining on said surface after producing said first latent electrostatic image while leaving said first visible powder image substantially undisturbed and

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adhering to said surface, exposing said surface bearing said first visible powder image thereon to a corona discharge to produce a second latent electrostatic image thereon in reverse configuration with respect to said first latent electrostatic image but having the same polarity of charge as said first latent electrostatic image, removing said first visible powder image leaving said second latent electrostatic image substantially undisturbed, and developing said second latent electrostatic image with a finely-divided developer powder to produce a second visible powder image in reverse configuration with respect to said first visible powder image.

2. A method of electrostatic printing comprising the steps of exposing photoconductive insulating surface to a corona discharge to produce a substantially uniform electrostatic charge across said surface, exposing said surface to a light image of a type to which said surface is sensitive to produce thereon a first latent electrostatic image, developing said first latent electrostatic image with a finely-divided developer powder thereby forming a loosely held first visible powder image on said surface, uniformly exposing said surface bearing said first visible powder image to light of a type to which said surface is sensitive to substantially discharge the electrostatic charges remaining on said surface after exposing said surface to said light image while leaving said first powder image substantially undisturbed and adhering to said surface, exposing said surface to a corona discharge to produce thereon a second latent electrostatic image in reverse configuration with respect to said first latent electrostatic image but having the same polarity of charge as said first latent electrostatic image, removing said first visible powder image leaving said second latent electrostatic image substantially undisturbed and developing said second latent electrostatic image with a finely-divided developer powder to produce a second visible powder image in reverse configuration with respect to said first visible powder image.

3. Method of claim 1 wherein removal of said first visible powder image is accomplished concurrently with the production of said second powder image by contacting across said surface a mixture of magnetic carrier particles and developer powder particles held in a loose coherent mass with a magnetic field.

References Cited in the file of this patent

UNITED STATES PATENTS

2,297,691	Carlson	Oct. 6, 1942
2,357,809	Carlson	Sept. 12, 1944
2,573,881	Walkup et al.	Nov. 6, 1951
2,647,464	Ebert	Aug. 4, 1953
2,681,473	Carlson	June 22, 1954
2,741,959	Rheinfrank	Apr. 17, 1956
2,752,833	Jacob	July 3, 1956
2,756,676	Steinhilper	July 3, 1956
2,808,328	Jacob	Oct. 1, 1957
2,817,598	Hayford	Dec. 24, 1957
2,833,648	Walkup	May 6, 1958

FOREIGN PATENTS

154,222	Australia	Nov. 18, 1953
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