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EQUIPOTENTIAL XEROGRAPHIC MEMBER AND
PROCESS OF PRINTING THEREWITH
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3,145,655

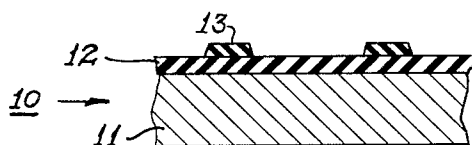


Fig. 1

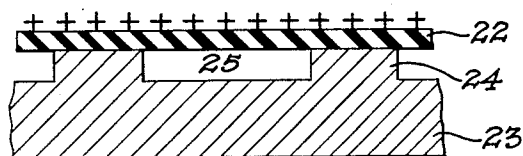


Fig. 2

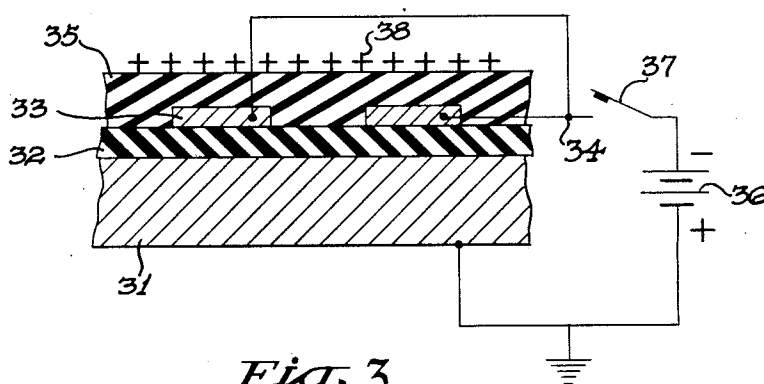


Fig. 3

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EQUIPOTENTIAL XEROGRAPHIC MEMBER AND PROCESS OF PRINTING THEREWITH

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This invention relates to xerography and to a method and means therefor.

Xerography was discovered by Chester F. Carlson in the late 1930's. Essentially, the process involves the utilization of an electrostatic image created in response to light. In the process as described in U.S. 2,297,691, to C. F. Carlson, a layer of photoconductive insulating material is uniformly charged in the dark and a light pattern projected thereon to selectively dissipate the electrostatic charge. The result is to create on the photoconductive insulating layer a pattern of electrostatic charge corresponding to the areas of shadow of the light image projected hereon. This electrostatic charge pattern is then developed, i.e., made visible, by contacting the surface with finely-divided electrostatically charged marking particles. The visible powder image may then be affixed to the photoconductive insulating surface, transferred to a suitable image support member such as paper or otherwise utilized as is well known to those skilled in the xerographic art.

As can be seen, the xerographic process is essentially a photographic process requiring light for the formation of the electrostatic charge pattern. Various ingenious means have been devised to provide multiple copies without subsequent exposure of the xerographic plate. Such processes include dividing up the powder image in a succession of transfer steps to the paper support (U.S. 2,812,709) or multiple developments and transfers of the pre-existing charge pattern combined with various process steps necessary to preserve the electrostatic image. These processes all have various inherent limitations. Thus, to divide up a single electrostatically adhering powder image by the multiple transfer method results in at most about fourteen copies and often less. More important, the multiple copies are obtained at the loss of image density of the original.

The various processes based on multiple development and transfer of the electrostatic image require, first, of course, operation in the dark; second, controlling the electrostatic field at the transfer step so as to prevent charge transfer as well as powder transfer to the image support member; and, third, while the photoconductive insulating material is an excellent insulator, it does lose charge even in the dark (a property termed "dark decay") and as the charge cannot be renewed without destroying the electrostatic image, the dark decay limits the period of utilization of the electrostatic image. Thus, while a number of copies or reproductions of a single original may be produced in this manner, it is evident that the photographic basis of xerography limits the total number so that the result is in no sense a printing or mass reproduction process.

Accordingly, Mr. Carlson in U.S. 2,357,809 disclosed for the first time apparatus and a process whereby the principles of electrostatic image development and transfer were utilized in a true mass production printing process. A more advanced application of this invention (termed "xerography") is described by Dr. Schaffert in his patent U.S. 2,576,047. Two alternative means for xerography were disclosed. In the first, the powder image on the xerographic plate was permanently fused or fixed to the photoconductive insulating surface there-

by creating on the surface of the xerographic plate an electrically insulating, light-insensitive image pattern. On uniformly charging such a plate and then flooding it with light, the electrostatic charge would be retained only on the light-insensitive image areas, the photoconductive background being discharged by the light. Such a plate could be cycled in a rotary apparatus using only the xerographic steps of charging, uniform exposure to light, contact with electrostatically charged marking particles and transfer of the developed image. While such a process had the potentiality of a true printing or mass production type of operation, in practice this potentiality has not been realized. Thus, photoconductive insulating materials, while possessing vastly superior physical properties to photographic emulsions, are far short of the requirements for physical performance imposed in a printing operation. In particular, wear and abrasion of the photoconductive insulating layer limit the life of this type of xerographic plate.

Even more important, photoconductive insulating materials inherently contain essentially no free charge carriers. Rather, charge carriers are injected into the layer by the absorption of light which generates a hole-electron pair. In any single charge-discharge cycle, some of the charge carriers are trapped in the bulk of the photoconductor building up a residual charge in the layer. This charge is termed "residual potential." For many photoconductors this charge is significant—several hundred volts for even a single cycle of operation. Repetitive cycling, as is inherent in a printing operation, results in even greater build-up of residual charge. As a result, after the xerographic plate has been charged, the subsequent irradiation of the plate with light fails to discharge the previously "light-sensitive" background material. As a result, the electrostatic contrast between the light-insensitive image areas and the so-called light-sensitive image areas becomes less and less—in extreme cases vanishing altogether.

Accordingly, Carlson and Schaffert disclosed another type of xerographic plate to obviate these difficulties. The plate consisted of a light-insensitive electrostatically insulating character on an electrically conductive backing. One method of forming such a xerographic plate was to form a xerographic plate as described above, that is, fuse a powder image onto the photoconductive insulating layer of a xerographic plate but then, rather than utilizing this as the xerographic plate, subject the structure to a further treatment as by chemical etching or heating to selectively remove the photoconductive insulating material leaving only a light-insensitive image thereon. In the case of anthracene as the photoconductive insulating material, it was found that the material sublimed from the xerographic plate at a temperature substantially below the decomposition temperature of standard fused xerographic image materials.

An alternative method of forming a xerographic plate was to transfer an image from a xerographic plate to a metal backing or alternatively to utilize a silk screen or other means to form an electrically insulating image directly on a metal backing. The resulting image is then permanently affixed or bonded to the metal substrate as by heat or contact with solvent vapor. The main difficulty with such a xerographic plate is in the charging operation. When charge is applied to a surface consisting of alternate areas of insulating material and electrically conductive material, the charge tends to flow mainly to the electrically conductive areas as representing the easiest path to ground. In effect, such areas constitute a short circuit for the charging current. In a high production, continuous xerographic process, the time available for charging is extremely short, at most a few seconds, and in high speed processes, even less. The

amount of charge applied to the image areas under these conditions is of inadequate density to provide a dense powder image when contacted with the supply of marking particles, and further, is apt to be variable depending upon the relative density of the image areas as compared to the non-image or electrically conductive areas of the plate.

Accordingly, it is an object of the instant invention to provide a process and means for making multiple copies by the transfer of an electrically controlled developer powder from an insulating non-conductive image at high speeds in practicable and efficient fashion.

Another object of the invention is to afford a process whereby xeroprinting may be carried out on a novel xeroprinting plate of rigid or flexible construction which may be easily and uniformly charged.

It is still another object of the instant invention to provide a xeroprinting process which can reproduce both heavy and thin letters with excellent image density.

In addition, it is an object of the instant invention to provide a xeroprinting master which permits the charging operation to be carried out with lower energy carriers and can be easily controlled despite varying ambient conditions. These and other objects will appear clearly in the following specification when read in connection with the drawings, the novel features being pointed out in the claims at the end of the specification.

In the drawings:

FIG. 1 is a cross-section of a xeroprinting plate illustrative of the instant invention;

FIG. 2 is a cross-section of a portion of a xeroprinting plate according to another embodiment of the invention; and

FIG. 3 is a cross-section of a xeroprinting plate according to another embodiment of the instant invention along with semi-diagrammatic representation of apparatus used therewith.

In a xeroprinting master the electric charge density varies from point-to-point in a pattern corresponding to graphic information which can be rendered visible by development. To improve the efficiency of the charging step, and particularly, to assure good resolution, image density and uniformity it has been found that it is essential to charge the xeroprinting master to a uniform potential during the charging or sensitizing step. The only means previously known to accomplish this was by the use of a light-sensitive member for the master, i.e., the use of a xerographic plate for the xeroprinting master. Means have now been found to accomplish this objective without the use of a light-sensitive photoconductive member. The novel xeroprinting master thus eliminates the need for alternate periods of darkness and illumination and control of charge build up in the photoconductor required in cycling the photoconductive master. Equally important is the freedom to select materials for the xeroprinting master based on optimum "printing" rather than "photo" (or xerographic) properties. Other advantages of the instant xeroprinting masters include ease of cleaning, higher operating fields, ease of fabricating large sizes or special shapes and overall increased mechanical flexibility.

Unless otherwise specified, the xeroprinting masters in each of the examples below were charged using corona charging as described in U.S. 2,588,699 (apparatus particularly useful therefor are described in U.S. 2,777,957 and 2,879,395); developed using cascade carrier development as described in U.S. 2,618,551, U.S. 2,618,552, and U.S. 2,638,416; and transferred to a paper web using electrostatic transfer as described in U.S. 2,576,047. The overall xeroprinting process and apparatus suitable therefor are described in the aforesaid U.S. 2,576,047 to Schaffert. Liquid development, as described for example in S.N. 531,280, filed August 29, 1955 by Eugene C. Ricker, is particularly useful in xeroprinting due to ease of fixing and the variety of colors available.

The process of the instant invention utilizes a xeroprinting master which is initially charged to a uniform potential without the necessity for using a light-sensitive substrate therefor. A preferred embodiment of this type of master is illustrated in FIG. 1. The master, as illustrated in FIG. 1 is termed a "time decay" xeroprinting master. It comprises a layer of electrically conductive material 11 having coated thereon a layer 12 of poorly insulating, light-insensitive material to be described in detail hereafter. On top of layer 12 is formed a xeroprinting image 13 of electrically insulating light-insensitive material as is common in the xeroprinting art.

Layer 12 is so selected as to have a resistivity sufficiently high to accept an electrostatic charge thereby permitting the electrostatic charging of the surface of the xeroprinting master to a uniform potential. However, the resistivity is sufficiently low so that by the time the xeroprinting master has moved from the charging station to the development station substantially all of the electrostatic charge has been lost, i.e., discharged to the conductive backing 11. Suitable resistivities for layer 12 lie in the range of 5×10^{10} to 10^{13} ohms-cm. Such materials will lose over two-thirds of the applied voltage in a period ranging from about two seconds for the upper limit of resistivity to less than one-tenth of a second for a material having the lower limit of resistivity. In very high speed processes a resistivity of 10^{10} ohms-cm. decaying in two milliseconds may be used. The time rate of decay of voltage is also dependent on the dielectric constant of the material and may be either higher or lower than the figures given dependent on this factor. The material for image 13 is highly insulating. Thus, layer 12 has a resistivity selected so as to discharge before the development step while layer 13 has a resistivity selected so as to retain an electrostatic charge at least through the development step. As the time available for the various xeroprinting steps may vary, similarly the relative resistivities of layer 12 and 13 may vary as described.

In operation a uniform charge is applied to the surface as by corona discharge, for example, which brings the surface to a uniform electrostatic potential. The charge on the high resistivity portion of the surface, that is, layer 13, is static, while the charge on the moderately high resistivity portion of the surface, that is, layer 12, leaks to the substrate 11. The resulting electrostatic image on layer 13 is developed and then transferred to another surface as is commonly known in both xerography and xeroprinting.

One type of xeroprinting plate made in this manner was formed by coating an aluminum plate with a film of alkyl resin (obtained from E. I. duPont de Nemours & Co. under the trade name Duco Black Gloss Enamel). After drying the enamel layer, it was then coated with a layer of Kodak Photoresist. The plate was then exposed using ultraviolet light to form a line-copy image thereon, the unexposed photoresist being removed by washing with the developer recommended by the manufacturer. The plate was thoroughly dried and then used in the xeroprinting process.

A xeroprinting master was prepared by coating a contact printing paper (obtained from Haloid Xerox Inc., Rochester, New York, under the tradename "Haloid F2 Contact Print Paper") with Kodak Photoresist and drying the coated paper. The paper was then exposed to an ultraviolet light image which not only hardened the photoresist but also formed a corresponding, visible, sepia print in the print out paper. The master was then processed to remove the unexposed photoresist with the developer recommended by the manufacturer. The master was thoroughly dried, mounted on a sheet of aluminum with adhesive and utilized in the xeroprinting process.

Both xeroprinting plates produced heavy black letters giving excellent quality images of high resolution (over 250 lines per inch). Unexpectedly, it has been found possible to print continuous tone and half-tone images

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on these masters. In addition to Kodak Photoresist, xerographic toners as from polystyrene or rosin-modified phenol-formaldehyde without conductive pigments such as carbon black have been successfully used for insulating image areas 13; while materials successfully used for layer 12 include Warren's Lusto Gloss and Chrome Coat paper, epoxy resin (obtained from the Bakelite Co. under the trade name ERL 2774 with hardener ZZL0803), rubber adhesives (obtained from the B. F. Goodrich Co. under the trade names 604 and A598B), and bleached shellac. The thickness of layer 12 is not critical. In the examples given, the thickness ranged from about 0.001 to about 0.005 inches.

Another type of xeroprinting master capable of accepting uniform electrostatic charge is illustrated in FIG. 2. Such a master is termed a "variable capacitance" master. It comprises a thin insulating film 22 in contact with a raised conductive pattern 23 containing image areas 24 and non-image areas 25. Such a master was constructed by placing a layer of polyethylene terephthalate 0.5 mil thick on a cast type slug. The background of the type was about 0.050 inch below the character face. Cuts of 0.020 inch and 0.002 inch have also been used effectively. This master can be charged to a uniform potential. The differential electrostatic image obtained with this master arises from the fact that those areas of the insulating film which are in contact with the image areas 24 of the conductive layer 23 have a high capacitance and, hence, accept a large charge density while those areas of film 22 which are in contact with the non-image areas 25 of conductive backing 23, i.e., are spaced from layer 23 by a dielectric (in this case of air, although the space 25 may be filled with a solid dielectric—termed "backfilling"—either the same or different from that used for layer 22, if desired), have a low capacitance and, hence, accept a negligible quantity of charge. In xerography, development, i.e., deposition of electrostatically charged marking particles, is in response to electrostatic fields, not charge. Fields are quickly quenched when very small charges are their source. Thus a minimum charge density is necessary for development of an electrostatic image. Therefore, only those areas of the insulating film in contact with the underlying type, i.e., those areas contacting the image areas 24 of conductive layer 23, will acquire a deposit of toner during development. An epoxy resin obtained from the Bakelite Co. under the trade name ERL 2795 with ZZLD 0814 hardener was used to backfill providing a flush surface. The resulting master with a solid dielectric for space 25 operated satisfactorily. Polystyrene film has also been used for layer 22.

Another method of construction of a variable capacitance master is to etch a positive image (using Kodak Photoresist or xerographic toner for masking) on a sheet of copper-clad epoxy-filled fiber glass. The copper surface is then placed in contact with an electrically grounded base and the surface of the epoxy-filled fiber glass charged and developed. Preferably the conductor should be thick and the dielectric thin, as, for example, 0.005 inch for the conductor and 0.001 inch for the dielectric. The conductor thickness is limited by etching and the dielectric by the requirement for support. However, the relative dimensions may vary widely. Thus, in the instant case the copper foil was 0.0015 to 0.0010 inch while the epoxy-filled fiber glass was 0.0035 to 0.0040 inch thick. The resulting images were of fair density and resolution.

Still another embodiment is shown in FIG. 3. This type of xeroprinting master is termed a "floating electrode" master and comprises a four-layer sandwich comprising a conductive base material 31, a thin electrically insulating layer 32 thereon having formed on its upper surface a continuous, electrically conductive image pattern 33 connected to a terminal 34 and, finally, a uniform electrically insulating layer 35 covering both the conductive image pattern 33 and insulating layer 32.

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In operation, the upper-most insulating layer 35 is charged to a uniform potential as by corona discharge and the terminal 34 of the conductive pattern is then connected to a source of D.C. voltage as battery 36 as by closing switch 37. Where the potential of the source 36 is such as to apply a potential to conductive pattern 33 of opposite polarity to the sensitizing charges 38 uniformly coated on layer 35, the result will be to create a strong internal electrostatic field between pattern 33 and the portions of the electrostatic charge layer 38 immediately above such pattern. When electrostatically charged marking particles are contacted with such a surface they will see only the electrostatic fields from the areas having no underlying conductive image pattern 33. Thus, they will deposit on such areas giving a negative or reversal of the conductive pattern 33. If it is desired to form a positive or direct reproduction of pattern 33, the potential applied thereto by source 36 must be of the same polarity as that applied on layer 35. This voltage will be additive with the voltage on the free surface of layer 35 resulting in a substantially greater electrostatic potential over the areas of layer 35 corresponding to conductive pattern 33. In other words, with the top surface (of layer 35) charged to a given potential, then a potential applied to the conductive image pattern alters the field configuration on the surface of layer 35 over the image pattern while the surface potential of the portions of layer 35 not over the image pattern remains constant. Utilizing a development process which develops potential gradients rather than absolute potentials, a process such as cascade carrier development, permits development of the image on the free surface of layer 35 without deposition of toner particles in the background areas. High quality xerographic images of good density may be developed by this process. However, since the conductive pattern must be continuous to permit application of the potential thereto to modify the potential on layer 35, island development is not possible by this method without a considerable increase in complexity.

Thus, the instant invention provides a light-insensitive, non-photoconductive xeroprinting master chargeable to a uniform potential to produce a charge density which varies from point-to-point in a pattern corresponding to graphic information either immediately on charging or thereafter independent of activating radiation.

The instant invention is in the novel xeroprinting master and the xeroprinting process using these master, not in any particular electrostatic charging, developing or transfer process or means. Accordingly, any charging, developing or transfer process or means known to those skilled in the art may be used with the novel xeroprinting masters of the instant invention in the xeroprinting process.

The term "graphic information" has been used herein as a generic expression covering the image configurations to be reproduced in the xeroprinting process. Such configurations include, of course, not only alpha-numeric material but also, charts, symbols, printed circuits, decorative designs (as for decals, textiles, etc.), half-tones and continuous tone pictures, and so on.

We claim:

1. A light-insensitive, non-photoconductive xeroprinting master comprising a conductive support member, a first insulating layer coated thereon, an electrically continuous conductive pattern on said insulating layer, a second insulating layer on top of said conductive pattern and means to connect said conductive pattern to a source of D.C. potential.

2. A process of xeroprinting comprising uniformly charging the surface of a xeroprinting master, varying the surface electrostatic energy distribution in image configuration while maintaining said uniform potential, thereafter contacting said surface with electrostatically attractable marking particles to form a visible image corresponding to said energy distribution and transferring said marking particles to an image support member.

3. A process of xeroprinting comprising, forming areas of high capacitance and areas of low capacitance on an insulating layer, said areas of high capacitance corresponding to graphic information to be reproduced, charging said insulating layer to a uniform potential, thereafter contacting said layer while at a uniform potential with electrostatically charged marking particles to form a visible image corresponding to said graphic information, and transferring said marking particles to an image support member in image configuration.
4. A process of xeroprinting comprising, forming on a layer having a uniform substantially fixed resistivity of between about 10^{10} and 10^{13} ohm-cm. a more highly electrically insulating image pattern thereby forming a xeroprinting master, charging said layer to a uniform potential, permitting said layer to discharge in non-image areas only, thereafter contacting said xeroprinting master with electrostatically attractable marking particles thus forming a visible image corresponding to said image pattern, and transferring said marking particles to an image support member in image configuration.
5. A process of xeroprinting comprising, forming in image configuration on a conductive support first areas of inherently electrically resistive material sufficiently electrically resistive to accept and retain an electrostatic surface charge and second areas of inherently less resistive material sufficiently electrically resistive to temporarily accept and thereafter dissipate an electrostatic charge, corona charging said areas to a substantially uniform potential, permitting charge to leak off said second areas, and developing the thus formed electrostatic charge pattern with electrostatically attractable material.
6. A process of xeroprinting comprising, corona charging to a uniform potential a xeroprinting master having first areas of substantially fixed resistivity which will accept and retain a corona applied electrostatic charge and second areas of substantially fixed resistivity which will accept and thereafter dissipate a corona applied electrostatic charge, contacting the electrostatic pattern formed on said

- master after the charge has dissipated from said second areas but remains on said first areas with electrostatically attractable marking particles to form a visible image, and transferring said marking particles to an image support member in image configuration.
7. A process of xeroprinting comprising, corona charging to a uniform potential a xeroprinting master having a printing surface consisting essentially of first corona chargeable areas of substantially fixed resistivity which will accept and retain a corona applied electrostatic charge and second corona chargeable areas of substantially fixed resistivity less than that of said first areas which will temporarily accept and then retain for a short time only a corona applied electrostatic charge, permitting charge to leak off said second areas only, contacting the thus formed electrostatic pattern on said master with electrostatically attractable marking particles to form a visible image, transferring said marking particles to an image support member in image configuration, and repeating the foregoing steps in their given sequence to form a multiplicity of identical images on image support members.

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