

July 7, 1970

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3,519,461

ELECTROSTATIC DIPOLE PRINTING

Original Filed April 19, 1968

2 Sheets-Sheet 1

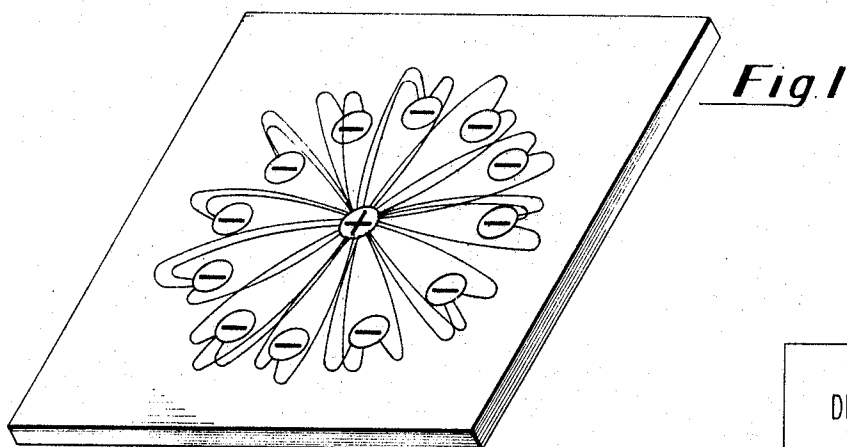


Fig. 1

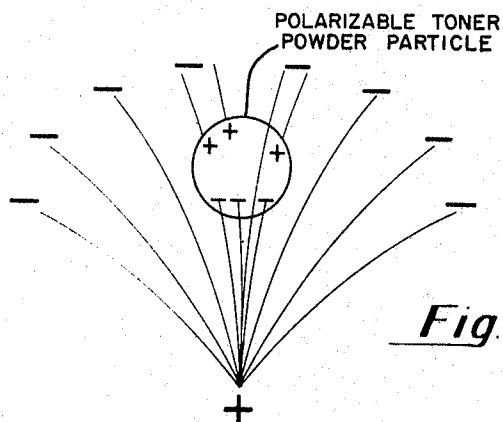


Fig. 2

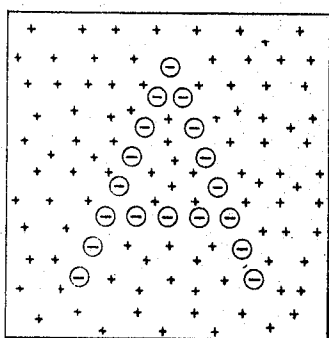


Fig. 4

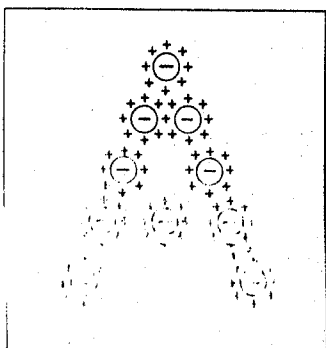


Fig. 6

Fig. 3

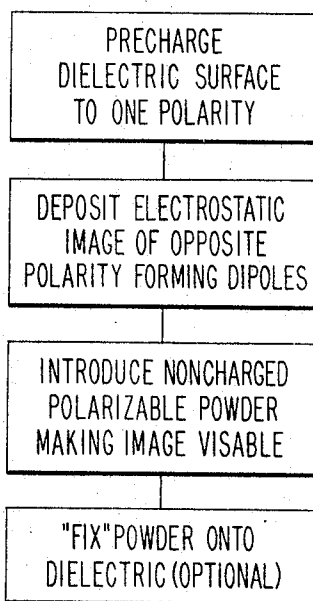
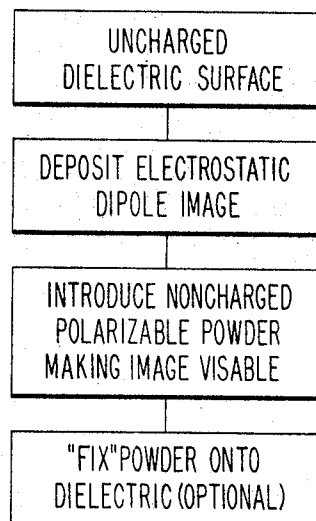


Fig. 5



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FIG. 7

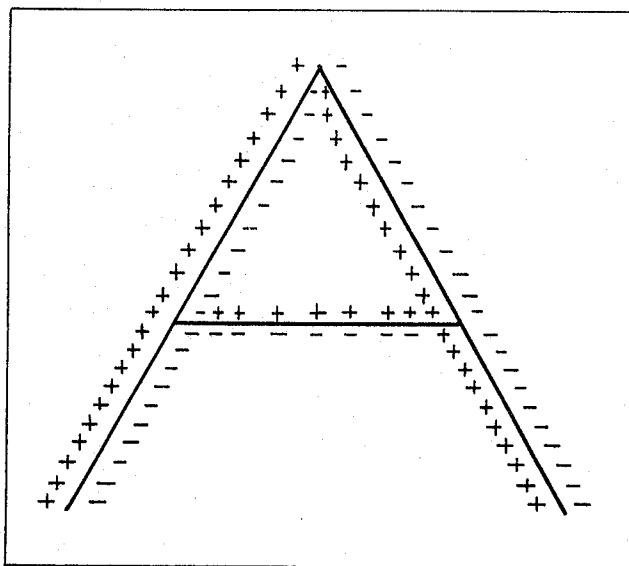
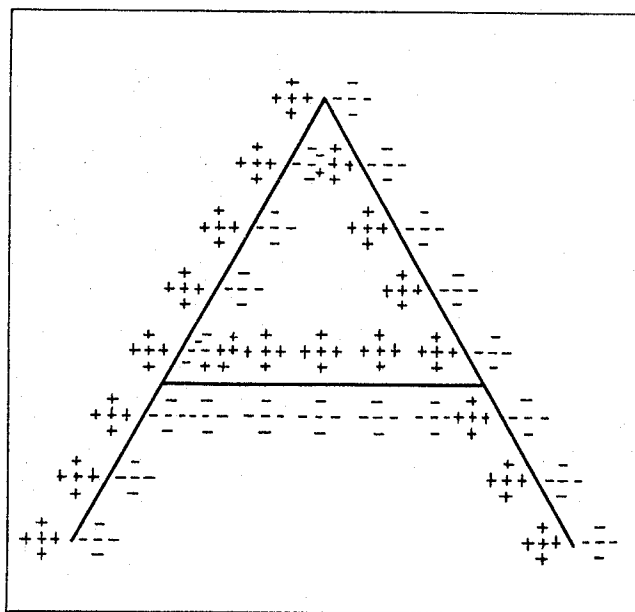


FIG. 8



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1

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ELECTROSTATIC DIPOLE PRINTING

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Continuation-in-part of application Ser. No. 379,088, June 30, 1964, and also is a continuation of application Ser. No. 733,184, Apr. 19, 1968. This application Sept. 2, 1969, Ser. No. 856,893

Int. Cl. G03g 13/00

U.S. Cl. 117-17.5

15 Claims

ABSTRACT OF THE DISCLOSURE

A method of electrostatic printing by producing electrical dipoles on a dielectric surface, introducing uncharged polarizable toner powder particles into the field created by the dipoles, and causing the particles to be polarized in this field and thereby be attracted to and deposited upon the dipole areas of the dielectric surface.

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of my application Ser. No. 379,088; filed June 30, 1964 and now abandoned, and a continuation of my application Ser. No. 733,184, filed Apr. 19, 1968, also abandoned. This invention relates to electrostatic printing and, more specifically, to electrostatic printing in which the highly divergent field created by an electrostatic dipole image is utilized to polarize an uncharged toner particle.

An electrostatic printing process is one for producing a visible record, reproduction, or copy, and includes as an intermediate step the conversion of a light image or an electric signal to a latent electrostatic charge pattern on an electrically insulating surface.

Conventional electrostatic printing utilizes electrostatic monopoles as images; that is, the image consists of a distribution of electrostatic charges of one polarity on a dielectric surface. Previously either polarity has been used for these images. In the prior art it is of importance that on any particular item of electrostatic copy the entire image is of one polarity with respect to the base of the dielectric surface and the rest of the dielectric surface surrounding the image areas is essentially uncharged.

The image is made visible by applying a finely divided powder to the charged surface. This powder has a charge opposite in polarity to that of the image. The powder, which may be applied either dry or dispersed in a liquid, may be charged either by electrostatic induction in the field of the image or precharged by triboelectrification against a dissimilar material such as resin coated glass beads or iron filings held by a magnet or by a non-conductive liquid dispersant.

The use of an inductively charged powder has had the advantages of simplicity and speed of application. Its disadvantages have been that, because it is unselective of image polarity, it left no basis for discrimination against unwanted background charges, and, because it must be conductive, it was sharply limited as to color possibilities. Further, erasure of an electrostatic image has been difficult because surface charges had to be reduced essentially to zero in order to prevent powder adhesion.

The use of triboelectrically charged powder has had the advantage that, because the powder charge polarity is independent of the image charge polarity, it is possible to discriminate sharply against unwanted background charges by printing desired images at the opposite polarity to that of any such background charges. The background has been intentionally precharged to a polarity the same as that of the powder and opposite to that of the image. This assures that all background will be of the correct

2

polarity to be discriminated against by the charged powder, and reveals a useful technique for erasing unwanted images by overprinting them with a charge of opposite polarity.

Because conductivity in a triboelectrified powder may be very low, it is easier to prepare such developer powders in a wide range of colors. However, the techniques for triboelectrification of developer powders are all much slower and more involved than the techniques necessary for inductively electrified powders. This unduly complicates the equipment and reduces the practically attainable speeds at which developing can be done.

OBJECTIVES AND SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to improve the methods of electrostatic printing.

A still further object of this invention is to create an electrostatic image with an uncharged developer powder.

Another object of this invention is to permit image erasure by overprinting.

A further object of this invention is to provide an improved method of electrostatic printing in which there is discrimination against background charges.

An additional object of this invention is to provide an improved method of multicolor electrostatic printing employing uncharged toners.

The foregoing objects and other advantages may be accomplished in accordance with applicant's invention which comprises methods of polarizing minute uncharged toner particles having a high relative dielectric constant by introducing them into a highly divergent electrostatic dipole field which is established by placing in close proximity charges of comparable magnitudes and opposite polarities. The uncharged dielectric toner is polarized in the field and attracted to and deposited upon the areas of maximum intensity between these opposite charges and thereby a visible image is formed.

Other objects and advantages of the invention are brought out in the following specification to be considered in connection with the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a representation of a plurality of dipoles which extend radially from a center charge.

FIG. 2 is illustrative of the polarization of a single toner particle at the point of maximum divergence.

FIG. 3 is a flow sheet illustrating one method of applicant's invention.

FIG. 4 illustrates the charge pattern resulting from the deposition of charges in accordance with the method of the present invention as shown in FIG. 3.

FIG. 5 is a flow sheet showing another method according to this invention.

Each of FIGS. 6, 7, and 8 illustrates the charge pattern resulting from the deposition of charges in accordance with method of the present invention as shown in FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENT

It is well known that in a non-conducting material the positive and negative charges are bound elastically in small aggregates, either atoms or molecules; that is to say, the positively charged nucleus is surrounded by electrons in sufficient numbers to make the net charge of the atom zero. Therefore, in the absence of an externally applied electric field, the center of negative charge coincides with the center of positive charge. The application of an electric field to the atom produces forces in opposite directions on the positive and negative charges causing the charges to shift relative to each other. The center of negative charge is then at a different position

3

from the center of the positive charge and the atom is said to be polarized. In other words, the application of an electric field causes merely a shift in the relative positions of the atomic charge and no steady flow of charge. This same theory is applicable to molecular structures as well.

As shown in FIG. 1, a positive charge is placed upon a dielectric surface and is surrounded by a plurality of discrete negative charges spaced therefrom. This results in the forming of a plurality of radially oriented dipole fields. Apparatus is available, as shown in Epstein et al. Pat. No. 2,919,171, assigned to the same assignee, by which such an image could be formed with the charges being separated by approximately 10 thousandths of an inch. The potential between these charges would be approximately 800-1200 volts. Any particle of high relative dielectric constant and capable of polarization is polarized in this field when it enters the point of maximum divergence of the field as illustrated in FIG. 2.

As shown in FIG. 3, a dielectric having a volume resistivity in excess of 10^{15} ohm centimeters, such as polyvinyl acetate, polyvinyl acetate crotonate, polyethylene and polypropylene, or any other high polymer organic resin, is precharged to one polarity by suitable means such as by placing wires in close proximity to the dielectric through which wires will be passed approximately 3,000 volts. A number of factors such as the ambient temperature of the air and impurities suspended in the air affect the actual voltage which is realized on the surface of the dielectric. For practical purposes it is in the neighborhood of 400-600 volts.

The charging is due to the mechanism of a corona discharge from the wires. This discharge is a source of ions which a high D.C. potential will drive to the dielectric. The ions so driven are all of one polarity.

A pattern of electrostatic charges, with potential equal but of polarity opposite to that of the background charge, is deposited on the dielectric. This can be done by placing the dielectric on an anvil adjacent to which is a matrix of electrode pins, as shown in Epstein et al. Pat. No. 2,919,171. As the charge is deposited, the area of the dielectric beneath the electrode pins passes rapidly from its precharge potential to the charge potential. Progressing away from the center of the charged area, the charge decreases in magnitude until an area is reached in which the new charge potential cancels the precharge potential and a small uncharged area results between the two opposite charges which assures a high potential gradient. It is this difference in potential across the surface of the dielectric which establishes the dipole.

A noncharged polarizable developer powder, having a size of less than 40 microns, is then introduced into the field created by the dipoles. The electric field will polarize the developer powder or toner particles and due to their small size they are attracted to and deposited upon the surface areas of the dielectric where the potential gradient on the dielectric surface is at a maximum.

The material to be used for the toner powder must be dielectric and must also be non-conductive. As was previously stated, the powder particles must be capable of dielectric polarization. They must also have other properties that would make them usable for developing the image such as a desirable color. The powder also may have the capability of making the image permanent by a fixing process. Examples of suitable materials include but are not limited to the following: Polymeric resinous materials which are dielectric and non-conductive such as polyvinyl copolymers including polyvinyl acetate, polyvinyl butyral and polyvinyl chloride, polystyrene and its copolymers, polyolefins including polyethylene and polypropylene. Other examples of usable materials for the developer are acrylics, polycarbonates, polyester resin and epoxy resin as well as powdered amber and powdered sulphur.

4

In some applications, it would be desirable to have the dielectric printing surface in the form of an endless belt so that after the visible electrostatic image has been utilized, it could be easily erased and the same surface be reused. Erasure may be accomplished by overprinting in a manner similar to that hereinabove described for pre-charging the dielectric surface.

On the other hand, depending on the end use considerations, the visible powder image may be fixed, i.e., made permanent. A suitable method of fixing the powder is shown in Epstein et al. Pat. No. 2,919,171.

FIG. 4 shows the deposition of charges on the dielectric in which the letter A is considered to be representative.

DESCRIPTION OF THE ALTERNATE EMBODIMENTS

Each of FIGS. 5, 7, and 8 illustrates a second method of pattern deposition in which the dielectric surface is uncharged. This may be accomplished by grounding the dielectric surface before the charge deposition is made. An electrostatic dipole image is then created on this surface by the deposition of small spots of charge which may be adjacent circular spots, or in the form of parallel lines, or a concentric circle and spot, etc., but which are of opposite polarities and have comparable voltage magnitudes. These opposite charges would be placed approximately 8 to 10 thousandths of an inch from each other, and the potential existing between the two would be approximately 800-1200 volts. A plurality of electrostatic dipole fields would then exist between the two unlike charges. The introduction of an uncharged polarizable toner powder into the highly divergent fields existing above these dipoles causes the powder to be polarized and to be attracted to the areas of maximum potential gradient on the dielectric surface, thereby making the deposited image visible.

Apparatus for accomplishing this method includes the use of a type face, having two areas of equal potential but opposite polarity thereon, to deposit the charges on the dielectric by momentary contact therewith. An additional means for accomplishing the deposition would be the use of pin electrodes to place a spot of one potential on the dielectric surface and then, by reversing the polarity of the pin, causing a small center area of the charge to be discharged and charged to the opposite polarity with a small area surrounding this new charge being uncharged. Both the means described above utilize the principle of having two charges discretely spaced apart with an uncharged area therebetween forming an electrostatic dipole.

The final step of fixing or erasing is optional as hereinabove described, with the exception that erasing would be accomplished by simply discharging any previous charge existing on the dielectric surface. One of the prime advantages of either of the two methods described is the utilization of a toner which is nonconductive in bulk. A toner of this type cannot become charged by induction; therefore, it will be attracted to and held only by a highly divergent field such as that over a dipole. Since electrostatic dipoles rarely occur naturally as background charges on dielectrics, the powder will discriminate against accidental monopolar background charge patterns and adhere only to the intentionally deposited dipole images. In addition, as described in the first method, when the background is uniformly precharged to some potential of either polarity, any accidental dipoles or monopolar images will be erased.

Representations of the results of this second method again forming the letter A are shown in FIGS. 6, 7, and 8 in which a concentric circle of charges has been placed around a single spot of charge, parallel lines of opposite polarity charges have been deposited, and adjacent circular spots of opposite polarity charges have been deposited, respectively.

5

In either case, if the potentials are high, such as 400–600 volts, and the spacing of the spots is close, the divergence of the electrostatic field in the air above the dipole will be great and a strong attractive force will act on small particles of any dielectric developer powder which falls into this field. It should be noted that it is no longer necessary for the powder to be electrostatically charged to be attracted to the image. This is of great advantage because uncharged powder will discriminate against monopole images of either polarity including background charges.

It will be noted that the foregoing is superficially similar to the technique for erasure and background elimination described heretofore in discussing the uses of triboelectrified developer powder in which the background was uniformly overprinted with charge before printing the desired image. However, in the case of applicant's improved methods of electrostatic dipole printing, discrimination against background is polarity independent and actually reduces to discrimination against monopole images of either polarity.

Applicant's improved methods of electrostatic dipole printing have the advantages of discrimination against accidental background charges together with ease of image erasure which heretofore had been advantages peculiar to electrostatic printing processes using triboelectrified developer powders. Further, they have the advantage which heretofore had been peculiar to those processes which used low conductivity powders, that being the ability to utilize powders in a wide variety of colors. Moreover, there is an additional advantage common to the inductively electrified powders, that being that it can be used in very simple equipment and at high speed. Another advantageous characteristic found in neither type of electrostatic developer powder but utilized by ferromagnetographic developer powders is the capability of being dispersed in an air stream.

Applicant's improved methods of electrostatic printing avoid the disadvantage of triboelectrified powders which require slower and more complicated equipment for image development due to the complex triboelectrification process.

While in this description two methods of employing applicant's new electrostatic printing process have been described, it should be noted that the scope of the invention does not exclude various other changes and modifications that are within the skill of those familiar with the art, the scope of the invention being limited only by the following claims.

I claim:

1. The improved method of electrostatic printing comprising the steps of:

establishing an electrostatic image by placing in close but spaced apart proximity on a dielectric surface charges of substantially equal magnitude but of opposite polarity to form one or more electrical dipoles on said dielectric surface, and

introducing minute uncharged non-conductive polarizable toner powder particles into the electrical field created by each of said dipoles to develop the image, said toner powder particles being polarized by the electrical field, and

said polarized toner powder particles being attracted to and deposited on the dielectric surface in the space between the opposite charges of each dipole where the electrical field is of maximum intensity.

2. The method of claim 1 including the additional step of fixing said visible electrostatic image on said dielectric surface.

3. The method of claim 2 including the additional step of erasing said visible electrostatic image from said dielectric surface to permit said dielectric surface to be reused.

4. The method of claim 3 wherein said step of erasing

6

comprises discharging the charges on said dielectric surface.

5. The method of claim 4 wherein the resistivity of said dielectric surface is in excess of 10^{15} ohm centimeters.

6. The method of claim 5 wherein said polarizable non-conductive toner powder particles are less than 40 microns in size and may have color.

7. The method of claim 1 wherein the step of establishing an electrostatic image comprises the steps of: precharging said dielectric surface to one polarity and a particular intensity, and depositing charges on said dielectric surface, said charges being of opposite polarity and substantially equal intensity to said precharged surface to form radially oriented dipoles.

8. The method of claim 7 including the additional step of fixing said visible electrostatic image on said dielectric surface.

9. The method of claim 8 including the additional step of erasing said visible electrostatic image from said dielectric surface to permit said dielectric surface to be reused.

10. The method of claim 9 wherein said step of erasing comprises overprinting said dielectric to a uniform charge of one polarity.

11. The method of claim 10 wherein the resistivity of said dielectric surface is in excess of 10^{15} ohm centimeters.

12. The method of claim 11 wherein said polarizable non-conductive toner powder particles are less than 40 microns in size and may have color.

13. The method of claim 1 wherein charges of a first polarity are disposed in a generally linear configuration, and charges of the opposite polarity are disposed in a generally linear configuration and substantially parallel to the charges of said first polarity to form a plurality of dipoles on said dielectric surface.

14. The method of claim 1 wherein charges of a first polarity are arranged in a series of generally circular configurations, and charges of the opposite polarity are arranged in generally circular configurations adjacent to but spaced apart from the charges of said first polarity to form a plurality of electrical dipoles on said dielectric surface.

15. The method of claim 1 wherein charges of a first polarity are arranged substantially in circles, and charges of the opposite polarity are disposed within said circles to form a plurality of radially oriented dipoles on said dielectric surface.

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U.S. Cl. X.R.

101—426; 346—1, 74