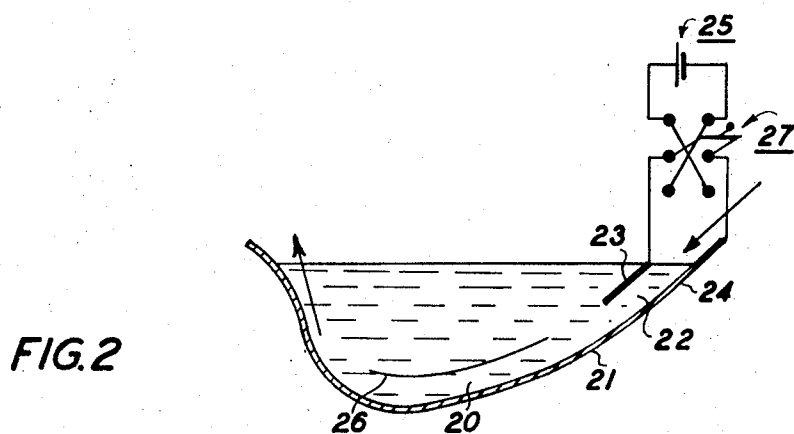
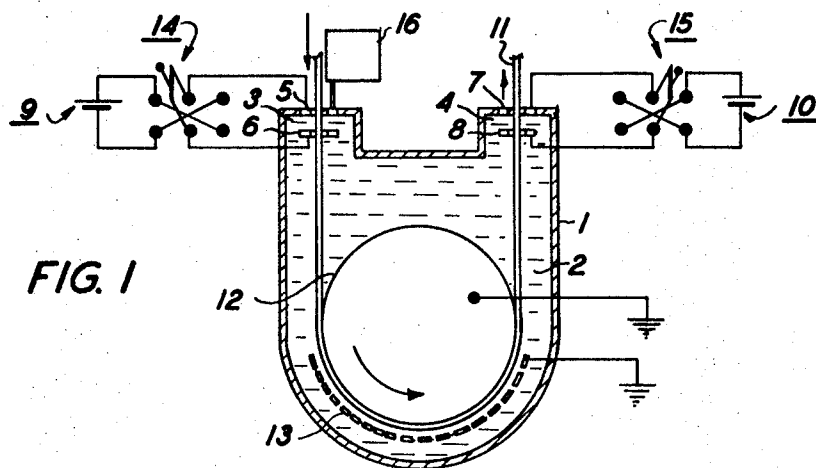


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LIQUID DEVELOPMENT OF ELECTROSTATIC LATENT IMAGES
UTILIZING A TOWER-FREE ZONE
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**LIQUID DEVELOPMENT OF ELECTROSTATIC
LATENT IMAGES UTILIZING A TONER-
FREE ZONE**

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15 Claims

ABSTRACT OF THE DISCLOSURE

Images are formed by providing a liquid developer bath comprising a continuous insulating liquid carrier phase and a discontinuous particulate toner phase, forming in the bath at least one zone substantially free of the toner phase, transporting an imaging member bearing an electrostatic latent image through the toner-free zone and thereafter passing the imaging member through the remainder of the bath. The imaging member may be transported through a substantially toner-free zone in the bath after development of the latent image to further improve image quality.

BACKGROUND OF THE INVENTION

This invention relates to imaging systems, and more particularly, to an improved method of developing electrostatic latent images with a liquid developer.

The formation and development of electrostatic latent images on an imaging surface with a liquid developer is well known. It is also well known that the liquid development technique is capable of producing images characterized by very high resolution and density. The resolution and image density obtained with liquid development systems is due primarily to the use of extremely fine toner particles having a particle size as small as about 0.1 micron. In addition to contributing to image quality, the small toner particle size is desirable in liquid development systems to promote developer stability.

Although many advantages are derived from the use of the liquid development technique, difficulties are encountered because the fine toner particles tend to form undesirable deposits on the background areas of imaging surfaces. Although it is not entirely clear, the deposition of toner particles in the background areas of imaging surfaces is believed to be due to the existence on the imaging surface of weak attractive forces other than electrostatic forces which aid in the entrapment of toner particles in minute crevasses existing in the imaging surface.

It has been found that background deposits may be substantially decreased or eliminated by moistening an electrostatic latent image bearing surface with a pure insulating liquid free of toner particles prior to development. The thin layer of insulating liquid apparently prevents deposition and/or entrapment of toner particles on the background areas of the electrostatic latent image bearing surface. Similarly, it has been discovered that the treatment of an imaging surface with toner free insulating liquid after development reduces the amount of toner deposits in the background areas. Unfortunately, the pre-treatment and after-treatment of an imaging surface with a toner free insulating liquid requires additional complex, expensive, and space consuming equipment which increases the processing time for forming an image. Further, the liquid employed for the aftertreatment step rapidly becomes contaminated with toner particles which were removed from the imaging surface and therefore must be frequently replaced or treated to remove the accumulated particles. Thus, there is a continuing need for an improved imaging system.

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SUMMARY OF THE INVENTION

It is therefore, an object of this invention to provide an imaging system overcoming the above noted deficiencies.

It is another object of this invention to provide an imaging technique which improves electrostatographic image resolution.

It is a further object of this invention to provide more compact imaging system.

It is still another object of this invention to provide an imaging technique which reduces or eliminates background toner deposits.

It is another object of this invention to provide an imaging technique which forms images with greater speed.

It is a further object of this invention to provide an imaging technique superior to those of known techniques.

The above objects and others are accomplished by providing a liquid developer bath comprising a continuous insulating liquid carrier phase and a discontinuous particulate toner phase, forming in the bath at least one zone substantially free of the toner phase, transporting an imaging member bearing an electrostatic latent image through the toner-free zone and thereafter passing the imaging member through the remainder of the bath. The imaging member may be transported through a substantially toner-free zone in the bath after development of the latent image to further improve image quality.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages of the improved electrostatographic imaging system of this invention will become even further apparent upon consideration of the following disclosure of the invention, particularly when taken in conjunction with the accompanying drawing wherein:

FIG. 1 is a schematic sectional view of an electrophotographic imaging apparatus employing the pretreatment and aftertreatment means of this invention.

FIG. 2 is a schematic sectional view of an alternative form of the apparatus shown in FIG. 1.

**DESCRIPTION OF THE PREFERRED
EMBODIMENTS**

Referring now to FIG. 1, reference character 1 designates a light impervious, closed vessel filled with a liquid developer bath 2 comprising a conventional insulating carrier liquid and charged toner particles dispersed therein. Zones 3 and 4 substantially free of toner particles are formed in the developer bath by applying an electrostatic field between electrodes 5 and 6 and electrodes 7 and 8, respectively, by means of direct current sources 9 and 10, respectively. The carrier liquid in zones 3 and 4 is an integral part of the continuous carrier liquid phase of the developer bath 2 and therefore permits rapid treatment of an imaging surface with a minimum amount of equipment and space. The electrode 5 is provided with an insulated slit, not shown, through which an electrostatic latent image bearing web 11 can pass into vessel 1. Upon entering vessel 1, web 11 is transported through toner-free zone 3 where it is pretreated with a carrier liquid. A conductive web driving roll 12 is driven by suitable means not shown in the direction indicated by the curved arrow. A development electrode 13 having uniformly distributed apertures therethrough for passage of developer material is positioned closely adjacent to but separated from the web surface to be developed. The driving roll 12 and development electrode 13 may be electrically connected to a suitable reference potential or to ground as is well known in the art.

Double pole double throw switching means 14 and 15 are provided between direct current sources 9 and 10,

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respectively, to reverse the field direction in zones 3 and 4, respectively. When the switching means 14 or 15 is closed, an electrostatic field parallel to the surface of the web 11 is formed between the pair of electrodes 5 and 6 or the pair of electrodes 7 and 8, respectively. The charged toner particles present between the electrodes are electrophoretically attracted to one of the pair of electrodes in each zone thereby forming a zone substantially free of the toner phase. The toner particles will migrate to and deposit on the electrode having a polarity opposite to the polarity of the toner particles. Since an electrical field vertical to the surface of the web 11 will adversely affect the electrostatic latent image by inducing a uniform charge on the web 11, a field parallel to the surface of the web 11 is employed. Considerable latitude in electrode spacing and applied voltages exists in the system of this invention. Satisfactory toner-free zones are formed in a zone between a pair of electrodes 2 millimeters apart when a voltage potential of about 1000 volts is applied to the electrodes. Generally, the size of the toner-free zone, i.e., the space between the electrodes, to be employed depends upon the speed of the web through the zone. Thus, the zone should be sufficiently large to coat the web surface with a thin film of carrier liquid which fills the interstices in the irregular surface of the web thereby preventing toner particles from becoming entrapped on the surface of the web in the non-image areas. The electrostatic field emanating from the electrostatic latent image on the surface of the web is sufficiently strong to cause toner particles to migrate through the thin surface layer of toner-free carrier liquid to deposit in the image areas. The development electrode 13 promotes the formation of toner image having a density distribution substantially proportional to that of the charge density on the electrostatic latent image and prevents the well known edge effect from occurring and aids in the prevention of toner deposits in the background areas.

After development in the developer bath 2, the web 11 is transported through the second toner free zone 4 wherein the developer liquid adhering to the surface of the web 11 is washed and replaced by toner-free carrier liquid. This washing step further contributes to the reduction of toner particle deposition in the background areas.

When the apparatus illustrated in FIG. 1 is operated for prolonged periods of time, toner particles will gradually accumulate on one of the electrodes of each pair. To avoid toner accumulation, the polarity of the electrodes may be reversed intermittently by means of the double pole double throw switches 14 and 15. Preferably, the electrode on which the toner particles accumulates is vibrated mechanically by a vibrating solenoid 16 connected to an appropriate source of electrical energy not shown. Obviously, other sources of vibratory energy such as a transducer may be substituted for the solenoid. Optimum results are obtained with vibration frequencies in the ultrasonic range. When relatively large toner particles having a diameter about 1 micron are employed in the developing liquid, the particles are readily redispersed into the liquid carrier phase by merely reversing the polarity of the electrodes. When conductive toner particles are employed in the liquid developer, the charge on the toner particles will be neutralized and a charge of opposite polarity will be imparted to the toner particles upon contact with an electrode. Since this phenomenon will cause reciprocation of the conductive toner particles from one electrode to another thereby rendering it impossible to create a toner-free zone, electrodes covered with a thin insulating coating should be employed with developers containing conductive toner particles. Any suitable insulating coating material which is not soluble in the carrier liquid may be employed to coat the electrodes.

In FIG. 2, another embodiment of the invention is shown wherein a liquid developer bath 20 is contained in a conductive vessel 21 having a single toner-free zone 22 between two electrodes 23 and 24. The electrodes 23 and 24 are connected through a suitable switching device 27

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to a direct current source 25. A development electrode 26 is provided adjacent to and spaced from the bottom of vessel 21. During operation, an electric field is applied across zone 22 to remove substantially all the toner particles present therein. A sheet bearing an electrostatic latent image is thereafter inserted into the toner-free zone 22 in the direction indicated by the arrow. However, immediately prior to entry to the sheet into toner-free zone 22, the electrodes 23 and 24 are inactivated by suitable means such as a microswitch, not shown, operated by the progress of the sheet into vessel 21. After passage through the developer-free zone 22, the sheet is developed in a manner similar to that described above with reference to FIG. 1. Since sheet material is developed in the embodiment illustrated in FIG. 2, the direction of the electrical field applied to toner-free zone 22 may be reversed after passage of each sheet to aid in the removal of accumulated toner particles. Obviously, vibratory means may be necessary if relatively fine toner particles are employed. The available time for passage of the sheet into the toner-free zone 22 after termination of the applied electrostatic field and before the toner-free zone becomes recontaminated with toner particles depends upon numerous factors including the dimensions of the toner-free zone, the configuration of the toner-free zone, the viscosity of the liquid developer, the size of the toner particles in the liquid developer and the concentration of toner particles in the liquid developer.

The following examples further specifically define and describe the imaging system of the present invention for providing a substantially toner-free zone comprising carrier liquid in a liquid development bath for the treatment of imaging surfaces. These examples are intended to illustrate the various preferred embodiments of the present invention.

EXAMPLE 1

A development vessel similar to the development system illustrated in FIG. 2 is filled with a commercial liquid developer comprising an insulating carrier liquid and toner particles having an average particle size of about 1 micron. The electrodes are spaced 2 millimeters apart and a voltage potential of about 1000 volts is applied across the electrodes until substantially all of the toner particles in the zone between the two electrodes are electrophoretically removed. The voltage potential is then removed and a zinc oxide photoreceptor sheet bearing an electrostatic latent image is immediately passed through the toner-free liquid carrier between the two electrodes and into the remainder of the bath which contains both the insulating carrier liquid and the toner particles. Excellent dense images corresponding to the electrostatic latent image are obtained with substantially no background toner deposits.

EXAMPLE II

A development vessel similar to the development system illustrated in FIG. 1 is filled with a commercial liquid developer comprising insulating carrier liquid and toner particles having an average particle size of about 0.1 micron. The two pair of electrodes are spaced 2 millimeters apart and a voltage potential of about 1,000 volts is applied across the electrodes until substantially all of the toner particles in the zone between the electrodes in each pair are electrophoretically removed. A transducer is mechanically connected to one of the electrodes of each pair to which the toner particles migrate to periodically vibrate the electrodes to aid in the removal of accumulated toner particles. A vibration frequency of about 20,000 cycles per second is employed. A zinc oxide photoreceptor sheet bearing an electrostatic latent image is passed between the toner-free liquid carrier between the pair of electrodes positioned at the entrance to the vessel and thereafter into the portion of the bath which contains both the insulating carrier liquid and the toner particles. After the toner particles have deposited on the photore-

ceptor sheet, in image configuration, the sheet is passed through the toner-free liquid carrier between the pair of electrodes located at the exit point of the vessel. High resolution images characterized by a minimum amount of background toner deposits are obtained.

As indicated above, conventional liquid developer materials and techniques may be employed to develop the electrostatic latent image after passage of the electrostatic latent image bearing surface through a toner-free zone.

The imaging technique of this invention, as may be clearly understood from the foregoing description, provides a system in which high quality dense images having extremely low background toner deposits may be obtained with a simplified, compact apparatus. These improved images are realized by pretreating an electrostatic latent image bearing surface in a zone of the developer bath in which toner particles have been electrophoretically removed. A further improvement in the reduction of toner deposits in the background areas is achieved by the aftertreatment of the imaging surface in a toner-free zone similar to the pretreatment zone.

While the invention has been particularly shown and described with reference to the preferred embodiments thereof, other modifications and ramifications of the present invention will appear to those skilled in the art upon a reading of the disclosure. These are intended to be included within the scope of this invention.

What is claimed is:

1. An electrostatographic imaging method comprising providing a liquid developer bath comprising a continuous insulating liquid carrier phase and a discontinuous electrostatically attractable particulate toner phase, establishing an electrostatic field in said bath to form at least one zone substantially free of said toner phase, transporting an imaging member bearing an electrostatic latent image through said zone prior to passage through at least a portion of said bath containing said particulate toner phase and thereafter transporting said imaging member through at least a portion of said liquid developer bath comprising said liquid carrier phase and said discontinuous particulate toner phase whereby at least a portion of said particulate toner phase is electrostatically attracted to and deposits on said imaging member in accordance to said electrostatic latent image thereby forming a visible image.

2. An electrostatographic imaging method according to claim 1, including transporting said imaging member, after said visible image is formed, through a zone in said developer bath substantially free of said toner phase, said zone formed by establishing an electrostatic field in said developer bath.

3. An electrostatographic imaging method according to claim 1, including electrophoretically removing said particulate toner phase from a portion of said bath to form said zone substantially free of said toner phase.

4. An electrostatographic imaging method according to claim 3, wherein said particulate toner phase is electrophoretically removed from said zone by establishing an electrostatic field perpendicular to the path of said imaging member prior to passage of said imaging member through said zone.

5. An electrostatographic imaging method according to claim 3, wherein said particulate toner phase is electrophoretically removed by means of an electrostatic field which is terminated substantially immediately prior to passage of said imaging member through said zone.

6. An electrostatographic imaging method according to claim 5, wherein said electrostatic field is parallel to the path of travel of said imaging member through said zone.

7. An electrostatographic imaging method according to claim 3, including electrophoretically removing said particulate toner phase from said zone by establishing an

electrostatic field across said zone between at least two electrodes thereby electrophoretically depositing said particulate toner phase in said zone on at least one of said electrodes.

8. An electrostatographic imaging method according to claim 7, including periodically reversing the direction of said electrostatic field between said electrodes.

9. An electrostatographic imaging method according to claim 7, wherein said electrodes are coated with a thin insulating coating.

10. An electrostatographic developing apparatus comprising a vessel adapted to contain a liquid developer bath comprising a continuous insulating liquid carrier phase and a discontinuous electrostatically attractable particulate toner phase, said vessel including at least one pair of parallel electrodes positioned with respect to said vessel to permit at least partial immersion of said electrodes in said liquid developer and spaced in relationship to each other to define an elongated zone therebetween and positioned to permit passage of an imaging member through said zone prior to passage through at least a portion of said bath containing said particulate toner phase, means adapted to electrically connect said electrodes to a direct current source to establish an electrostatic field and form in said bath in said elongated zone liquid carrier substantially free of said toner phase, and means to convey an imaging member bearing an electrostatic latent image through said elongated zone into intimate physical contact with said liquid developer to render said electrostatic latent image visible.

11. An electrostatographic developing apparatus according to claim 10 including switch means for selectively reversing the electrical connection between said electrodes and said direct current source.

12. An electrostatographic developing apparatus according to claim 10 including switch means for selectively making and breaking the electrical connection between said electrodes and said direct current source.

13. An electrostatographic developing apparatus according to claim 10, wherein said electrodes are positioned to form an electrostatic field parallel to the path of travel of said imaging member between said parallel electrodes.

14. An electrostatographic developing apparatus according to claim 10, wherein said electrodes are positioned to form an electrostatic field perpendicular to the path of travel of said imaging member between said parallel electrodes.

15. An electrostatographic developing apparatus according to claim 10 wherein said electrodes comprise a conductive core covered with an insulating coating.

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Application having been made by Masamichi Sato, Yasuo Tamai, Seiji Matsumoto, and Goro Akashi, the inventors named in the patent above identified, and Xerox Corporation, Rochester, N.Y., a corporation of New York, the assignee, for the issuance of a certificate under the provisions of Title 35, Section 256, of the United States Code, adding the name of Satoru Honjo as a joint inventor, and a showing and proof of facts satisfying the requirements of the said section having been submitted, it is this 23rd day of May 1972, certified that the name of the said Satoru Honjo is hereby added to the said patent as a joint inventor with the said Masamichi Sato, Yasuo Tamai, Seiji Matsumoto, and Goro Akashi.

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