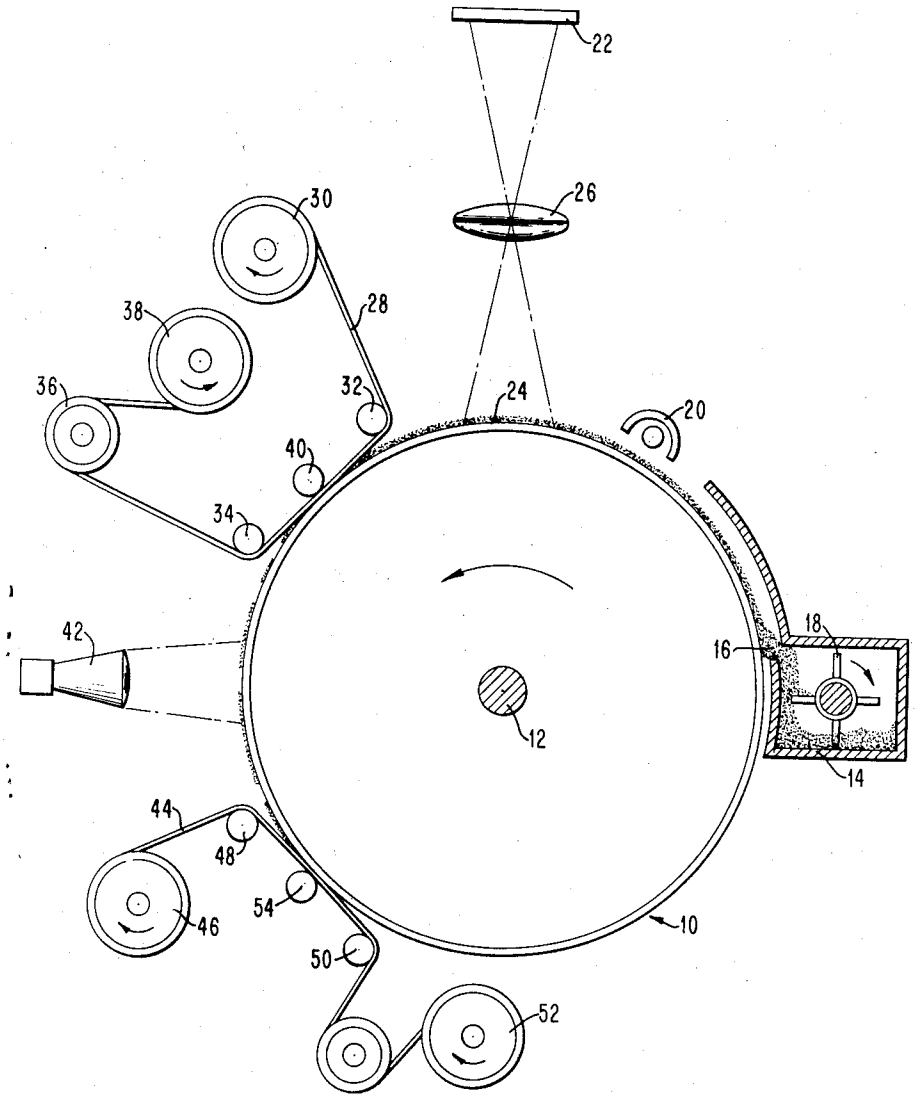
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MACHINE AND METHOD FOR REPRODUCING IMAGES WITH PHOTOCONDUCTIVE INK

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MACHINE AND METHOD FOR REPRODUCING IMAGES WITH PHOTOCONDUCTIVE INK

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This invention relates to a photoconductive photographic and printing method and to apparatus for practicing the method, and more particularly to a method and to an apparatus for producing images formed of photoconductive powder. The invention contemplates certain improvements over so-called xerographic printing.

In the xerographic process, a plate of electrically conductive material, such as metal of any suitable character, has formed thereon a coating of a suitable photoconducting material, i.e., a material which possesses the tendency of being electrically conductive only when exposed to light. Among such materials are anthracene and selenium. The metal plate so coated is provided with an electrostatic charge, such as a positive charge, by any desired means, including, for example, by friction or by being exposed to charges resulting from electron emissions from suitable filaments energized by high voltage. The plate, thus charged and while being maintained in darkness, is next exposed in any of the ways that a conventional photographic plate may be exposed. Wherever light strikes the charged plate the surface coating thereon becomes conductive thereby permitting the electrostatic charge to be conducted to the metal portion of the plate where it is dissipated. Wherever no light strikes the charged plate, the electrostatic charge remains upon the coating so as to produce on the exposed coated plate a so-called latent electrostatic image.

The electrostatic image is then developed by bringing into contact therewith an electroscopic powder or xerographic toner, as it is sometimes called; this powder, which may have different compositions, is a very fine powder, usually made up as a resin base material. It also usually contains a color imparting material such, for example, as dye or pigment.

The xerographic toner may be negatively charged in respect to the image charge on the plate and is attracted only to the unexposed charged portions of the coated plate. The powder on the exposed areas will not adhere to the coated plate and can be removed by gravity or by shaking. This produces an electroscopic powder image which, as will be understood from the foregoing, is not fixed, but which at this point may be removed mechanically. The electroscopic powder image is then transferred to a paper sheet, this transfer being effected in part mechanically by bringing paper into contact with the plate carrying the powder image and in part electrically by having a substantial potential exerted across the plate and the opposite side of the paper which is held against the image-carrying surface of the plate. Upon separation of the paper and the plate, enough powder will adhere to the paper so that the image may be seen. This powder image is, however, still only loosely adherent to the paper and may be easily wiped off at this point.

Finally, the powder image is fixed unto or into the paper to produce a permanent print of the matter reproduced as aforesaid. This may be done in several

ways. For example, it has been proposed to press the powder into the paper; to heat the powder and paper sufficiently to fuse at least one element of the powder and thereby cause this element to carry enough of the pigment into the paper as a molten material to fix the images on the paper; or to expose the unfixed powder image to a material which is a solvent for at least one constitutent of the powder, thereby dissolving enough of the powder so that the solution thereof penetrates into the fibers of the paper and fixes the image indelibly into the paper.

The foregoing method for the reproduction of images has been subject to certain difficulties inherent in the method itself. In the first place, the coated plate, usually in the form of a drum, is subject to deterioration as time passes. The surface coating is subject to fatigue, a permanent decrease in resistivity is evident, and the coatings heretofore employed are usually mechanically soft and, therefore, susceptible to scratching and general damage. The drums employed in present day xerographic operations have a useful life of from a mere three hours to an average of one hundred hours, at best. Furthermore, these drums are made by vacuum deposition of the photoconducting coating which requires special equipment and involves a greater cost. Another difficulty experienced in the xerographic method of reproduction is that characters appear hollow in the line reproduction of large dark areas. In the zerographic process, charged toner particles are frequently brought into an electric field such that they are attracted to the region of highest field gradient. This results in a greater toner deposit along the edges of the image with the result that characters so formed appear to be hollow by reason of the darker edge areas.

It is the object of this invention, therefore, to provide a method and an apparatus for performing a reproduction process which eliminates the foregoing and other disadvantages inherent in previous methods and to provide a method in which the drum or plate utilized to form the images is free from deterioration, one in which both temporary and permanent dark resistance changes are decreased, one in which hollow characters in line reproduction of large dark areas as avoided, and one in which a wider variety of photoconductors may be employed in the exercise of the process.

It is a further object of the invention to provide an apparatus for reproducing images which employs, as a principal element thereof, a plate or drum which does not require predeposited photoconductive coatings and which, therefore, does not require special equipment and expensive fabricating procedures. Withal it is an object of the invention to provide reproducing equipment which embodies plates or drums, which operates effectively for unlimited periods of time, and which can be made with the tools and machines usually found in machine shops.

The invention proceeds on the basis that the conventional photoconductive coating on the drum or plate can be eliminated, utilizing only a photoconductive powder by which the image is formed and which powder is removed in its entirety from the plate or drum when the reproduction has been made.

The details of the method and of suitable apparatus can be explained best by reference to the single drawing, forming a part hereof, in which the single figure is a diagrammatic representation of suitable apparatus for practicing the printing process.

The central element of necessary mechanism is a surface **10** on which photoconductive powder can be deposited and treated for the formation of a reproduction image. In the drawing, the surface **10** is illustrated in the form of a rotary drum adapted to rotate about an axis **12**. The drum **10** may be of any suitable material,

either a conductive material such as metal, or dielectric material such as glass. The drum is suitably charged prior to the time the photo-conductive powder is applied to its surface. Located adjacent the drum and extending across its width is a receptacle **14** having an opening **16** therein located close to the peripheral surface of the drum through which a photoconductive powder contained within the receptacle **14** may be ejected to the drum face. Within the receptacle **14** is disposed an agitator **18** having a plurality of radially extending arms and being adapted for rotation on its longitudinal axis. The agitator **18** results in the triboelectric charging of the photoconductive powder within the receptacle such that particles of powder will be attracted to the face of the drum. It is understood, of course, that if the powder has a positive charge imparted thereto the attraction is increased where the drum is negatively charged.

The agitator **18** in the powder receptacle **14** also effectively generates a powder cloud with the result that a thin uniform layer of photoconductive powder is formed at the aperture **16** where it is deposited on the drum surface. If desired, the film of powder on the surface of the drum may be further charged in a positive direction by a corona discharge device **20**. It is anticipated that for most cases, however, the corona discharge device **20** may be unnecessary since the cloud of powder particles will usually be sufficiently charged within the powder receptacle **14** as they are violently thrown about by the agitator **18**.

A document **22** to be reproduced is subjected to a light source such that light rays reflected therefrom or projected therethrough will fall upon the photoconductive powder film as the drum is rotated, as indicated at the top of the drum **24**. Such light rays may be passed through a lens or focusing system **26** if so desired. The reduced resistivity at the areas where the photoconductive powder is exposed to light rays will be such that the potential of the powder is substantially equal to that of the drum surface. This results in the exposed powder being held to the drum surface so loosely that it may be removed to a paper sheet or web **28** on which the powder image so removed may be subsequently fixed.

In the drawing, the web **28** is taken from a supply reel **30** and is trained about guide rollers **32**, **34**, and a guide roller **36** before it is rereeled upon a roller **38**, or, alternatively, it may be removed from the apparatus in the form of sheets. The transfer of the image from the face of the drum to the web **28** may be facilitated by charging the web electrostatically by some suitable device **40**. The device **40** may also comprise means by which the powder image is fixed to the web.

The areas of the electroconductive powder on the face of the drum which were not subjected to light exposure still adhere tenaciously to the surface of the drum, such that the attraction between the remaining portions of the powder layer and the drum must be broken before these remaining portions can be transferred to a copy sheet. These remaining portions can be freed for transfer by further exposure thereof to a light source **42** which will condition these portions for removal by a second web or sheet **44**. Thus, as the drum **10** continues to rotate, the positive image which remains on the drum will be exposed to light from the source **42** such that the charge attracting the particles of photoconductive powder to the face of the drum will be dissipated. So conditioned, the positive image which remains can be deposited on the sheet or web **44** which is passed in contact with the drum surface from a supply roll **46**, over guide rollers **48** and **50** and to a takeup reel **52**, or alternatively, removed from the apparatus in any desirable way. It is contemplated that the portions of the powder layer remaining on the transfer surface may be freed from the surface for transfer to the web **44** by means other than exposure to light. For example, an electrical discharge device capable of developing a motive force extending from the drum to the web may be employed.

The transfer of the positive image into the sheet or web **44** can be facilitated by charging the sheet or web electrostatically by any suitable means **54** located at the point of contact between the sheet or web with the face of the drum. The positive image so removed from the face of the drum is then suitably treated to fix it on or in the sheet or web **44**. It will be understood, of course, that the apparatus will be suitably enclosed and compartmented such that the operation is performed in darkness except at the light exposure stations.

If the drum **10** is constructed of transparent material, whether it be a dielectric or conductive material, the photoconductive film may be applied as described and the exposure thereof to light may be made through the drum, thus exposing the area of drum-photoconductor contact with the result that a faster response can thus be obtained, less critical absorption characteristics in the photoconductor can be tolerated and less precision in the thickness of the powder film is required.

The photoconducting powder may be any one of a variety of compositions. While photoconductivity is the principal requisite for a useful powder in the foregoing process, other properties become more or less important depending on the variations in the application of the process. If an opaque drum is employed, the transmission of light by the powder film is important. The particles contacting the face of the drum must be capable of irradiation to form a background-free image. Conversely, if a transparent drum is employed such that the powder film is exposed to light from within the drum, the transmission properties of the powder are not so important. In the case of half-toned reproduction or photography, a wide distribution in particle size will enhance faithful reproduction of the image. On the other hand, for line reproduction, a very narrow particle size distribution is desirable. For a machine that operates at a substantial speed, a low resistivity photoconductor is quite satisfactory, whereas at lower operational speeds, a much higher dark resistivity is necessary unless provision is made for charging the drum surface immediately prior to exposure and/or development immediately following exposure.

Photoconductive materials which can be used are commercially available and include grey (hexagonal) selenium, monoclinic selenium, amorphous selenium, sulfur, photoconductive phosphors and photoconductive dyes.

From a consideration of the foregoing, it will be seen that a negative image is first obtained on the sheet or web **28** and that after further conditioning the remaining portions of the powder layer such as by exposure of the residual image on the face of the drum to the light source **42**, a positive image is deposited on the web or sheet **44**. If only a positive image is required, transfer of the exposed powder to the web or sheet **28** following the first exposure may be eliminated or replaced by electrostatic, gravitational or vibratory removal of the exposed powder areas, and the collection and return thereof to the powder receptacle **14**.

While the specific exposition of the method has referred to the use of an electrostatic force as an aid in transferring the exposed powder image to a copy sheet, other aids may be employed. The paper sheet or web can be charged triboelectrically or the image may be transferred by means of charge-carrying rollers; magnetic particles may be incorporated in the photoconducting powder such that the transfer may be accomplished magnetically. The paper sheet or web may have applied thereto a weak adhesive composition such that the powder particles are transferred to the sheet by adhesive attraction. Finally, the image may be transferred to the supporting surface by gravity, allowing it to fall or be "spun off" the drum. Whatever aid to the transfer step is employed, its selection for the removal of the negative image, whether to a copy sheet or not, must be con-

ditioned by the fact that the portions of the powder layer comprising the positive image must not be disturbed during the removal of the negative image.

While heat fixing of the image is conventional, other physical or chemical methods applicable to the fixing of xerographic prints may be usefully employed.

While the fundamentally novel features of the invention have been illustrated and described in connection with specific embodiments of the invention, it is believed that these embodiments will enable others skilled in the art to apply the principles of the invention in forms departing from the exemplary embodiments herein, and such departures are contemplated by the claims.

I claim:

1. The method of printing comprising the steps: forming a layer of a photoconductive powder directly upon a metallic transfer surface and maintaining such layer in contact with such surface by means of electrostatic action, exposing selected portions of such layer to the influence of light in the form of an image and thereby rendering conductive the portions of said powder which have been exposed to light and thereby breaking the electrostatic attraction between such portions and said surface, removing said exposed portions of said powder from said surface, breaking the electrostatic attraction between the remaining portions of such layer by exposing the same to the influence of light, transferring said remaining portions to a copy sheet by bringing such sheet into contact with said exposed remaining portions, and fixing said

transferred portions by the application of heat thereto to form a positive image upon said copy sheet.

2. The method of printing comprising the steps: forming a layer of a photoconductive powder directly upon a metallic transfer surface and maintaining such layer in contact with such surface by means of electrostatic action, exposing selected portions of such layer to the influence of light in the form of an image and thereby rendering conductive the portions of said powder which have been exposed to light and thereby breaking the electrostatic attraction between such portions and said surface, transferring said exposed portions from said transfer surface in the form of a negative image to a copy sheet by bringing such sheet into contact with said exposed portions of said powder, breaking the electrostatic attraction between the remaining portions of such layer by exposing the same to the influence of light, transferring said remaining portions of such layer from said transfer surface in the form of a positive image to a copy sheet by bringing such sheet into contact with said exposed remaining portions, and fixing said transferred portions by the application of heat thereto to form a positive image upon said copy sheet.

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