Dec. 19, 1961

W. E. BIXBY

3,013,890

PROCESS OF DEVELOPING ELECTROSTATIC IMAGES AND COMPOSITION THEREFOR

Filed July 8, 1958

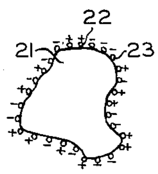

FIG. 1

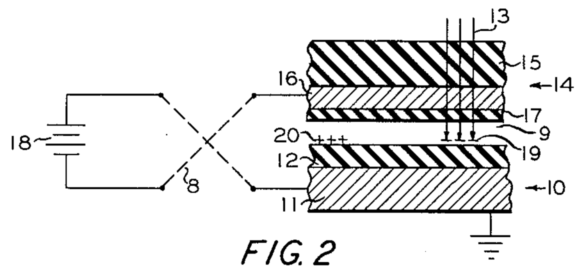

FIG. 2

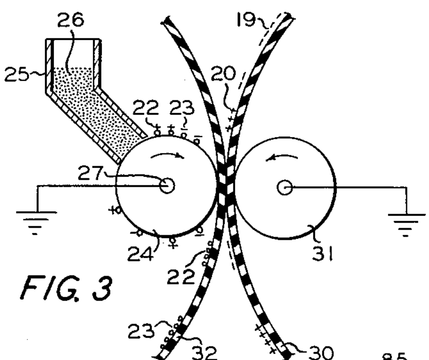

FIG. 3

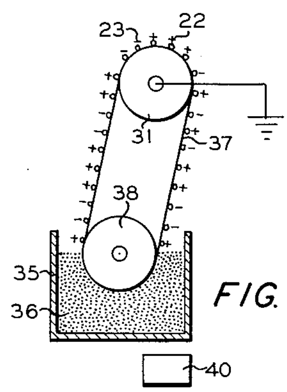

FIG. 5

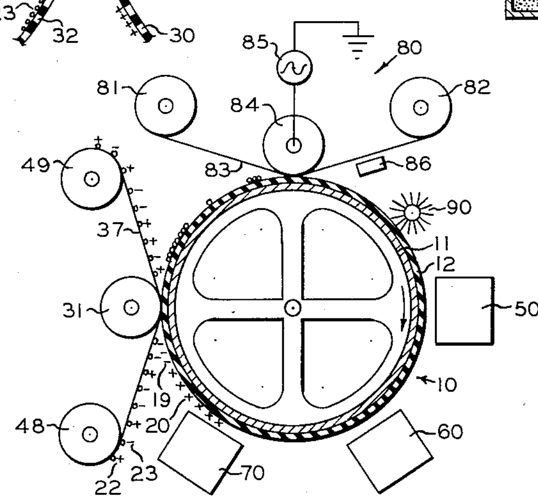

FIG. 4

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PROCESS OF DEVELOPING ELECTROSTATIC IMAGES AND COMPOSITION THEREFOR

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10 Claims. (Cl. 117—17.5)

This invention relates in general to a method and composition for making visible electrostatic images and in particular to a method and composition whereby both positive and negative electrostatic images may be developed simultaneously in one or two colors.

In xerography it is usual to form an electrostatic image on a surface. One method of doing this is to charge a photoconductive insulating surface and then dissipate the charge seletively by exposure to a pattern of activating radiation. These and other means of forming electrostatic images are set forth in U.S. 2,297,691 to C. F. Carlson. Still other means of forming electrostatic images are set forth in U.S. 2,647,464 to James P. Ebert, U.S. 2,576,047 to R. M. Schaffert and U.S. 2,825,814 to L. E. Walkup. Whether formed by these means or any other, the resulting electrostatic pattern is conventionally utilized by the deposition of an electroscopic material thereon through electrostatic attraction whereby there is formed a visible image of electroscopic patricles corresponding to the electrostatic image. Alternatively, the electrostatic charge pattern may be transferred to an insulating film and then electroscopic particles deposited thereon to form the visible image. In any case, this visible image in turn may be transferred to a second surface to form a xerographic print.

Modern business and computer needs require a variety of image recording means. For many purposes this information may be classified in two groups—fixed and variable information. An alternative classification is to divide data into background information and critical information. Many proposals exist for various combinations of xerographic and magnetic image techniques to obtain this desired differential presentation of information. Xerography, as a basic electrostatic process, has a great deal of flexibility permitting the formation of images by either optical or non-optical means (such as the use of a matrix of point electrodes, a stylus electrode, a shaped electrode as an electrode shaped as an alphanumeric character, etc.). In contrast to this, magnetic image formation is limited strictly to non-optical image formation, that is, using a stylus, a matrix, or a shaped pole piece. Thus machines designed to record information in both electrostatic and magnetic form in order to obtain differential recording of data require the full complement of both electrostatic and magnetic data recording instruments. Such machines are unduly cumbersome and complex. Further, the magnetic portion, being limited to non-optical recording methods, is inherently less flexible than electrostatic processes. Attempts to accomplish similar results, i.e., differential recording of information, by completely electrostatic processes have required multiple development and transfer steps thus necessitating excessive time in printing the data and increased complexity and cumbersomeness in the apparatus in solving the problems of registration, etc. Accordingly, it is an object of the instant invention to simultaneously develop both positive and negative electrostatic images.

Another object of the instant invention is to improve the quality of half-tone images using carrier development techniques, i.e., without the necessity of powder cloud development processes.

Still another object of the instant invention is the presentation of information in two colors by a single development step.

Another object of the instant invention is the presentation of two types of graphical information by an all electrical process without any necessity for a combination of electrostatic and magnetic processes, etc.

Another object is the use of an all optical system for the simultaneous presentation of differential types of information.

Another object is the formation of unique decorative effects particularly on ceramic and similar objects. Other objects and advantages of the present invention will, of course, become apparent and will immediately suggest themselves to those skilled in the art to which the invention is directed from a reading of the following description in connection with the accompanying drawings in which:

FIG. 1 is a cross section of a carrier granule coated with toner according to one embodiment of the invention;

FIG. 2 is a cross section of apparatus illustrating one method of forming both positive and negative electrostatic images;

FIG. 3 is a schematic diagram of xerographic apparatus illustrating the instant invention;

FIG. 4 is a schematic diagram of apparatus illustrating another embodiment of the instant invention;

FIG. 5 is a schematic diagram of apparatus illustrating another embodiment of the instant invention.

The general process of development to which this invention relates is termed "carrier development." In general, in carrier development the toner composition is loosely coated on the carrier surface to which it remains loosely affixed by reason of electrostatic attraction thereto. The type of carrier development most widely used commercially is called granular or cascade carrier development. This system is more fully described in U.S. 2,618,551 to L. E. Walkup and U.S. 2,638,416 to Walkup and Wise. In this process the electroscopic toner is desirably mixed with a granular carrier, either electrically conducting or insulating, magnetic or non-magnetic, coated or non-coated provided that the particles of granular material when brought in close contact with the toner particles acquire a charge having an opposite polarity to that of the granular carrier particles and adhere to and surround the granular carrier particles.

If a positive reproduction of the electrostatic image is desired, the carrier is selected so that the toner particles acquire a charge having the opposite polarity to that of the electrostatic image. Alternatively, if a reversal reproduction of the electrostatic image is desired the carrier is selected so that the toner particles acquire a charge having the same polarity as that of the electrostatic image.

Thus, in granular carrier development the materials for the granular material are selected in accordance with their triboelectric properties in respect to the electroscopic toner so that when mixed or brought into mutual contact one material is charged positively if the other is below it in a triboelectric series, and negatively if the other material is above it in a triboelectric series. By selecting materials in accordance with their triboelectric effects, the polarities of their charge when mixed are such that the electroscopic toner particles adhere to and are coated on the granular carrier particles. Thus, the development of the electrostatic image is accomplished by rolling or cascading across the image-bearing surface a developer composition of relatively large carrier particles having on their surface and electrostatically coated thereon, fine powder particles known as toner particles. In the normal positive-to-positive xerographic process, as the composition cascades or rolls across the image-bearing surface, these toner particles are electrostatically deposited on and secured to the charged portions of the image and are not deposited on the uncharged or background portions of the image. More than that, toner particles accidentally deposited on these background portions are physically removed therefrom by electrostatic action of the carrier particles passing thereacross whereby these toner particles are electrostatically secured to the rolling carrier particles and are picked up from the surface in this manner. The result is an excellent copy of the electrostatic image in the form of an image by the toner particles electrostatically clinging to the image surface and removable therefrom by any of various means such as adhesive transfer, electrostatic transfer or the like.

The granular carrier particles are grossly larger than the toner particles by at least one order of magnitude of size, and are shaped to roll across the image-bearing surface. Generally speaking, the carrier particles should be of sufficient size so that their gravitation or momentum force is greater than the force of attraction of the toner in the charged areas where the toner is retained on the plate in order that the granular carrier particles will not be retained by the toner particles, while, at the same time, the toner particles are attracted and held, or repelled, as the case may be, by the charged or uncharged areas of the plate since they acquire a charge of opposite polarity to the charge of both the granular carrier particles and the plate. It has been found best to use granular carrier particles of a size larger than about 200 mesh, usually between about 20 and about 100 mesh, and toner particles of a size from about 1 to 20 microns. The granular carrier particles may, if desired, be somewhat larger or smaller as long as the proper size relationship to the electroscopic toner is maintained so that the granular carrier particles will flow easily over the image surface by gravity when the plate is inclined without requiring additional means or measures to remove them.

The degree of contrast or other photographic qualities in the finished image may be varied by changing the ratio of granular carrier to electroscopic material. Successful results have been had with from about 10 to about 200 parts by weight of granular carrier particles capable of being passed through a 30 mesh screen and being collected on a 60 mesh screen to 1 part of the electroscopic toner having a particle size of 1 to 20 microns. Generally speaking, carrier-to-toner ratios in the order of about 100 to 1 prove satisfactory and preferred compositions run from about 50 to 1 to about 150 to 1. In such preferred compositions the carrier acts effectively to remove any toner particles which might tend to adhere to a non-image area and the toner itself forms a dense readily transferable and fusible image.

In addition to the use of granular particles to provide the carrier surface, the bristles of a fur brush may also be used. Here, also, the toner particles acquire an electrostatic charge of polarity determined by the relative position of the toner particles and the fur fibers in the triboelectric series. The toner particles form a coating on the bristles of the fur clinging thereto by reason of the electrostatic attraction between the toner and the fur just as the toner clings to the surface of the granular carrier particles. The general process of fur brush development is described in greater detail in U.S. patent application, Ser. No. 401,811, filed by L. E. Walkup on January 4, 1954.

Even more closely related to the cascade carrier development is magnetic brush development. In this process a granular carrier is selected having ferromagnetic properties and selected relative to the toner in a triboelectric series so as to impart the desired electrostatic polarity to the toner and carrier as in cascade carrier development. On inserting a a magnet into such a mixture of toner and magnetic granular material the carrier particles align themselves along the lines of force of the magnet to assume a brush-like array. The toner particles are electrostatically coated on the surface of the granular magnetic carrier particles. Development proceeds as in regular cascade carrier development on moving the magnet over the surface bearing the electrostatic image so that the "bristles" of the magnetic brush contact the electrostatic image-bearing surface.

Still another method of carrier development is known as sheet carrier development in which the toner particles are placed on a sheet or pellicle as of paper, plastic, or metal. The electrostatic attraction between the sheet surface and toner particles necessary to assure electrostatic attraction therebetween may be obtained by leading the sheet through a mass of the electroscopic toner particles whereby there is obtained a rubbing or sliding contact between the sheet and the toner. In general it is desirable to spray the surface of the sheet bearing the electroscopic toner particles with ions of the desired polarity, as by the use of a corona charging device. The surface of the sheet bearing the electroscopic toner is then contacted with the surface bearing the electrostatic image to develop the image.

Thus in carrier development the toner is electrostatically coated on a suitable carrier surface which is then in turn contacted with the surface bearing the electrostatic image whereby the electroscopic toner particles are transferred to the surface bearing the electrostatic image to form thereon a powder image corresponding to electrostatic image. The triboelectric relationship between the toner and the carrier surface assures the proper polarity and amount of charge on the toner and also acts to reduce deposition of toner in background areas.

Now according to the instant invention it has been discovered that if the carrier surface is coated with two toners so selected relative to their triboelectric properties that one is above and the other below the carrier surface in the triboelectric series, that the resulting carrier surface bearing both positive and negative toner may be used to efficiently and simultaneously develop both positive and negative electrostatic images. For example, using a polystyrene surface as the carrier, suitable toner materials which are positive relative to the polystyrene are gilsonite, either by itself or with Raven Beads carbon black to give a black toner; Amberol 800-P (a trade name of Rohm & Haas Co. for a synthetic resin) either with Hansa yellow (a trade name of General Dyestuff Corp.) for a yellow toner, or with Duplex Maroon lithol (a trade name of Calco Division of American Cyanamid Co.) for a red toner or wtih phthalocyanine blue for a blue toner. Suitable toner compositions which are negative relative to a polystyrene surface are Amberol F-71 (a trade name of Rohm & Hass Co. for a synthetic resin) with either Raven Beads carbon black or black iron oxide for a black toner.

In general, resins such as manjak, gilsonite, casein, polymethyl methacrylate and cellulose acetate give up electrons relatively easily, i.e., are easily charged to a positive potential triboelectrically. While materials such as Vinsol (a trade name of Hercules Powder Co. for a thermoplastic resin derived from pine wood), dammar, tartaric acid, polyvinyl butyral and various rosin-modified urea-formaldehyde resins easily acquire electrons, i.e., become negatively charged triboelectrically. In black pigments and dyes, it has been found that materials such as manganese dioxide, black iron oxide and Raven Beads carbon black easily acquire a negative charge, while nigrosine easily acquires a positive charge. The selection of suitable toner materials can be made by any one skilled in the art from the many materials that have been tested and occupy recognized positions in the triboelectric series. The dimension of the charge acquired by any particular material through triboelectric contact with any designated material is easily and readily determined as is well known to those skilled in the art.

The composition of the instant invention is particularly useful in simultaneously developing positive and negative polarity electrostatic charges. Such dual electrostatic images may be formed by a variety of ways. One such method known as TESI (for Transfer of Electrostatic Images) is described in U.S. 2,825,814 and in U.S. 2,833,648, both to L. E. Walkup.

Still another method is termed induction image formation. The basic process for induction image formation is described in U.S. 2,297,691 to C. F. Carlson. The method of using this process to form both positive and negative electrostatic images on the same xerographic plate is illustrated in FIG. 2 where a xepographic plate **10** comprising a layer of photoconductive insulating material **12**, as vitreous selenium, coated on an electrically conductive backing material **11**, as of brass, is sensitized by placing thereon in the dark a uniform positive charge as by corona discharge as disclosed in U.S. 2,777,957 to L. E. Walkup. Exposure of the sensitized plate to activating radiation creates thereon an electrostatic image creating areas of positive potential arranged on the selenium surface in image configuration. The electrostatic image so formed is a positive reproduction of the original and comprises areas of positive charge **20**, the electrostatic charges in the background areas having been discharged by the exposure.

The induction image process is a reversal process, i.e., it gives negative-to-positive or positive-to-negative reproduction. For this reason it is desirable to use the initial exposure for the variable information and the induction step for the fixed information which can be presented as a photographic negative. In this process a sheet of highly insulating material **17** as polyethylene terephthalate is placed on top of layer **12** and a transparent electrode **14** comprising a conductive surface **16** as of tin oxide coated on a transparent support base **15** such as glass is positioned on top of sheet **17**. A potential is now applied between layer **16** and **11** by suitable means as a battery **18**, the polarity of the applied potential being such that layer **11** is connected to the negative side of potential source **18** and layer **16** to the positive side during exposure. While the potential is applied, activating radiation **13** illuminates the plate in the image areas as opposed to the first step wherein the incident radiation constitutes the background areas. Thus the use of a photographic negative as the original in the induction step assures that the initial image is not erased during the second exposure. Care should be taken to assure that the exposures are carried out in register. When the radiation impinges on layer **12** it creates hole-electron pairs. Under the applied field from source **18** the holes migrate through layer **12** to conductive backing **11** while electrons **19** are retained on the surface layer **12** thereby creating image areas of negative polarity charges. These negative charges **19** are trapped on the surface by ceasing illumination **13**, and adjusting the applied potential so as to avoide charge transfer during separation of **17** from **12**. On removing layer **17** and electrode **14** there is now presented a surface having image areas of both positive and negative electrostatic potential. The method of obtaining electrostatic images of adequate density by induction is highly critical and is more fully disclosed in U.S. patent application Ser. No. 718,247, filed on February 28, 1958, by Byrne and Walkup.

In the process described above the insulating layer **17** is tightly pressed against photoconductive surface **12**. However, even under these conditions there is inherently a thin layer **9** of air between layer **12** and layer **17**. The drawing is exaggerated to more clearly depict the electrical relationships. The use of layer **17** compresses the dimensions of this air gap thereby increasing the voltage breakdown of the gap and thus the voltage directly induced on layer **12** during illumination. However, the breakdown potential of the gap is still sufficiently low so that only a small charge is directly induced thereon. Controlling the potential between electrodes **16** and **11** during separation after ceasing the illumination assures sufficient charge on layer **12** for adequate xerographic images with acceptable image densities.

In any event, the resulting positive and negative images are simultaneously developed, i.e., made visible, according to the instant invention by contacting the surface bearing the electrostatic images with a carrier surface having thereon both positively and negatively charged toner particles. Such a carrier is illustrated in FIG. 1 wherein there is shown a cross-section of a granular carrier particle **21** as described herein having electrostatically coated thereon toner particles **22** and **23**, toner particles **22** being positively charged and toner particles **23** being negatively charged.

A series of electrostatic images were developed using as the carrier surface a granular polystyrene resin having a particle size sufficient to pass through a 30 mesh screen and be collected on a 60 mesh screen. The positively charged toner consisted of 25% phenol-formaldehyde resin (obtained from Durez Plastics & Chemicals Inc. under the trade name Durez 570), 25% fortified maleic rosin ester (obtained from Rohm & Haas Co. under the trade name Amberol 750), 15% rosin-modified phenol-formaldehyde resin (obtained from Rohm & Haas Co. under the trade name Amberol F–71), 15% of a glyceryl ester of hydrogenated rosin (obtained from Hercules Powder Co. under the trade name Staybelite Ester No. 10), 12.5% ethyl cellulose (obtained from Dow Chemical Co. under the trade name Standard Ethoxy Ethocel, 10 cps.) 5% of a hydrogenated castor oil (obtained from E. I. du Pont de Nemours & Co. under the name Opalwax), and 2.5% coloring material. All parts are by weight.

The negatively charged toner consisted of 44.1% Durez 507, 21% polystyrene, 29.4% Amberol 750, 10.5% carnauba wax, and 5.25% coloring material. All parts are by weight.

In each case the toners were prepared by blending the ingredients together and then pulverizing to give an average particle size of about 5 microns. Using red negative toner (the coloring material consisted of Alkali Resistant Red Light RF–531–D from E. I. du Pont de Nemours & Co.) and green positive toner (the coloring material consisted of Ramapo green GP–501–D from E. I. du Pont de Nemours & Co.) in equal parts at carrier: total toner ratio (by weight) of about 40:1, the carrier-toner combination was cascaded over a surface carrying an electrostatic image. Three electrostatic images were developed in this way, the carrier-toner mass cascading over the surface six times for each development.

The first image developed consisted of positive electrostatic charges on an insulating surface. The result was a highly pleasing decorative combination comprising red image areas fringed with green. The second image consisted of negative electrostatic charges on an insulating surface and resulted in green image areas fringed with red. The third image consisted of both positive and negative electrostatic image areas on an insulating surface.

This "double" development of even single polarity charge images illustrates the distribution of the lines of force in an electrostatic image area: The lines of force emanating from the electrostatic charges on the insulating surface branch out from the surface terminating in the electrically conductive backing material **12**. This is particularly shown in U.S. 2,784,109 to L. E. Walkup, FIG. 3. The potential gradient along these lines of force results in both a relatively positive and a relatively negative portion of the gradient to attract toner thus causing deposition of both the positive and negatively charged toner as described. Very pleasing decorative effects may be obtained by making use of this property. A suitable blue toner capable of accepting a positive charge may be obtained by substituting 2.5% by weight of ultramarine blue for the 2.5% Ramapo green dye in the formulation of the positively charged toner.

The resulting decorative patterns obtained in this manner are particularly suitable for ceramic decoration. In this process it is generally desirable to transfer the decorative powder pattern to a flexible insulating sheet as of plastic, dry paper, etc. and then, preferably by electrostatic transfer, retransfer to the ceramic to be decorated. The process may also be used to apply the decorative pattern directly to a sheet of plastic to which it is permanently affixed as by heat, solvent vapor, etc.

Use may also be made of this effect of the fringing electric fields in the image areas to obtain excellent solid area coverage in developing half-tone images. In general, as disclosed in U.S. 2,784,109, electroscopic powder deposits only on the fringes of the electrostatic image areas resulting in the incomplete development of any solid image areas. To assure development of solid area images, it is essential to draw the lines of force externally above the image areas as described in the aforesaid patent U.S. 2,784,109 and in U.S. 2,777,418 to R.W. Gundlach. It is possible, however, by using the developer composition of the instant invention to obtain excellent coverage of solid areas without the necessity of drawing the lines of force externally.

Thus, a half-tone electrostatic image was formed by the conventional xerographic process, i.e., a commercial xerographic plate (comprising vitreous selenium on an aluminum backing obtained from Haloid Xerox Inc.) was sensitized in the dark by corona discharge to place a uniform positive charge on the selenium, and the selenium selectively discharged by exposure to a pattern of light and shadow projected through a half-tone screen having about 50% transmission to create an electrostatic image consisting of positive charges on the insulating surface. This image was then developed by cascading over the surface six times a carrier-toner mixture having a carrier: total toner ratio of 60:1 by weight. The carrier was glass beads (No. 8 glass beads from Minnesota Mining & Manufacturing Co.) while two toners were used in equal amount, both being black: the one comprising 95 parts Amberol F–71 and 5 parts carbon black (negative toner) and the other 95 parts gilsonite and 5 parts carbon black (positive toner), the toner particles having an average size of about 5 microns. No development electrode or device was used to draw the lines of force in the image areas externally above the image surface. Nevertheless, an excellent quality reproduction of the solid image areas was obtained. As both the positive and negatively charged toners were black, there resulted a high quality black on white half-tone reproduction of the original to be reproduced.

Another area wherein the developer compositions of the instant invention may be used to develop a single polarity electrostatic image is in xeroradiography. One of the principal objects in radiography is to detect "omissions," i.e., fractures, bubbles, etc. If the X-ray exposure is made on a xerographic plate (xeroradiography) as described in U.S. 2,711,481 to M. D. Phillips, such "omissions" will be characterized by an electrostatic gradient, which will actually be wider than the "omission" itself. If such an electrostatic image is now developed as described above using the red and green toner on a common carrier, the "omission" will develop as green on one side, red on the other and an undeveloped area in between. Thus the detection of hairline fractures, etc. is greatly facilitated using the composition and process of the instant invention.

While the developer composition of the instant invention is highly useful in obtaining solid area coverage of half-tone images as described herein, achieving novel decorative effects, and in xeroradiography, as can be seen from the above examples it cannot be used in the regular xerographic development process to give sharp, acceptable line copy images. As the area of greatest utility for the composition of the instant invention is in developing line copy electrostatic images, accordingly it is evident that it is essential to modify the development process so as to utilize the composition of the instant invention therein. Thus, in the induction image process described above combined with the regular xerographic process, there is obtained differential image information in the form of image areas of positive and negative electrostatic charge differential. Development of these images areas may be obtained in a single step using the novel developer composition of the instant invention. To assure sharp reproduction of the image areas, it is essential to draw the lines of force of the image areas externally above their surface as by using the development electrode as described in U.S. 2,777,418 cited above. Using the polystyrene carrier described above and a positive blue toner (having the same composition as the green toner supra but with ultramarine blue substituted for Ramapo green) and the negative red toner described above, there is thus obtained sharp and accurate reproductions of the image areas on the xerographic plate, the negatively charged image being developed by the blue toner and the positively charged image areas by the red toner, in each case without the contrasting color fringe.

There are illustrated in FIGS. 3, 4 and 5 other devices for developing positive and negative electrostatic images according to the instant invention wherein means are provided for drawing the lines of force of the image areas externally above their surfaces thus assuring faithful and accurate reproduction of the image areas without interference or blurring of the images due to the fringing of the electrostatic image areas.

Thus, in FIG. 3 there is shown a cylindrical drum **24** rotatably mounted on its longitudinal axis **27**. Desirably the drum is of conductive rubber or, if desired, may be formed of metal, plastic, plastic coated metal, etc. Suitable means as a hopper **25** holds a supply **26** of both positively and negatively charged toner so as to assure rubbing contact between the surface of cylinder **24** and the toner supply **26**. The toners are so selected relative to the material comprising the surface of cylinder **24** that one of the two toners assumes a positive charge through this rubbing contact while the other assumes a negative charge. Thus the surface of drum **24** becomes coated with positively charged toner particles **22** and negatively charged toner particles **23** (just as the granular carrier of FIG. 1.), the toner particles being bound to the surface of drum **24** by the combined forces of friction and electrostatic attraction. Suitable image support means as paper or plastic sheet **32** contacts drum **24** at a development station at which electrostatic image-carrying means **30** as a flexible xerographic plate or insulating material such as polyethylene terephthalate having thereon both positive and negative electrostatic images **20** and **19** respectively is yieldably urged into contact with sheet **32** at the developing station by suitable means as cylinder **31**. As stated, cylinder **24** is desirably formed of conductive rubber or, if necessary to assure the right triboelectric properties, of metal coated with a plastic having the desired triboelectric properties relative to the toner particles **22** and **23**. Thus cylinder **24** constitutes a grounded conductive electrode closely positioned relative to member **30** bearing the electrostatic images thereon. Hence, cylinder **24** acts as a development electrode to draw the lines of force of the electrostatic images externally above the surface of member **30**. Toner particles **22** and **23** are attracted to image support member **32** and deposit thereon in faithful conformity to the electrostatic image pattern on member **30**. If desired, member **32** may be dispened with and the toner particles permitted to deposit directly on member **30**. Cylinder **24** serves the triple function: First, of supplying the toner particles for development of the electrostatic images; second, drawing the lines of force of the electrostatic images externally above the surface of member **30** thereby preventing blurring due to fringe effects; and, third, preventing deposition of toner particles in non-image areas due to the electrostatic attraction between the surface of cylinder **24** and the toner particles **22** and **23**.

The device of FIG. 4 is similar to that in FIG. 3. Here sheet **37** as of metal, plastic, paper, or plastic coated metal or paper, bears on its surface a supply of positively charged toner **22** and negatively charged toner **23**. The surface of sheet **37** is so selected relative to toners **22** and **23** as to assure the proper triboelectric relationship therebetween. The toner-bearing sheet material **37** is fed from supply roll **48** to take-up roll **49**. Roller **31**, desirably of electrically conductive rubber, forces the toner-bearing surface of sheet **37** into contact with the member bearing positive and negative electrostatic images—in this case the surface **12** of the xerographic plate **10**. In addition to assuring contact, roller **31** acts as a development electrode to draw the lines of force of the image areas **19** and **20** externally above the surface of photoconductive insulating material **12**.

The xerographic plate **10** in this embodiment is in the form of a cylindrical drum. Positioned sequentially around the drum are charging means **50** as a corona generating electrode, optical exposure means **60** to thereby form electrostatic image areas on surface **12** having the same polarity charge as the sensitizing charges supplied by charging means **50** and TESI printing means **70** such as described in U.S. 2,833,648 to L. E. Walkup for placing electrostatic images on surface **12** of polarity opposite to the sensitizing polarity. After passing through the development zone wherein the surface **12** is contacted with toner bearing sheet **37** as herein described, the drum **10** passes through an image transfer station **80** whereat the powder image is transferred to an image support member **83** as plastic, paper, etc. and then past a cleaning station **90** such as a rapidly rotating fur brush.

Where use is made of an adhesive applied to the image support member to achieve transfer of the powder image from surface **12** it is evident that complete transfer is easily obtained. However, the use of such transfer means is severely restricted due to the problems of contaminating the photoconductive insulating surface **12** by the adhesive and by blocking of successive layers of adhesive with itself. As a result it is the almost universal commercial practice in xerography to transfer powder images electrostatically as described, for example, in U.S. 2,576,047 to R. M. Schaffert. While this process works admirably for the single polarity charge powders used in developing electrostatic images heretofore, it is evident that the process is attended with considerable difficulties when applied to transfer of the powder images formed by the process of the instant invention. Thus, whichever polarity of charge is used to effect transfer only one of the powder images is transferred thereby, the other being repelled. In the embodiment shown in FIG. 3 the problem of transfer is side stepped in that development occurs on the final image support material so that transfer is obviated.

There is shown in semidiagrammatic form in FIG. 4, means for efficiently and effectively transferring the powder images formed by the process of the instant invention. As there shown, the image support material **83**, as plastic or paper, is fed past the transfer station from supply roll **81** to take-up roll **82**. An electrically conductive roller **84** yieldably urges sheet **83** into firm contact with surface **12**. A suitable material for constructing roller **84** is an electrically conductive rubber. There is applied to roller **84** a suitable A.C. potential as 1400 volts from A.C. source **85**. By this means both the positive and negative toner images are effectively transferred to the image-support material **83**. The powder images electrostatically adhering to image-support material **83** may be then permanently affixed thereto by suitable means **86** as heat, solvent vapor, etc.

FIG. 5 shows a device for applying toner particles to a carrier surface which may then be used to contact the electrostatic image-bearing surface as described herein. In this embodiment sheet **37** is in the form of a continuous belt between two of cylindrical drums **31** and **38**. A supply of toner particles **36** is contained in a suitable reservoir **35**. The drum or cylinder **38** causes sheet **37** to dip into the supply of toner particles **36** in rubbing contact therewith as in the case of the contact between the surface of cylinder **24** and the supply of toner particles in FIG. 3. The result of this frictional contact is to coat the surface of sheet **37** with positively charged toner particles **22** and negatively charged toner particles **23**. Desirably, vibrating means **40**, as a solenoid, are provided to agitate reservoir **35** and prevent caking of the toner supply **36**. Drum **31**, which is desirably of electrically conductive rubber, acts as the developer electrode and to establish contact between the toner-bearing surface of sheet **37** and the member bearing the electrostatic image-bearing areas as does cylinder **31** in FIG. 4.

Thus, in accordance with the instant invention, there are provided means and processes whereby development of either single or double polarity electrostatic images occurs simultaneously with both positive and negative polarity toner. The instant invention makes possible the virtual elimination of the deposition of either polarity toner in background areas. In addition, means are provided whereby the unwanted image defects resulting from the fringing effects inherent in electrostatic images may be avoided thereby making possible clear, sharp, line-copy images. The use of a carrier surface to simultaneously charge both polarities of toners and prevent deposition in background areas as described herein apparently results in little or no agglomeration of the toners even though both polarities of toner are deposited on the single carrier surface. As a result the developing process and means of the instant invention afford and, indeed, make possible, high quality simultaneous recording of two polarity electrostatic images either in a single color or in two colors so as to obtain differential presentation of the information.

While the present invention as to its objects and advantages has been described herein as carried out in specific embodiments thereof, it is not desired 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. An improved composition for making visible electrostatic image comprising finely-divided powder particles uniformly electrostatically coated on a solid carrier surface capable of retaining said powder particles by electrostatic attraction, the carrier surface being adapted to make firm contact with a surface bearing an electrostatic image and having removably coated thereon by electrostatic attraction both positively and negatively charged toner particles having a particle size on the average less than about 20 microns.

2. A composition according to claim 1 wherein said positively charged toner particles are of a first color and said negatively charged toner particles are of a second color.

3. An improved xerographic developer comprising finely-divided powder particles electrostatically coated on solid carrier particles shaped to roll across a surface, the carrier particles being substantially spherical and of a size of at least about 200 mesh and having removably coated thereon by electrostatic attraction both positively and negatively charged toner particles, said toner particles having a particle size on the average less than about 20 microns.

4. An improved xerographic developer according to claim 3 wherein said positively charged toner particles are of a first color and said negatively charged toner particles are of a second color.

5. A process for developing an electrostatic image on an insulating surface comprising bringing to said insulating surface a solid surface having electrostatically coated thereon positively and negatively charged powder particles having a particle size on the average less than about 20 microns whereby said positively and negatively charged powder particles contact said insulating surface and are electrostatically attracted from the surface bearing said powder particles to deposit on said insulating surface in conformity with electrostatic lines of force of said electrostatic image.

6. A process according to claim 5 wherein said positively charged powder particles are of a first color and said negatively charged powder particles are of a second color.

7. A process according to claim 5 wherein said positively charged powder particles and said negatively charged powder particles are both of the same color.

8. A process for developing an electrostatic image comprising areas of positive and negative polarity charges on an insulating surface, said process comprising coating a solid carrier surface with first and second powder particles so selected relative to said carrier surface that said first powder particles assume a positive electrostatic charge and said second powder particles assume a negative polarity charge, said first and second powder particles being retained on said carrier surface solely by electrostatic attraction between said powder particles and said carrier surface, said powder particles having a particle size on the average less than about 20 microns, drawing the lines of force of said electrostatic image externally above said image-bearing surface and contacting said carrier surface with said image-bearing surface while said lines of force are drawn externally above said surface

whereby said first and second powder particles deposit on said image-bearing surface in faithful conformity with said electrostatic image thereby simultaneously developing both positively and negatively charged image areas.

9. A process according to claim 8 wherein said first powder particles are of a first color and said second powder particles are of a second color.

10. A process for the presentation of information which comprises establishing an electrostatic image comprising a halftone representation in electrostatic charges on an insulating surface of information to be reproduced, and bringing to said electrostatic image on said insulating surface a solid surface having electrostatically coated thereon positively and negatively charged powder particles having a particle size on the average less than about 20 microns whereby said positively and negatively charged powder particles contact said insulating surface and are electrostatically attracted from the surface bearing said powder particles to deposit on said insulating surface in conformity with electrostatic gradients of said electrostatic image.

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