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Ohno

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[54] **ELECTROSTATIC PRINTING METHOD AND APPARATUS**

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Feb. 12, 1971 Japan 46/5591

[52] **U.S. Cl.** ..... **355/10,** 117/37 LE, 355/16

[51] **Int. Cl.** **G03g 9/04**

[58] **Field of Search** ..... 355/10, 3, 16; 117/37 LE

[56] **References Cited**

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[57] **ABSTRACT**

Apparatus is disclosed for electrostatic printing, including a photosensitive plate, composed of a conductive substrate having fine pores distributed uniformly all over the surface thereof and a liquid-repellent photoconductive layer coating the surface of the substrate except the part of the pores. An electrostatic latent image is formed on the surface of the photosensitive plate, and a liquid developer is applied to the back side of the plate. The developer is prevented from exuding on that portion of the plate where said latent image does not exist due to the liquid-repellent property of the photoconductive layer. Conversely, the developer is received by those portions of the surface of the plate where the latent image exists due to decrease of contact angle in that part of the image. Finally, a paper is press-contacted onto the surface of the plate to transfer the image of exuded developer to the paper by the absorbing force of the paper.

8 Claims, 7 Drawing Figures

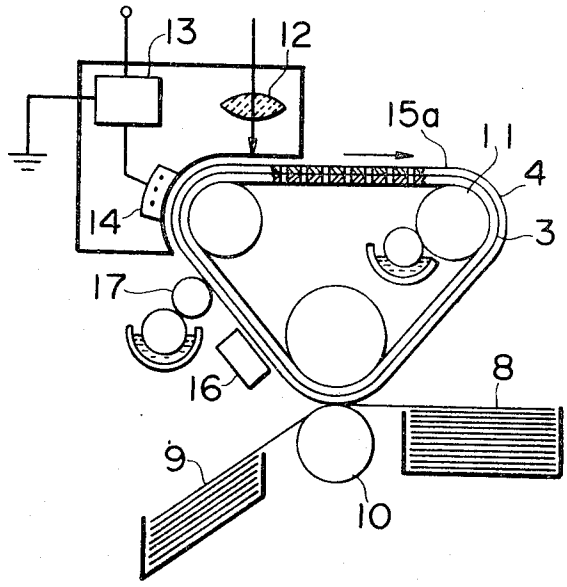


FIG. 1

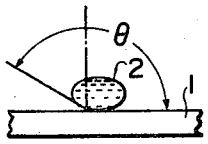


FIG. 2

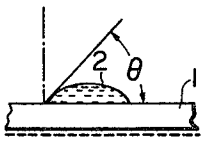


FIG. 3

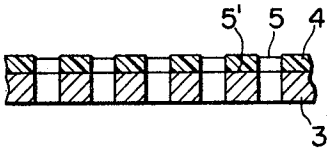


FIG. 4

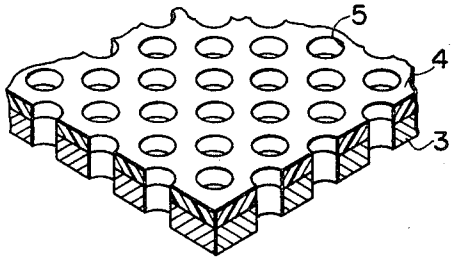


FIG. 5

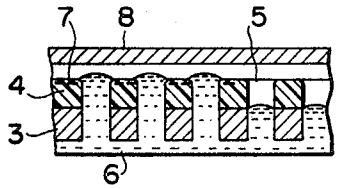


FIG. 6

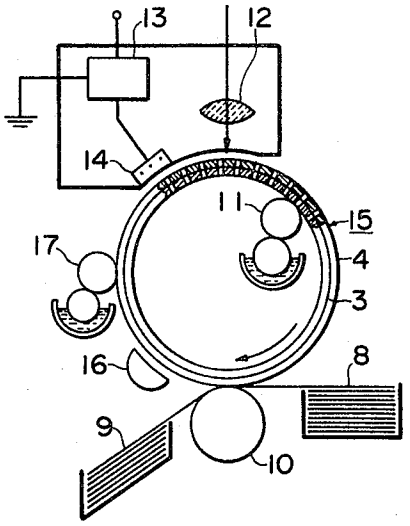
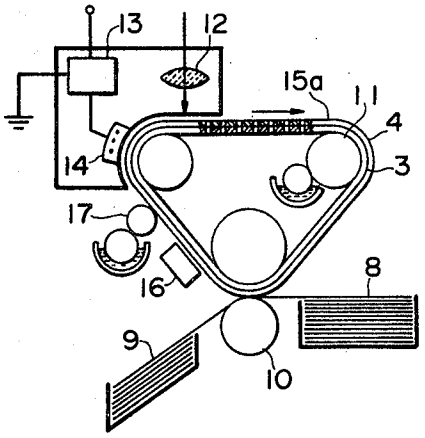


FIG. 7



ELECTROSTATIC PRINTING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and apparatus for electrostatic printing, and in particular to an electrostatic method liquid developer.

2. Description of the Prior Art

Developing techniques utilizing the xerography and space charges (such as the PIP) method are well known in electrostatic printing. In these methods, electrostatic latent images are formed on a photoconductive sensitive plate. In dry development, charged fine particles are used as a developer and are attracted to the latent images by electrostatic forces. In liquid development, charged toner particles used as a developer, are suspended in a liquid having a relatively high electric resistance and a low dielectric constant. The toner particles are also attracted to said latent image by electrostatic forces. The particles attracted to the image are then transferred to a paper to be printed.

This dry developing method has the defect that the required developing unit is a complex, expensive piece of machinery. Further, the developer particles are apt to be scattered, and the resulting printed image will lose its resolution. In wet methods, the surface of the photoconductive sensitive plates become wet due to the carrier liquid so that the plate cannot be continuously used. Applied voltages cause voltage breakdown to ignite fires upon transferring. Further, the carrier liquid has an objectionable odor and may be poisonous.

SUMMARY OF THE INVENTION

An object of this invention is to provide a simple electrostatic printing method and apparatus used therein, wherein the high image resolution is achieved without the possibility of fire or the use of a poisonous, odorous liquid.

This and other objects are achieved in accordance with the teachings of this invention by providing a photosensitive plate including a conductive substrate having fine pores distributed uniformly over the surface thereof and penetrating therethrough. A surface of the substrate is coated (except the pores) by a liquid-repellent photoconductive layer to provide a photosensitive plate. To reproduce an image, an electrostatic, latent image thereof is formed on the surface of the plate; a liquid developer is supplied from the back surface through the pores to the front surface of the plate. The liquid developer is prevented from exuding onto that portion of the front surface where the latent image does not exist due to the liquid-repellent property of the photoconductive layer. Conversely, the developer exudes due to capillary action onto that part of the plate where the latent images are present and the contact angle of the developer is decreased so that the latent images are developed.

Thus, in accordance with the teachings of this invention, the developer does not serve as a charge carrier as in the conventional liquid development processes. As a result, the liquid developer does not require a high resistance and low dielectric constant so that water and glycerol can be used as developer solution, which is neither poisonous, odorous nor highly volatile.

Another feature of this invention is that the paper to be printed is press-contacted to the developed liquid image on the surface of the sensitive plate. The transferring and printing of the image is carried out due to the absorption of the paper without the application of high voltages to establish electrostatic forces.

Therefore, the danger of fire due to discharge breakdown as occurs in conventional methods is considerably reduced. The resulting developing apparatus is simple because the voltage circuits and electrodes may be eliminated. The developer of this invention is a liquid solution of super-fine particles; hence, the resolution of the printed matter is high. Further, it is not necessary to stir the developer for charging it.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention will be more fully described in conjunction with the drawings, which include:

FIG. 1 shows the contact angle of a liquid drop on a liquid-repellent insulating film when the film is uncharged;

FIG. 2 shows the contact angle of a liquid drop on a charged, liquid-repellent film;

FIG. 3 shows a cross-sectional view of a photosensitive plate according to this invention;

FIG. 4 shows a perspective view of the plate shown in FIG. 3;

FIG. 5 shows a produced latent image in a cross-sectional view;

FIG. 6 shows an example of the electostatic printing apparatus according to this invention;

FIG. 7 shows another embodiment of the electrostatic printing apparatus in accordance with this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, when a liquid drop is placed on an uncharged surface of a liquid-repellent insulating film 1, the contact angle θ is more than 90° and the liquid drop does not wet the film surface. In contrast, as shown in FIG. 2, if the film is charged (indicated by a broken line), the contact angle θ is decreased to a value less than 90° and the liquid drop wets the film surface. This phenomenon depends on the liquid-repellent property of the film surface, the kind of liquid and the applied voltage. For instance, when a water drop is placed on a 3-fluoroethylen chloride resin film, the contact angle is 108° before it is charged and decreases to 56° to wet the film surface when it is charged by −500V.

In FIGS. 3 and 4, a conductive substrate 3 has a large number of fine pores 5 uniformly distributed over the surface. A part 5' of the substrate where no pores exist is coated by a liquid-repellent photoconductive layer 4. Thus, the photosensitive plate (or composite assembly) includes the substrate 3 and the photoconductive layer 4. The size of the fine pores 5 is determined by the resolution required in the printed matter. For example, the pore size may be 10 to 100μ, preferably 30 to 50μ in case of usual business. The space between pores is determined by the kinds of paper and ink used and is selected to permit the developer in one pore to spread and contact the developer in an adjacent pore upon transfer and printing; the space is preferably 10 to 100μ.

The thickness of the liquid-repellent photoconductive layer 4 is selected to be in the range of 3 to 400μ, preferably 3 to 100μ. If the thickness is less than 3μ,

contamination may be induced by non-uniformity of the pores and roughness of the paper. If the thickness is more than 400μ the effect of the latent charge upon the developer is reduced and development is not sufficiently carried out. If the size of pores is less than 10μ, they are often plugged up by impurities contained in the developer, and if the size is over 100μ, a uniform image is not obtained. If the space between pores is less than 10μ or more than 100μ, the accuracy of image is not good.

Such a finely porous substrate can be easily made by conventional methods of making a porous metal filter. A metal plate such as copper, having a 5 to 100μ thickness, may be photoetched so that pores are formed over the entire surface of the metal plate. Alternatively, a mesh can be used as a substrate of the photosensitive plate.

A coating solution taking the form of a mixture of photoconductive particles and a resin solution, is applied to the porous substrate 3 by an electrostatic painting method (the substrate 3 having been used as an electrode) to a predetermined thickness so that a photoconductive layer is formed on the surface of the substrate 3. Alternatively, a solution of the particles charged in a polarity opposite to that of the substrate are electrodeposited onto the substrate by spray coating. If an inorganic photosemiconductor such as amorphous selenium is used as photosensitive material, the layer can be easily formed by vacuum deposition under suitable voltages.

In order to obtain the liquid-repellent photoconductive layer, liquid-repellent resins such as polyethylene, polystylene, alkyd resin, silicone varnish or 3-fluoroethylene chloride resin are used as a binder in the coating solution. Next, the photoconductive material is mixed with the binder (see Example 1, for a binder-type photoconductive layer). Alternatively, a film of the above mentioned liquid-repellent resins may be formed on the photoconductive layer (see Example 2); this layer may be formed by vacuum deposition of an inorganic semiconductor. Thus, a liquid-repellent photoconductive photosensitive plate having fine pores over the surface is obtained. Other known photoconductive layers, if they are porous and liquid-repellent, may be used in this invention.

Developers used in this invention are liquid and include coloring agents, contact angle adjusting agents and viscosity adjusting agents. The liquid used in the developer of this invention has a contact angle not less than 90° with respect to uncharged surface of the photoconductive, photosensitive plate and less than 90° on the electrostatic latent image of the plate to thereby wet the surface. If the liquid-repellent material is made of polyethylene, polystylene, 4-fluoroethylene, 3-fluoroethylene chloride, silicone varnish or alkyd resin; water glycerol or ethylene glycol may be used as the developer solvent.

The coloring agent may be added to a solution, suspension or mixture of these aforementioned components. When water is used, hydrophilic dyes such as malachite green, methyl violet, victoria blue and persian orange are used. If a small amount of ethyl alcohol is contained as a contact angle adjusting agent, alcohol soluble dyes such as pigment green and carmine FB are used.

An organic or inorganic pigment such as carbon black and phthalocyanine may be dispersed into liquid by a suitable dispersing agent and is used as suspended coloring agent.

Contact angle adjusting agents are used for obtaining optimum contact angle in relation with the liquid-repellent property of the photoconductive photosensitive plate and the desired printing speed. Suitable contact agents are prepared by mixing two liquids having different surface tensions or utilizing a small amount of surface activator.

Viscosity adjusting agents are used for adjusting the fluidity of ink in relation with the printing speed. Liquid-soluble resins, for example, polyvinyl alcohol, dextrin, gelatin as methylol melamin, are used when the liquid is water. Viscosity adjusting agents also serve to fix the coloring agent to the paper when the developer has dried.

An electrostatic latent image 5 is formed as shown in FIG. 5 on the surface of the finely porous, liquid-repellent, photoconductive and photosensitive plate by a method properly selected for the photoconductive layer. The particular process of forming an electrostatic latent image includes:

1. forming directly thereon an electrostatic image,
2. irradiating a light image after uniformly charging the entire surface of the plate, and
3. charging the surface after forming a pattern by changing the conductivity and dielectric constant due to the light image irradiation.

After the formation of the electrostatic latent image 7 (indicated by the series of dashes), the developer is applied to the back surface of the photosensitive plate by a supply roller or the like. The developer will wet the inside of the fine pores 5 if the developer has a contact angle less than 90° with respect to the substrate 3, and a contact angle more than 90° with respect to the liquid-repellent layer 4. The developer will be forced by the capillary action of the wetted pores 5 to reach the surface of the liquid-repellent photoconductive layer. In those parts where the latent image does not exist, the contact angle is more than 90° because of the liquid-repellent property of the photoconductive layer so that the developer is prevented from advancing and does not exude onto the surface of the layer 4. In those parts where the latent image is present, the contact angle is decreased because of the electrostatic field induced on the liquid-repellent surface, and hence the developer wets the liquid-repellent surface and is directed by capillary action into the fine pores 5 to exude onto the surface of the layer 4.

Thus, the fine pores exposed to the electrostatic latent image are filled with the exuded liquid developer, the result is equivalent to the development of the latent image by using mesh points composed of fine pores.

Next, the paper to be printed is press-contacted to and then exfoliated from the surface of the developed photosensitive plate, and the exuded liquid developer is transferred to the paper by the absorbing force of the paper so that a print is obtained correspondingly to the original image.

After transfer, the residual charges are erased by either light irradiation or alternating corona discharge across the whole surface of the photosensitive plate and the liquid-repellent property of the plate is recovered. If necessary, the plate surface may be cleaned by a developer-soluble liquid and minute contaminations on the surface are removed to prepare for reuse.

Where an electrostatic latent image is composed of space charges on the photoconductive photosensitive plate, duplicate copies may be transferred and printed repeatedly only by adding a new supply of developer after each transfer.

In FIGS. 6 and 7, corresponding numbers are used to denote the similar parts in both Figures. The developing apparatus of FIG. 6 uses a photo-sensitive cylinder 15 and the apparatus shown in FIG. 7 uses a flexible belt 15*a* as the photosensitive plate. The photosensitive cylinder 15 and belt 15*a* are each composed of a finely porous conductive substrate 3 and a liquid-repellent photoconductive layer 4; the outside surface of the substrate 3 being covered by the layer 4 except that the fine pores are not covered. A latent-image-forming unit is composed of, for instance, a corona discharging unit 14 connected to an unidirectional high voltage source 13, and an image-projecting lens system 12. This unit forms an electrostatic latent mirror image of the original image (not shown) onto the cylinder 15 or belt 15*a*. The developing apparatus further includes a unit 10 including a rubber roller, for press-contacting a paper to the photosensitive layer 4, a unit 16 for erasing the latent image, and a unit 11 for supplying the developer from the back to the front surface of the photo sensitive layer, including a roller dipped into the developer and pressed against the back surface of the photosensitive layer.

The photosensitive plate is rotated in the direction of the arrow as shown, by a driving unit (not shown). The surface of the sensitive layer, on which a latent mirror image of the original picture is formed by the electrostatic latent image forming unit 12, is brought to the developer supplying unit 11 as the belt or cylinder rotates. The developer supplied to the back surface exudes onto that portion of the front surface of the photoconductive layer receiving the latent image and forms a fine mesh or point-like image of the developer corresponding to the latent image. This surface is further directed to the press-contacting unit 10 and is press-contacted to a paper 8 by the rubber roller, the paper being supplied by a paper-supplying unit or by hand.

The transferred image corresponding to the original image is formed by press-contacting the plate on the paper, and the printed paper is sent out to a receiver 9. The latent image of the photosensitive plate is erased by the latent image erasing unit 16 to restore the liquid-repellent property of the plate and to prepare these units for reuse. The erasure of the latent image is carried out by exposing the whole of layer 4 surface to light emitted from unit 16(if the latent image was formed by light exposure) or by corrona discharge.

When the liquid-repellent property of the surface of the photosensitive plate is recovered, the remaining developer sweeps down to the conductive substrate.

If any developer remains on the surface of the photoconductive layer 4, the developer can be easily removed by arranging a cleaning roller 17 containing a developer-soluble solution to be applied to the photosensitive layer 4.

The above-mentioned process may be repeated and a plurality of printed paper can be continuously produced. In order to more fully explain this invention, illustrative examples of the various agents and solutions will be given.

Example 1 — A photo-sensitive paint solution was prepared of the following components:

Zinc oxide ZnO 50 g
Silicone varnish (resin: 5 percent) 50 g
Rose bengal (1 percent methenol solution) 15 cc
Thinner 150 cc

Brass particles (grain size was 50μ) were press-sintered and 3 mm thick, finely porous conductive substrate was produced from sintered brass. The surface of the substrate was polished to serve as an electrode; an opposite electrode was placed 5 mm apart from the substrate and the photosensitive solution was electrostatically painted onto the surface of the substrate at 200V, to form thereby a repellent photoconductive layer having a thickness of 50μ after drying.

The resultant photo sensitive layer was charged uniformly over its entire surface by 6 KV corona discharge, and then a mirror image of the original image picture was projected to produce an electrostatic latent image. The liquid developer may be composed of the following components:

Methylene blue 3 g
Polyvinyl alcohol (4 percent solution) 50 cc
Water 50 cc

This developer was supplied from the back surface of the plate by continuous bubble sponge roller to be exuded onto the portion of the surface of the photosensitive plate having the latent image thereon to develop the latent image.

High quality paper (65g/mm^2) for printing was press-contacted thereon and exfoliated therefrom and a distinct blue print was obtained therefrom.

Then, the whole surface of the photo-sensitive plate was irradiated by light and the above mentioned processes were repeated so that a duplicate print could be obtained

Example 2 — In a second embodiment of this invention, a 100μ thick copper plate was photo-etched to provide fine pores of a 40μ diameter, at a density of 225 pores per 1 mm^2. The photosensitive paint solution may be composed of the following components:

Cadmium sulfide activated by copper 90 g
Alkyd resin 20 g
Xylene 50 cc
Toluene 20 cc

This solution may be electrostatically coated onto the above described conductive plate in the same manner as described in Example 1. The obtained photoconductive layer has 100μ thickness after drying.

The resultant plate was negatively charged by 7 KV corona discharge and a silicone varnish (resin 2 percent) was electro-deposited by a spray nozzle at 1 KV. Thus, a liquid-repellent insulating layer was obtained having a thickness of 8μ after drying.

The photosensitive surface of the obtained plate was positively charged by 6 KV corona discharge, and a mirror image of the original image was projected by 15 lux tungsten-filament lamp for 0.1 to 0.5 seconds under 6 KV alternating corona discharge. Further, the surface was exposed to a 10 W tungsten-filament lamp for 1 to 2 seconds to form an electrostatical latent image corresponding to the original image.

Next, a developer mixed from the following components was applied to the plate:

Carbon black 5 g
Victoria blue 0.1 g
Gelatin 2 g
Glycerol 5 g
Water 100 cc

More specifically, the developer was supplied to the back surface of the photosensitive plate by a sponge roll to exude the developer onto the portion of the surface having the latent image thereon. The developed image was transferred to a paper in the same manner as described in Example 1 so that a distinct blue-black print was obtained.

The developer may be again supplied to the photosensitive plate and a second transfer may be carried out in the same manner as the first to obtain a duplicate print. The photosensitive plate could be reused when the latent image was erased by an alternating corona discharge.

Example 3 — In a still further embodiment of this invention, a metallic mesh made of brass (250 mesh) was used as a finely porous conductive substrate. The photosensitive paint solution of Example 1 was applied to the substrate in the same manner as described in Example 1. The liquid-repellent photoconductive layer was formed to a thickness of 50μ after drying. The resultant layer was negatively charged by 7 KV corona discharge, and particles of silicone varnish were electrodeposited onto the plate by a nozzle under 1 KV. Thus, a liquid-repellent insulating layer was obtained, having a thickness of 25μ. The developer of Example 2 was applied and printing was carried out by the method of Example 1 to provide a distinct blue-black print.

Numerous changes may be made in the above described apparatus and the different embodiments of the invention may be made without departing from the spirit thereof; therefore, it is intended that all matter contained in the foregoing description and in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for electrostatically reproducing an original image onto an image bearing medium, said apparatus comprising:

a composite assembly including a conductive substrate having a first exposed surface and a photoconductive layer disposed upon said conductive substrate, said photoconductive layer having a liquid repellent second surface, said composite assembly having a plurality of openings disposed therethrough;

means for directing an image onto said second surface to form an electrostatic latent image corresponding to the original image thereon;

means for supplying a liquid developer to said first surface to direct the developer through said openings and onto those portions of said second surface having the electrostatic latent image formed thereon;

means for causing contact between the medium and said second surface to thereby reproduce a printed image corresponding to the original image on the medium; and

means for erasing the latent image from said second surface.

2. Apparatus as claimed in claim 1, wherein said composite assembly comprise a cylindrical member comprising said substrate and said photoconductive layer.

3. Apparatus as claimed in claim 1, wherein said composite assembly comprises a continuous, flexible belt comprising said substrate and said photoconductive layer.

4. Apparatus as claimed in claim 1, wherein said photoconductive layer comprises a liquid-repellent resin binder and a photoconductive material.

5. Apparatus as claimed in claim 1, wherein said photoconductive layer has a thickness in the range of 3 to 400μ.

6. Apparatus as claimed in claim 1, wherein said openings have a diameter in the range of 10 to 100μ.

7. Apparatus as claimed in claim 1, wherein said openings are spaced apart a distance in the range of 10 to 100μ.

8. A method of electrostatically reproducing an original image onto an image bearing medium utilizing an assembly comprised of a conductive substrate having a first exposed surface and a photoconductive layer having a liquid repellent, second surface, said assembly having a plurality of uniformly distributed openings disposed therethrough, said method comprising the following steps:

forming an electrostatic latent image on the second surface of the assembly;

supplying a coating solution to the first surface of the assembly to facilitate solution flow through the openings onto that portion of the second surface receiving the electrostatic latent image; and

contacting the medium onto the second surface of the assembly to transfer a portion of the coating solution to the medium to thereby form an image on the medium corresponding to the original image.

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