March 12, 1968 W. E. BIXBY 3,373,019

METHOD AND APPARATUS FOR PRODUCING IMAGES

Filed May 21, 1964

FIG. 1

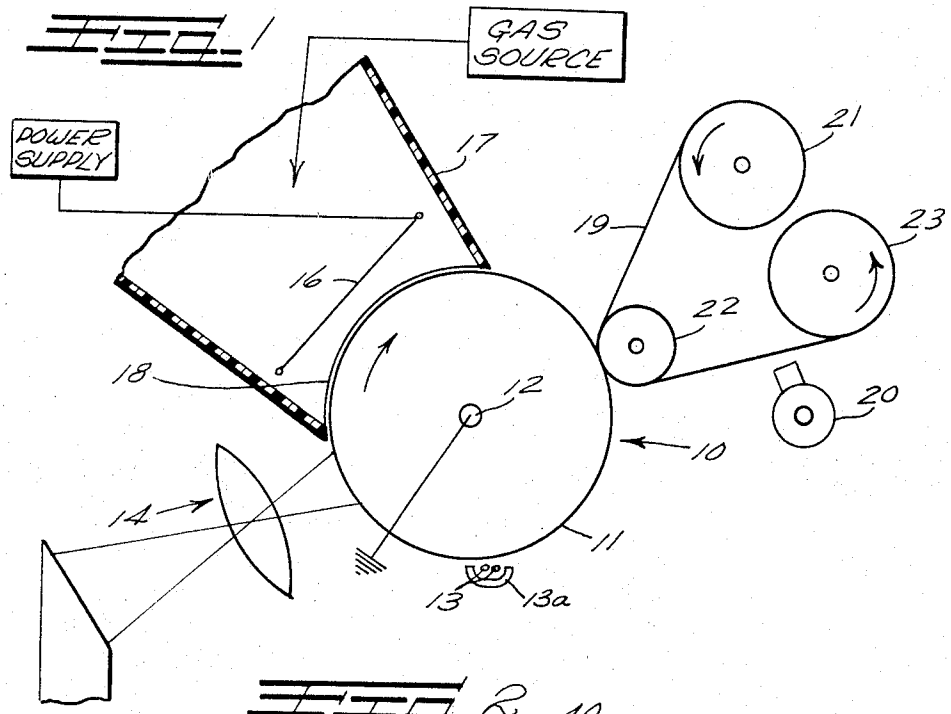
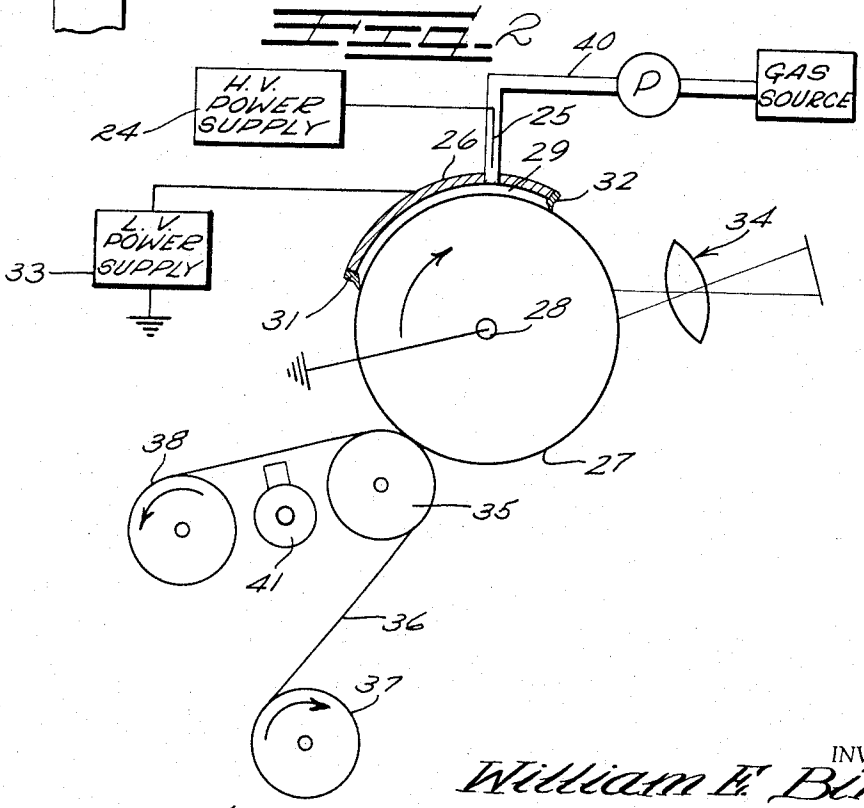


FIG. 2



INVENTOR.
William E. Bixby
BY
Kill, Sherman, Meroni, Gross & Simpson
ATTORNEYS

United States Patent Office 3,373,019
Patented Mar. 12, 1968

3,373,019

METHOD AND APPARATUS FOR PRODUCING IMAGES

William E. Bixby, Deerfield, Ill., assignor to Bell & Howell Company, Chicago, Ill., a corporation of Illinois

Filed May 21, 1964, Ser. No. 369,123
19 Claims. (Cl. 96—1)

ABSTRACT OF THE DISCLOSURE

A copying method and apparatus wherein an electrostatic charge pattern is formed in a photoconductive surface corresponding to an image, for example, through an optical system forming a greatly reduced microimage, and a gaseous material is ionized to form gas ions of polarity opposite that of the charge image. The resulting ions are then deposited on the surface to form a latent image at the charge pattern and a copy medium is then contacted against the thus treated photoconductive surface, the copy medium being provided with a surface capable of reacting with the image to form a permanent visible image on the copy medium. By having the gaseous material comprise an alkaline reacting material and by having the copy medium coated with a diazonium compound, microimages of particularly high resolution may be formed on the copy medium.

The present invention relates to a method and apparatus for producing images with high resolution and in accordance with techniques and apparatus which lend themselves to high speed continuous operation as well as with a cyclic or planetary recording machine.

The system of the present invention is applicable to various types of image reproducing systems, and is particularly useful in the field of micro-images. Among the advantages which stem from the system are the absence of powders, carriers, and their associated hardware, lack of necessity to replenish toner-carrier mixtures, eliminating the need for cleaning residual toners from reusable photo-conductors, and eliminating the resultant wear caused by cleaning photoconductors.

In the production of micro-images by known processes, for example using the principles of electrostatography, the size of the developer particles becomes a limiting factor in achieving satisfactory resolution capability at reduction ratios in excess of 10 or 12 to 1. At a reduction of 20 times, for example, it is necessary that the developer particles be smaller than about 5 microns in diameter. Larger reductions require still smaller particles. As the particle size decreases, the production, feeding, and control of the particles becomes more and more difficult. It therefore becomes necessary to provide other methods by which micro-images can be produced with consistent resolution capability of at least 100 line pairs/mm. on the finished micro-image when utilizing the N.B.S. 1010 Microcopy Resolution Test Chart as the original target. The provision of methods and apparatus to accomplish this objective constitutes the principal object of the present invention.

Another object of the invention is to provide a powderless system for developing micro-images in a continuous manner, thus obviating the need to clean residual powder from a reusable photoconductor.

A further object of the invention is to provide a process for micro-imagery which employs an ionized gas as a molecular developer medium.

A still further object of the invention is to provide an apparatus for producing micro-images of high resolution by a combination of electrostatic, photoconductive and diazo techniques.

Basically, the method of the present invention involves producing high resolution images by charging and exposing a photoconductive surface to produce a latent electrostatic image and then effecting a print-out by ionizing a gas, which may be an alkaline material, to produce ions capable of being directed against or onto the photoconductive surface to deposit a molecular layer on the surface having a capability of developing or transferring a permanent utilitarian image of high resolution on a suitable film or record medium conditioned to react with or receive the molecular image layer. In one embodiment of the invention a photoconductive surface is charged with an ion source such as a corona discharge device, the charged surface is exposed to a light image through an optical system to effect a reduction to a micro-image, a gaseous ionized alkaline material whose ions are capable of developing a color producing compound is deposited as a molecular layer on the image area, and the surface is then brought into contact with a copy medium which has a suitable compound thereon to form a micro-image of high resolution on the copy medium. A particularly preferred reaction system involves the use of diazo compounds as the color producing materials.

The techniques of diazo printing have been the subject of extensive investigation and development for many years. Basically, the diazo method involves the use of diazonium compounds which decompose upon exposure to light, releasing two nitrogen atoms. The undecomposed diazo compound remaining in the areas not exposed to light can then be coupled with a coupling reagent in the presence of an alkali, while the compounds remaining after light decomposition are incapable of combining with couplers to form an azo dye. In a typical system, both a light-sensitive diazo compound and a coupling agent are coated onto a support and dried, together with various stabilizing substances designed to prevent thermal decomposition of the diazo material as well as premature coupling between the diazonium salt and the coupler. The sensitized sheet is placed under the material to be reproduced and exposed to light of the wavelength and intensity required to destroy or decompose the diazonium compound at the points to which the light penetrates. Development is usually brought about by treating the paper with ammonia vapor to neutralize the stabilizing acid and raise the pH to the value at which coupling takes place.

While there are literally hundreds of diazonium compounds which can be and have been used for the diazo printing process, the following will serve to provide a representative list: diazonaphthalsulfonic acids, ortho and para amino diazo compounds such as p-dimethyl- aminobenzene diazonium chlorides; diazo compounds of aromatic diamines; p-tertiary-amino-anilines; amino-diphenylmethanes; amino-acylamines; and amino-phenyl ethers. Typical coupling agents include phenols, naphthols, amines, phenol ethers, naphthol ethers, acetoacetanilides and nitroparaffins.

The preferred alkaline reacting materials which are ionized to provide the necessary alkalinity for the diazo coupling reaction are gaseous ammonia, and ammonium compounds such as ammonium bicarbonate, acetate, and formate. Less reactive compounds which might also be employed are materials such as urea, methyl urea, ethyl urea, and naphthylamine.

While the reaction conditions will vary substantially depending upon the particular reactants, and the conditions of reaction, it is contemplated by the present invention to provide an ionizing potential gradient in the order of 1,000 to 50,000 volts per inch. Such gradient functions as an ionizing field to supply ionized gas which is directed toward the photoconductive surface. If desired, the ionizing source can be located adjacent or near the photoconductive surface.

Under the conditions noted, some of the alkaline materials may decompose into simpler compounds, but these compounds, in turn, can be ionized under the conditions existing to provide ions which not only act as developers at an extremely small, practically molecular size, but will be capable of being deposited on an image in the form of a molecular layer. The gas ions of polarity opposite to that on the image are attracted to the image areas. As long as the gas molecules remain in that position on the charged plate, they can be detected by bringing a sheet of diazo material near the plate so that it color couples only in the areas of the ionized gas which represent the image area.

The photoconductive material on which the image is actually formed can be any of the organic or inorganic photoconductive materials displaying photoconductive characteristics. In a typical process, a base plate of relatively low electrical resistance or a sheet of paper or other supporting media is provided with a photoconductive insulating surface which is electrostatically charged in the dark. The charged coating is exposed to a light image, and the charges leak off rapidly to the base plate into a suitable ground in proportion to the intensity of light to which any given area is exposed. Photoconductive materials such as anthracene, sulfur, or sulfur-selenium mixtures are satisfactory, and a particularly good photoconductor is highly purified vitreous selenium. It is also possible to use photoconductive members made by mixing and grinding together a photoconductive insulating material in a high electrical resistance binder. The photoconductive insulating layer may comprise a solution in a suitable solvent which is flowed onto the base material or otherwise coated thereon. The composition may also be rendered flowable by using a thermoplastic resin as the insulating binder and heated to render the composition deformable. Another variation consists in making a solvent solution of the coating composition which is then emulsified or dispersed in water and the emulsion or dispersion is coated on the base material. Typical photoconductive materials usable in such manner are cadmium-zinc sulfide phosphors, antimony sulfide, zinc oxide, zinc silicate, zinc-cadmium sulfide, zinc-magnesium oxide, calcium-strontium sulfide, and the like.

A further description of the present invention will be made in conjunction with the attached sheet of drawings which illustrates several embodiments of typical apparatus employed in connection with the practice of the novel methods contemplated.

In the drawings:

FIGURE 1 is a somewhat schematic view of a continuous recording system utilizing a gas ionizing arrangement for the purposes of the present invention; and

FIGURE 2 is a somewhat schematic representation of another system utilizing an alternative embodiment which can be employed for the purposes of the present invention.

As shown in the drawings:

The principles of the present invention are of general applicability to any form of copy media such as sheets, roll film or film strips. In its broader aspects the invention contemplates the use of a photoconductor capable of retaining a charge pattern in the form of a latent image, ionizing a gaseous activator to deposit a molecular layer on the image charge pattern, and then engaging the molecular layer against a compatible image carrier to form an image of high resolution. Since the invention is of particular utility in high speed continuous microimagery production, an arrangement for effecting such a continuous process is illustrated by way of example.

In FIGURE 1, reference numeral **10** indicates generally a photoconductor taking the form of a drum composed of a material having a relatively low electrical resistance, usually metal. The drum **10** is provided with a surface coating **11** of a photoconductive material which may be one of the organic and inorganic photoconductors previously referred to and characterized by having electrons in the non-conductive energy level activatable by illumination to a different energy level, whereby an electric charge is free to migrate under an applied electric field in the order of at least 10^3 volts per cm., the composite resistivity of the photoconductor being at least 10^{10} ohms-cm. in the absence of illumination and having a decay factor of less than 3.0. The drum **10** is mounted for rotation on a grounded shaft **12**. In order to apply a uniform charge to the photoconductive surface, an ion producing source such as a corona charging unit is provided. For example, a pair of corona charging wires **13** are connected to a source of high electrical potential and are enclosed in a shield **13***a* causing some ionization of the air constituents, and resulting in an electrostatic charge appearing at the photoconductive layer **11**.

A light image is then projected towards a focal plane coincident with the photoconductive surface by means of an optical track containing a lens system exemplified by a lens **14** in FIGURE 1. The charges existing on the coating **11** leak off rapidly to the base material of the drum or to an appropriate grounding circuit in proportion to the intensity of light to which any given area is exposed. Thus, a charge pattern exists on the surface of the drum **11** which is in the shape of the image.

The drum **11**, with the latent electrostatic image area carried thereon, then rotatably moves to a position in which an alkaline material capable of developing a color producing diazo compound is ionized and directed toward the image area. The gaseous material may be directed at the surface of the drum **10** in the form of a stream confined within a conduit **17** made of electrically non-conductive material and having a mouth **18** spaced adjacent the surface of the drum **10**. An ion source **16** such as a corona discharge unit is positioned to extend across the conduit **17**, thereby intercepting the stream of gas. The potential on the ion source **16** will produce ionization of the alkaline material, resulting in the production of gas ions which are attracted to the oppositely charged portions of the electrostatic charge pattern on the drum surface. The resulting ions are, of course, extremely small, and since the image produced on the surface of the drum is a micro-image, the inherently small size of the ions makes it possible to produce a pattern of ions on the previously charged plate in an exact reproduction of the micro-image which has been applied to the drum with an improved resolution capability.

After treatment with the ionized gas, the movement of the drum **10** carries the exposed and treated surface to a station where the surface is engaged against a copy medium. In the exemplary system illustrated, a web of paper **19** or the like coated with a diazo reaction system is supplied from supply reel **21** about a roller **22** in closely spaced relation to the periphery of the drum **10**. The copy medium consisting of a film **19** or any other suitable image carrier will typically contain a diazonium compound and a coupling agent, together with inhibitors or the like which prevent premature reaction between the diazonium compound and the coupler, but will permit such reaction to take place under alkaline conditions. The presence of the ionized alkaline material provides such alkaline conditions, and the distribution of the ions on the charged image area of the drum can be detected and reproduced by effecting contact between the copy medium **19** and the surface of the drum **11**. Because of the high resolution capability of the finished micro-image on the copy medium, it is possible to obtain an image exhibiting a resolution in excess of 100 line pairs per mm. A heater **20** directs heated air at the reacted copy medium to eliminate excess alkaline material. A take-up reel **23** then winds up the developed print, making the entire system continuous in operation.

Another embodiment of the ionized gas concept of the present invention is illustrated in FIGURE 2 of the drawings. There is provided an electrode **26** conforming in con-

tour to the periphery of a drum **27**, the latter being mounted for rotation on a grounded shaft **28**. An annular space **29** is left between the inner periphery of the electrode **26** and the outer periphery of the drum **27**. A supply of alkaline reacting gas from a source so indicated is pressurized by a pump P and is driven in the form of a stream through conduit **40**. A corona discharge unit **25** is conduit **40** and maintained at a potential of 5,000 to 20,000 volts by high voltage power supply **24**, ionizes the stream of gas passing through conduit **40** producing a supply of ionized gas in annular space **29**. A low voltage direct current power supply **33** connected to electrode **26** has a potential and polarity such that the ionized gas is driven to the surface of the photoconductor. With a selenium photoconductor, the electrode may be held at a positive potential of 600 volts to uniformly charge the selenium surface to a positive potential. A partial seal is provided for the space **29** by the provision of a pair of resilient, non-conductive sealing lips **31** and **32** on opposed sides of the electrode **26**.

The thus charged photoconductive surface is then exposed to a light image by means of an optical system generally indicated at numeral **34** in FIGURE 2. The light image then forms a selective electrostatic charge pattern on the previously uniformly charged area, thereby causing the release of some of the ionized gas molecules in the form of free gas molecules. The retained ions on the unexposed areas provide the necessary alkaline environment for the development of an image on a suitable copy medium such as film or paper or any other carrier. As previously described, development takes place by continuously passing a copy medium **36** of a diazo treated web or film such as an "Ozalid" paper into contact with the portion of the drum periphery at which the latent electrostatic image appears. The web **36** is taken off a supply reel **37** and is pressed against the drum **27** by a roller **35**. A heater **41** serves to volatilize off excess alkaline material before the web is wound up on a take-up reel **38**.

A conventional plate consisting of a metal drum coated with a vitreous selenum photoconductive coating can be charged in the dark by means of a conventional corona charging unit. A micro-image of an original reduced 10× to 40× can then be applied to the charged surface through optical projection techniques. Ammonia gas is then ionized by passing it through a series of charging wires maintained at a potential on the order of about 10,000 volts with respect to the periphery of the drum. The charged ammonia ions are attracted to the still charged image areas which are then contacted with a film or "Ozalid" type paper containing a diazonium compound and a coupler, the trapped ions serving to provide an alkaline medium for initiating the diazo reaction and providing a color reaction upon contact, thereby producing a finished micro-image exhibiting a resolution of at least about 100 line pairs per mm.

I wish to embody within the scope of the patent warranted hereon all such modifications as reasonably and properly come within the scope of my contribution to the art.

I claim as my invention:

1. The copying method which includes the steps of,

(a) forming an electrostatic charge pattern in a photoconductive surface corresponding to an image,

(b) ionizing a gaseous material to form gas ions of polarity opposite that of the charge pattern,

(c) depositing the resulting ions on the surface to form a latent image at the charge pattern, and

(d) contacting the thus treated surface with a copy medium having a surface capable of reacting with said image to form a permanent visible image on said copy medium.

2. The method of claim **1** wherein said charge pattern is formed by projecting the image through an optical system having a reduction of at least 12×, thereby to form a micro-image.

3. The method of claim **1** and wherein said gaseous material comprises an alkaline reacting material.

4. The method of claim **1** wherein said copy medium is coated with a diazonium compound.

5. The process of recording a micro-image which includes the steps of,

(a) placing sensitizing electrostatic charges of one polarity on the surface of a member comprising a backing and an insulating layer of photoconductive material,

(b) projecting an image through a lens of an optical system to reduce the image,

(c) exposing the charged photoconductive surface to the reduced image, whereby a charge pattern is formed in said photoconductive surface,

(d) ionizing a gaseous material to form ions of a polarity opposite to said charges,

(e) depositing the ions thus produced on the surface to form a latent image corresponding to the charge pattern, and

(f) contacting the thus treated surface with a copy medium having a surface capable of reacting with said image to form a permanent micro-image on said copy medium having a resolution of at least 100 line pairs per mm.

6. The method of claim **5** wherein said copy medium consists of a transparent film.

7. The method of claim **5** wherein said gaseous material comprises an alkaline reacting material capable of being ionized to provide the necessary alkalinity for a diazo-coupling reaction and wherein said copy medium is coated with a diazonium compound.

8. The method of claim **5** wherein said photoconductive material is selected from the group consisting of organic and inorganic photoconductors.

9. The method of claim **5** and further characterized by reducing the image in step (b) at least 12 times to form a micro-image charge pattern.

10. In a method of producing high resolution micro-images from a photoconductive surface by diazo printing from said surface, the steps of ionizing an alkaline material to produce ions capable of developing a color producing diazo compound and directing the ions at said photoconductive surface.

11. The method of producing images from a photoconductive surface which includes the steps of

electrostatically charging a photoconductive surface,

exposing the charged surface to an image to form a charge pattern corresponding to the image,

directing a gaseous ionized alkaline material whose ions are capable of developing a color producing diazo compound at the surface to form a latent image at the charge pattern, and

bringing the thus treated surface into contact with a copy medium having a diazo compound thereon to form a visible image on the copy medium.

12. The method of claim **11** in which said alkaline material is ammonia.

13. The method of claim **10** in which said alkaline material is an ammonium compound.

14. The method of producing high resolution micro-images which includes the steps of charging a photoconductive surface with a gas containing ions capable of developing a color producing diazo compound, exposing the surface with the ions thereon to a light micro-image, and thereafter bringing the exposed surface into contact with a copy medium having such diazo compound thereon.

15. The method of claim **14** in which said gas is ammonia.

16. The method of claim **14** in which said gas is a vaporized ammonium compound.

17. An apparatus for producing a micro-image comprising,

a rotatable drum having

a photoconductive coating thereon,

corona means spaced from said drum for charging said coating electrostatically,

an optical system arranged to project a reduced light image towards a focal plane coincident with the charged surface of said drum,

means for ionizing a gaseous alkaline reacting ionizable compound, means for driving the ionized gaseous compound in the form of a stream,

an ionizing charging means through which said stream is directed, means for directing and confining the charged stream adjacent the drum so that the resulting ions are attracted to the image bearing surface of said drum, and

means for contacting a copy medium having a diazo compound thereon against the thus treated surface of said drum to thereby develop the image from said image bearing surface.

18. Micro imagery apparatus comprising,

a member comprising a backing and an insulating layer of photoconductive material,

an optical system including a lens to form a reduced image,

means to support said member and said optical system with said layer positioned at the focal plane of said lens, thereby to expose the layer to a micro-image,

means for pre-charging said layer with sensitizing electrostatic charges of one polarity,

means for ionizing gas molecules with electrostatic charges of an opposite polarity,

means for depositing said ionized gas molecules of an opposite polarity on said layer to form a latent molecular image on said layer, and

means for contacting a reactive copy medium against said molecular image to form a permanent image on the copy medium.

19. In an apparatus for producing a micro-image,

a support member having

a photoconductive surface formed thereon adapted to carry an electrostatic charge pattern corresponding to a light image,

means ionizing a gaseous material capable of inducing a diazo color reaction with a diazo compound to form electrostatically pre-charged gas ions of molecular size,

means for depositing said ionized gaseous material on said photoconductive surface in a form corresponding to the electrostatic charge pattern,

and means for contacting the thus treated photoconductive surface with a sheet-form copy medium coated with a diazonium compound,

thereby to form a high resolution micro-image on the copy medium.

References Cited

UNITED STATES PATENTS

2,690,394	9/1954	Carlson	95—1.7
2,692,948	10/1954	Lion	250—65
2,752,833	7/1956	Jacob	95—1.7
2,756,676	7/1956	Steinhilper	96—1 X
3,005,726	10/1961	Olson	96—1 X
3,083,117	3/1963	Schmiedel et al.	96—1.4
3,138,438	6/1964	Kimble et al.	96—1.8
3,178,281	4/1965	Jarvis	96—1.2
3,253,913	5/1966	Smith et al.	96—1.2
3,283,680	11/1966	Switzer et al.	96—1.7

J. TRAVIS BROWN, *Acting Primary Examiner.*

NORMAN G. TORCHIN, *Examiner.*

C. E. VAN HORN, *Assistant Examiner.*