United States Patent [19]

Royka et al.

[11] **3,776,723**

[45] **Dec. 4, 1973**

[54] **IMPROVED LIQUID TRANSFER ELECTROPHOTOGRAPHIC DEVELOPMENT PROCESS**

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[73] Assignee: **Xerox Corporation**, Rochester, N.Y.

[22] Filed: **Aug. 9, 1972**

[21] Appl. No.: **279,164**

[52] **U.S. Cl.** .... **96/1 LY**, 96/1.4, 117/37 LE, 118/637, 355/10

[51] **Int. Cl.** **G03g 13/10**, G03g 13/14

[58] **Field of Search** .... 96/1 LY, 1.4; 117/37 LE; 118/637

[56] **References Cited**

UNITED STATES PATENTS

3,102,045	8/1963	Metcalfe et al.	96/1 LY
3,251,688	5/1966	Mihajlov	96/1 LY
3,472,676	10/1969	Cassiers et al.	96/1 R

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[57] **ABSTRACT**

An improved liquid transfer development process comprising:

electrically charging the photoconductive surface of an imaging member comprising a photoconductive insulating layer overlying a transparent electrically conductive substrate;

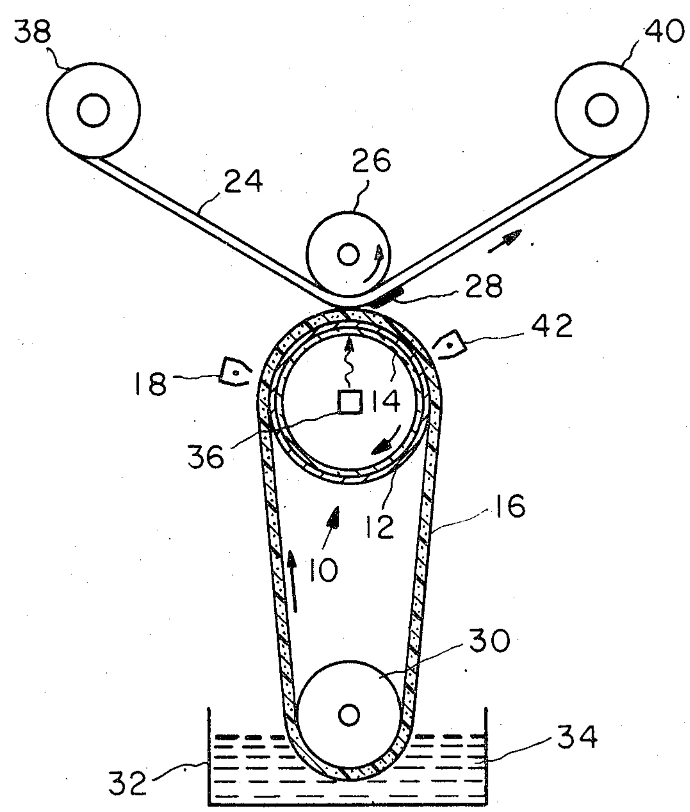
exposing the photoconductive surface of said imaging member through said transparent substrate to a pattern of light and shadow;

contacting the photoconductive surface of said imaging member with a developer-laden web, said developer comprising particulate toner dispersed in an insulating liquid carrier;

contacting said developer-laden web with an image receiving web to selectively deposit particulate toner in conformance with said pattern of light and shadow; and,

separating said image receiving web from said developer-laden web.

11 Claims, 4 Drawing Figures



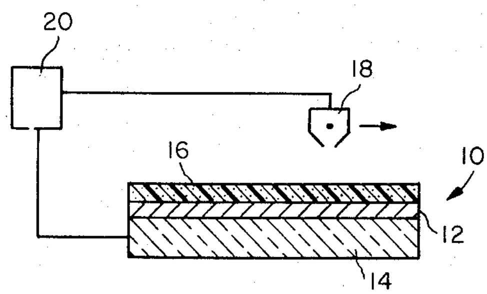


Fig. 1a

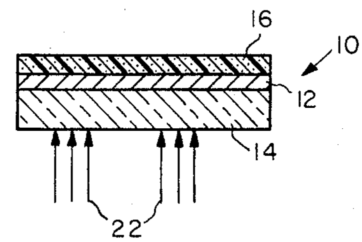


Fig. 1b

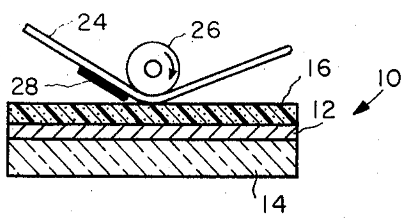


Fig. 1c

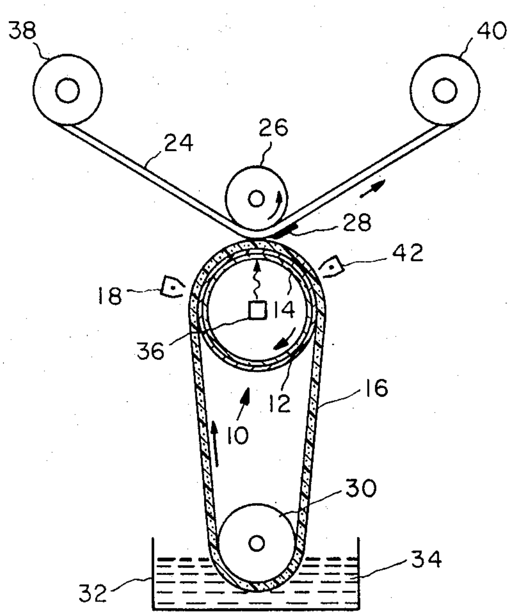


Fig. 2

IMPROVED LIQUID TRANSFER ELECTROPHOTOGRAPHIC DEVELOPMENT PROCESS

This invention relates to an improved liquid transfer development process. More particularly, this invention relates to a method of uniformly applying and maintaining a constant liquid layer on a development surface in a liquid transfer development process.

The development of electrostatic latent images with liquid development systems is well known. Generally, in such systems, the electrostatic latent image is developed and transferred in image configuration to a suitable transfer material such as paper, plastic or the like. If desired, the transferred image can be fixed to the transfer material by application of heat, pressure, solvent vapors or some combination thereof.

Effective transfer, however, is often difficult and inconvenient. Moreover, it imposes several restrictions on the selection of materials and, most importantly, on the ultimate operating speed. Methods have heretofore been developed which eliminate the transfer step as a separate operation relying instead, on a system of transfer-development from a plate precoated with liquid developer. One such system is disclosed in the Mihajlov patent, U.S. Pat. No. 3,251,688, which is incorporated herein by reference.

The system disclosed in said patent comprises initially coating an imaging surface with a suitable liquid developer. Coating has heretofore been effected by immersion, electrophoresis, spin coating, vacuum coating or other similar techniques. The liquid developer generally comprises a toner material which is dispersed in and immiscible with an insulating carrier liquid. A uniform electrostatic charge of the same polarity as that of the toner is then applied to the coated imaging surface such as by a corona discharge electrode. The charged plate is then exposed to a pattern of light and shadow. Thereafter, a suitable transfer material is brought into light pressure contact with the layer of liquid developer by moving a pressure roller across the surface of the transfer material resulting in the formation of a toner image on the transfer material corresponding to the non-light struck areas of the plate.

Although this liquid transfer development process avoids many of the problems associated with the transfer step in conventional electrostatography, it requires careful process control to assure uniform distribution of the liquid developer on the plate throughout the process and careful pressure regulation. If the liquid developer is not applied uniformly and/or maintained in that state during processing, it has been found that there is a tendency for (1) the concentration of toner particles to vary over the imaging surface regulating in non-uniform developed densities and (2) the liquid layer to vary in thickness resulting in non-uniform paper contact during transfer. These problems become especially significant when low viscosity liquids are employed in a system configuration wherein gravity exerts a disrupting influence on the liquid layer during processing. Moreover, the pressure exerted on the transfer material must be carefully controlled so that ideally the transfer material "floats" gently on the liquid surface. Too much pressure results in excessive background and non-uniform transfer density.

It is, therefore, an object of this invention to provide an improved liquid development process which overcomes the above-noted deficiences.

It is another object of this invention to provide methods for uniformly applying and maintaining a constant liquid layer on an imaging surface.

It is still another object of this invention to provide methods which effectively reduce the constraints which heretofore give rise to rigid process control thereby imparting greater flexibility to the process and its areas of application.

These as well as other objects are accomplished by the present invention which provides an improved liquid transfer development process comprising:

electrically charging the photoconductive surface of an imaging member comprising a photoconductive insulating layer overlying a transparent electrically conductive substrate;

exposing the photoconductive surface of said imaging member through said transparent substrate to a pattern of light and shadow;

contacting the photoconductive surface of said imaging member with a developer-laden web, said developer comprising particulate toner dispersed in an insulating liquid carrier;

contacting said developer-laden web with an image receiving web to selectively deposit particulate toner in conformance with said pattern of light and shadow;

separating said image receiving web from said developer-laden web.

The present invention will become more apparent from the ensuing discussion and drawing wherein:

FIG. 1 is a schematic illustration of an embodiment of the present invention which illustrates the sequential operation of the liquid transfer development process;

FIG. 2 is a schematic illustration of an alternative embodiment of the present invention which illustrates a continuous mode of operation.

Referring now to FIG. **1**, there is shown an imaging member **10** which comprises a photoconductive insulating layer **12** overlying a conductive substrate **14.** Overlying the photoconductive layer **12** and in contact therewith is a developer-laden web **16** which is described in more detail hereinbelow. The conductive substrate should be transparent to permit imaging therethrough. The conductive substrate can be prepared by overcoating a layer of optically transparent glass with a layer of tin oxide. Substrates of this type are commercially available under the name NESA glass from Pittsburgh Plate Glass Company.

A uniform electrostatic charge of the same polarity as that of the toner in the liquid developer is applied to the plate by corona discharge electrode **18.** A suitable corona discharge electrode may comprise one or more fine conductive strands maintained at a corona discharge potential by high voltage source **20.** The conductive strands are positioned within a shield and are maintained at a desired corona discharge potential such as, for example, a potential in the order of several thousand volts and may be controlled to deposit on the surface electrical charge of the desired polarity. As illustrated in FIG. *1a* corona discharge electrode **18** is being moved across the plate surface from left to right to deposit electrical charge on the liquid developer ladened web **16** previously deposited on the imaging member **10.**

FIG. 1*b* illustrates exposure of the charged member **10** to a pattern of light and shadow. A light pattern illustrated by arrows **22** is projected upon the photoconductive insulating layer **12** of imaging member **10** through conductive transparent backing **14.**

After completing the foregoing steps, a copy may be made on suitable transfer material by the transfer-development procedure illustrated in FIG. 1*c*. Image receiving web **24** is brought into pressure contact with the liquid developer-laden web **16** by moving roller **26** across the web in the direction indicated by the arrow. This results in the formation of toner image **28** corresponding to the non-light-struck areas of the plate **10** on image receiving web **24.** Toner image **28** may then be removed on image receiving web **24** by separating it from the developer-laden web **16.**

Roller **26** desirably comprises an electrically conductive material such as conductive rubber, although other materials including non-conductive materials can be used. When a conductor is employed, print quality is enhanced by applying an electrical potential to the roller. Relatively small quantities of toner may adhere to the image receiving material in non-image areas thereby causing the appearance of background in the prints if the roller is allowed to electrically float. This undesired phenomenon can be appreciably reduced by applying an electrical potential of the same polarity as that of the toner to roller **26.** Electrical potentials between about ground and about the potential of the discharge areas of the surface bearing the charge pattern have been found generally suitable. Comparatively light copies having a washed out appearance have been found to result when a potential of greater magnitude is applied to the roller. On the other hand, substantial background in non-image areas is noted when an electrical potential of opposite polarity of that of the toner is applied to roller **26.**

FIG. 2 shows an embodiment of the present invention found suitable for continuous operation wherein the transfer-development procedure is conducted simultaneously with the exposure step. In this embodiment, imaging member **10** comprises a photoconductive layer **12** overlying a transparent backing **14** such as glass or plastic. To impart the desired electrical characteristics, at least one side of transparent backing **14** may have a conductive coating such as tin oxide. NESA glass, mentioned earlier, has been found suitable for use as the transparent conductive backing member.

In this embodiment, the developer-laden web **16** is an endless web which passes around the imaging member **10** which is in the form of a roll or drum and around a roller **30** spaced therefrom. Roller **30** is situated at least partially within developer sump **32** which contains liquid developer **34** in sufficient quantity to laden belt **16** therewith and continuously replenish developer removed during the development process. Although FIG. 2 illustrates loading of web **16** with developer from a sump, it is readily apparent that developer loading of the web can be effected at any point in the process prior to imaging. Thus, if desired, the web **16** can be laden with developer by spraying the developer onto the web just prior to entry into the imaging zone defined by the zone of contact between the web **16** and the image receiving web **24.** Other techniques for loading the web **16** with liquid developer such as by contact with a developer-laden roller or the like can similarly be employed.

As shown, the photoconductive state of imaging member **10** is electrostatically charged upon passage past corona discharge electrode **18.** If desired, however, the imaging member **10** can be charged before it is contacted with the developer-laden web **16** as by positioning the corona discharge electrode within the zone defined by imaging member **10,** roller **30** and the interior surface of web **16.** Preferably, charging is effected in the manner illustrated in FIG. **2** since it has been found that in this manner, the toner particles in the developer-laden web are driven toward the imaging member **10** resulting in a clear layer of carrier liquid contacting the imaging receiving web **24** thereby reducing background deposits.

Thereafter, the photoconductive surface of imaging member **10** is exposed to a pattern of light and shadow to be reproduced via projection means **36.** As shown, the light pattern is projected toward the transparent backing **14** of the imaging member **10.** Simultaneously, image receiving web **24** is brought into pressure contact with the developer-laden web **16** in the imaging zone via pressure roller **26,** whereby toner particles are transferred from the developer-laden web **16** to the image receiving web **24** in the non-light-struck areas to form a toner image **28** in conformance with the original. The image receiving web **24** can be continuously supplied to the imaging zone from feed roll **38** and can be continuously removed therefrom by wind up roll **40.** Any residual charge on the imaging surface can be removed after the transfer development operation by use of an a.c. coroton **42** or simply by complete exposure to light such as with a light source (not shown).

Reversal development, or toner deposition conforming to discharged areas of the plate, may be accomplished by using a suitable toner which is electrically charged to a polarity opposite to that of the electrostatic charge applied to the plate. For such applications of the present invention, it is desirable that an electrical potential of opposite polarity to that of the toner be applied to the pressure roller. Thus, for example, an appropriate combination for reversal development would comprise using a positively charged toner, applying a negative electrostatic charge to the plate, and biasing the pressure roller with a negative electrical potential.

In the conventional liquid transfer development process such as disclosed in U.S. Pat. No. 3,251,688, liquid developer must be applied uniformly to the photoconductive surface and the spacing between the image receiving web and the photoconductive surface must be rigidly controlled. The use of a developer-laden web in accordance with the present invention removes the constraints imposed upon the liquid transfer development process since the web uniformly delivers liquid developer to the imaging surface and acts as a spacer and support for the image receiving web thereby controlling the separation between the imaging member and the image receiving web during processing.

The developer-laden web can be fine-meshed or porous insulating hydrophobic material which can entrap liquid developer between the interstices thereof via surface tension and/or capillary action. Typical of such materials are fine-meshed fabrics such as silk, nylon, polyesters, rayon and the like. The fabrics may be woven as desired. The interstices of the meshed or porous materials must be large enough to permit passage of the particulate toner but small enough to entrap the liquid developer therein due to capillary action and surface tension forces. Generally, the interstices can range in size from about 15 microns to about 2,000 microns. Both the thickness of the web and the size of the interstices therein can influence the volume of developer liquid which can be laden into the web. Generally, web thickness should be minimized consistent with providing sufficient web thickness for processing. Web thicknesses up to about 0.01 inch have been found suitable. The diameter of the fibers employed in the web can have an effect upon image resolution. For best results, fiber diameter should be kept to a minimum. Fibers having diameters up to about 0.005 inch have been found suitable for use in the webs of the present invention.

Several materials have been found suitable for use as the image receiving web in the production of copies according to the present invention. Electrically conductive as well as electrically nonconductive materials including various bond papers, baryta-coated papers, plastic films such as Mylar film and Saran film, steel and brass foil, aluminum and paper Multilith masters as well as very thin aluminum foil have been used successfully.

Developer compositions suitable for use in the present invention comprise dispersions of toner particles formed in a liquid carrier for example by stirring or other methods well known to those skilled in the art. It is understood that the toner particles may be liquids, solids or organosols capable of being dispersed in the carrier. Thus, suitable dispersions, suspensions, and emulsions and other colloidal systems are within the scope of this invention.

The carrier liquid is preferably a highly insulating material with a volume resistivity of at least about 10^{13} ohm-centimeters Suitable liquids include hydrocarbons such as benzene, xylene, hexane, naphtha, cyclohexane, etc.; halogenated hydrocarbons such as carbon tetrachloride, trichlorethylene, chloroform, Freon (a trade mark of E.I. du Pont de Nemours & Co. for various fluorinated compounds), Genetron (a trade mark of Allied Chemical Co. for various fluorinated compounds), etc.; miscellaneous liquids such as silicone liquid, turpentine, etc. A particularly useful material of refined petroleum hydrocarbon class is Sohio Odorless Solvent (SOS) sold by the Standard Oil Company of Ohio.

If desired, the carrier may comprise a material that is a solid at room temperature such as Bioloid paraffin wax. In such applications, an additional step is required in practicing the present invention to temporarily liquify the developer prior to imaging such as by heating the web. Alternative liquification methods may be employed, depending upon the composition of the carrier. For instance, the developer may be exposed to a vapor solvent for the carrier to accomplish the same functional result. The liquification step may be combined with transfer-development by, for instance heating pressure roller **26**.

Liquid toner particles may be substantially immiscible with the carrier liquid and capable of being dispersed in the form of very small droplets. An almost limitless number of suitable materials exist which may be used in conjunction with the present invention. One suitable class of materials comprises aqueous inks such as ordinary commercial fountain pen inks. Another particularly useful class of materials includes glycols, preferably including soluble dyes in order to render the image visable.

Suitable solid toner particles include pigments, dyes, resins, metals, and materials such as charcoal and graphite and similar material, having a fine particle size and being insoluble in the carrier liquid. In general, the finer the powder, the better the grain in the developed image. It is preferred that the average particle size be no larger than about 20 microns and for high quality work, it is preferred that the average particle size be no more than about 5 microns.

If desired, the transferred image may be permanently fixed to the image receiving web by any suitable method such as heat, pressure, vapor fusing and the like. If desired, the separate fixing step may be obviated by an appropriate selection of developer components. For instance, self-fixing characteristics may be imparted to the developer by using toner particles comprising resins which are binders or film-forming. A composition suitable for this purpose comprises an organosol in which a solution of a resin binder in a polar solvent is dispersed in a non-polar carrier. Another suitable composition comprises a suspension of finely divided resin dyestuff in molten paraffin wax. Solidification of the wax upon cooling to room temperature serves to fix the image to the image receiving web.

Other modifications of the present invention will occur to those skilled in the art upon a reading of the present disclosure. These are intended to be included within the scope of this invention.

What is claimed is:

1. An improved liquid transfer development process comprising:

electrically charging a photoconductive surface of an imaging member comprising a photoconductive insulating layer overlying a transparent electrically conductive substrate;

exposing the photoconductive surface of said imaging member through said transparent substrate to a pattern of light and shadow;

contacting the photoconductive surface of said imaging member with a porous electrically insulating hydrophobic developer-laden web, said developer comprising particulate toner dispersed in an electrically insulating liquid carrier;

contacting in the imaging zone said developer-laden web with an image receiving web to selectively deposit on said image receiving web particulate toner in conformance with said pattern of light and shadow; and,

separating said image receiving web from said developer-laden web.

2. Process as defined in claim **1** wherein the photoconductive surface of the imaging member is electrostatically charged through the developer-laden web in contact with such surface.

3. Process as defined in claim **1** wherein the polarity of the electrostatic charge is the same as that of the toner in the liquid developer.

4. Process as defined in claim **1** wherein the developer-laden web continuously passes the imaging member.

5. Process as defined in claim **1** comprising the additional step of removing any residual charge on the imaging surface after separating said image receiving web from said developer-laden web.

6. Process as defined in claim **1** wherein the polarity of electrostatic charge applied to the imaging surface is opposite that of the polarity of the toner in the liquid developer, whereby toner deposits on the image receiving web in areas conforming to the discharged areas on the photoconductive surface of the imaging member.

7. Process as defined in claim **1** wherein the developer-laden web is a fine-meshed or porous insulating hydrophobic material having a plurality of interstices therein adapted to entrap liquid developer via surface tension and/or capillary action, said interstices ranging in size from about 15 microns to about 2,000 microns.

8. Process as defined in claim **7** wherein the developer-laden web has a thickness up to about 0.01 inch.

9. Process as defined in claim **1** wherein the liquid developer comprises a dispersion of toner particles in an electrically insulating carrier liquid, said carrier liquid exhibiting a volume resistivity of at least about 10^{13} ohm-centimeters.

10. Process as defined in claim **1** wherein the developer comprises a dispersion of toner particles in an electrically insulating carrier which is normally solid at room temperature, said developer being liquified prior to entering the exposure zone.

11. Process as defined in claim **1** wherein after separating said image receiving web from said developer-laden web, the toner image on said image receiving web is fixed thereto.

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