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ELECTROSTATIC PRINTING

Filed March 19, 1956

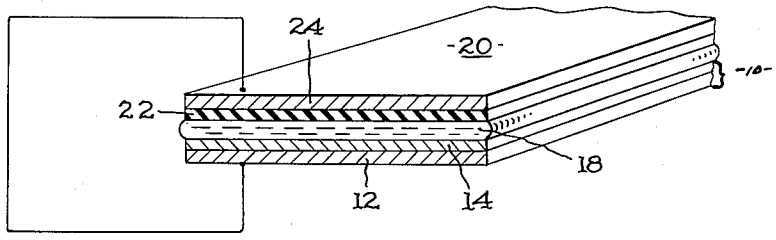


FIG. 1.

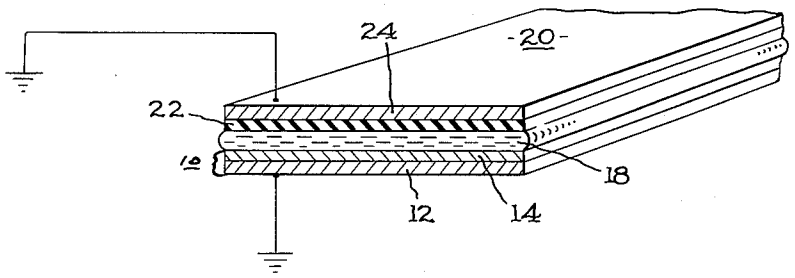


FIG. 2.

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The present invention relates to electrostatic photography and more particularly to the manner in which a latent electrostatic image is converted into a visible image.

A number of patents have recently been granted on inventions made in the field of xerography. Among these are Butterfield Patent 2,693,416 and Greaves Patent 2,726,166 which describe improvements of the basic process. From these patents and from other published information relating to this art, the xerographic process may be generally described in the following manner. A photosensitive element is fabricated with a layer of photoconductive material supported on an electrically conductive layer, the photoconductive material being chosen from among those materials such as amorphous selenium which become electrically conductive when exposed to light and which are classed as electrical insulators at other times. An electrostatic charge is then imparted to the photosensitive element in any known fashion, for example, by rubbing or friction or by action of ion or electron emission, e.g., by means of a corona discharge. The photosensitive element, carrying an electrostatic charge, is then exposed by projecting a light and shadow image onto the element, whereby the illuminated areas become partially conductive and are discharged while the conductivity of the non-illuminated areas is not changed and they retain their charge. As a consequence, what is called a latent electrostatic image is formed in the photoconductive layer. This latent image is then developed into a visible image by bringing it into contact with an electrostatically attractable particulate material. The particulate material is attracted to the charged area of the photosensitive element and reproduces a visible manifestation of the latent electrostatic image. The visible image is then either erased or it may be transferred to a permanent record medium, such as a sheet or tape of suitable material and, if desired, fixed on the surface or in the body of the permanent record medium.

The specific photosensitive element and the manner in which the latent electrostatic image is formed on the specific photosensitive element used form no part of this invention, which relates particularly to an improvement in the manner in which the latent electrostatic image is transformed into a visual representation of the invisible latent image.

Two approaches have previously been followed in effecting this portion of the xerographic process. In the first of these, the latent electrostatic image has been brought into contact with a finely divided dry powder, as shown in Carlson Patent 2,297,691 or with a liquid mist, spray or fog as shown in Carlson Patent 2,551,582 or with a liquid containing electrostatically attractable particulate material as in Mayer application Serial No. 380,285, filed September 15, 1953, or indeed with any material which is sufficiently attracted by the electrostatic charge to convert the latent image into a visual image. Because of the extremely delicate nature of the surface of the photoconductors presently employed, direct contact of the photoconductor with somewhat abrasive particles of the

developer has been found to be undesirable since it leads to marring of the uniform surface of the photoconductor which is necessary to the production of high quality visual images faithfully reproducing the original. When the visual image is transferred to a permanent record medium by pressure or by heat and pressure as described in the aforesaid Carlson patents, further damage to the delicate photoconductor inevitably takes place. Furthermore, the removal of adherent developer particles in order to prepare the photoconductor for subsequent use, in a repetition of the procedure of charging, exposing and developing, usually involves the use of cleaning means which further abrades and mars the delicate surface of the photoconductor. It will thus be readily apparent that processes which include direct contact between the photoconductor and a particulate electrostatically attractable material suffer from a plurality of operational factors which tend to limit the service life of the carefully prepared photoconductor.

A method which avoids the disadvantages produced by permitting the particulate developer to come into direct contact with the photoconductor is described in Butterfield Patent 2,693,416. In the method disclosed by Butterfield, the delicate photoconductive portion of the photosensitive element is protected from direct contact with particulate developer material or cleaning means by a sheet of transparent or translucent electrically insulating material such as paper, cloth or a plastic material. Thus instead of a two-layer photosensitive element composed of a photoconductive material supported on an electrically conductive layer, Butterfield employs a three-layer photosensitive element in which the third layer, overlying the photoconductive layer, protects it from direct contact with foreign materials. The three-layer photosensitive element is charged by a corona discharge wire maintained at a potential of 5000–10,000 volts relative to the metal support layer; and the charged photosensitive element is then exposed in the usual manner. A latent electrostatic image is thereby formed in the translucent or transparent layer, on the portion of this layer adjacent to the photoconductor. The visual image is then formed on the translucent or transparent layer by contacting the outermost surface of this layer with an electrostatically attractable particulate developer, after which the translucent or transparent layer, bearing the particles forming a visible image is separated from both the photoconductor and the conductive layer secured to and supporting the photoconductor. The visible image is then fixed in the usual fashion if a permanent record is desired. By this procedure the photoconductive layer does not come in direct contact with any abrasive particulate material since the latent electrostatic image is formed and developed in a protective overlying layer of transparent or translucent material. Nor does the method require that cleaning means be applied directly to the photoconductor. The method while free from many of the disadvantages of the methods first above-described, possesses certain inherent limitations which severely restrict its application to the reproduction of images having a great deal of detail. While both of the embodiments described in the patent are capable of producing visible images by a xerographic process in which the developer particles do not directly contact the photoconductor, and while such images are generally satisfactory for many purposes, it has been found that the modification represented in Figure 1 of Butterfield often results in a loss of contrast in the final image, and that the modification represented in Figure 8 of the patent is often productive of images with a low degree of resolution. It is believed that each of these limitations is inherent in the practice of the invention as disclosed in Butterfield.

A technique has now been discovered whereby the

advantages of modifying the xerographic process to one in which the visible image is not produced directly on the photoconductor may be obtained without either the loss in contrast or the loss in resolution inherent in the procedures set forth in Patent 2,693,416.

Essentially our discovery involves the formation of a temporary assembly including at least four distinct components, preferably in the form of thin layers. The photosensitive element is integrally formed of two of these, a photoconductor and an electrically conductive material supporting the photoconductor in the usual manner. The remaining two components are combined in another unitary assembly on which the visual image is ultimately developed. These components consist of a second electrically conductive material and an electrically insulating material. The four essential components of the temporary assembly are disposed so that the electrically conductive materials are each outermost (when a section is taken through all four components of the assembly) and the photoconductor and electrical insulator are innermost. While the elements are so-disposed in assembled relation and after a latent electrostatic image has been formed on the photoconductive material, electrical contact is established between the electrically conductive layers either by effecting a direct connection by means of a conductor connected to both layers, or by an indirect connection, e.g., by connecting both layers to ground. Thereafter the temporary assembly is separated into two portions, one comprising the photoconductor and the electrically conductive material supporting it and the other comprising the electrically insulating material and the electrically conductive material united to it. After separation into these two sub-assemblies, it has been found that the latent electrostatic image previously present in the photoconductor has redistributed itself so that a portion of the charge pattern has been transferred to the surface of the insulating material. The transferred charge image has been found to conform faithfully to the original latent electrostatic image, with particular reference to charge density. When the transferred image was developed by known techniques forming no part of this invention, it was found that the resulting visible image was produced with a higher degree of resolution and with better contrast than images obtained from similar subjects reproduced in the manner set forth in the Butterfield patent.

We have further found that both the degree of resolution and the contrast ultimately achieved may be further enhanced by including an additional component in the temporary assembly when practicing this invention as above described. The additional component is preferably a liquid having a high dielectric strength and a high resistance, and is disposed between the two subassemblies previously described.

Although any of the prior art photosensitive elements such as those described in the above patents may be used, the photosensitive element preferred in the practice of this invention consists of a selenium photoconductor supported on an electrically conductive backing material. The conductive backing material is first degreased with an organic solvent such as trichloroethylene and after degreasing is then placed in apparatus in which selenium is evaporated onto the freshly cleaned electrically conductive surface. When the photoconductive material has been deposited in a continuous film of up to about 25μ in thickness, the photosensitive element is withdrawn from the evaporator and allowed to age for about one day in order that the photoconductor may attain its full sensitivity to light.

The other portion of the temporary assembly comprises an electrically conductive supporting layer and a layer of electrically insulating material supported thereon and preferably affixed thereto. One combination of materials which we have found satisfactory is a film of Mylar, a polyester material, attached to aluminum foil. Combinations consisting of 0.00025 inch of polyester resin on 0.00035 inch of aluminum foil, and on 0.002 inch of aluminum foil have both been used satisfactorily, the thicker foil providing a greater resistance to tearing. Increasing the thickness of the electrically insulating material to between 0.5 and 1 mil would appear to produce corresponding benefits.

In order that our invention may be more fully understood, we will now describe several embodiments of our process two preferred embodiments being shown schematically in the accompanying drawings in which:

Figure 1 is a perspective view in section taken through a temporary image transfer assembly; and

Figure 2 is a similar view of a modification in which no external source of impressed potential is required.

In a first embodiment of the process, an electrostatic charge is imparted to the photoconductor by known methods. Suitable charging techniques are disclosed in the Carlson patents previously mentioned. After the photoconductor is charged, it is exposed by projecting a light and shadow image of a Standard Resolution Chart (National Bureau of Standards) onto the photosensitive element. Exposure of the photosensitive element produces a latent electrostatic image on the photoconductor which is similar in all respects to the image of the resolution chart projected thereon. Charging and exposure in the manner described are well known in the art and form no part of the present invention.

After the latent electrostatic image has been produced, the photosensitive element **10** is brought into intimate contact with a plate **20** consisting of an electrically insulating material **22** and an electrically conductive material **24**, both in the form of relatively thin layers. The two plate-like elements are disposed so that the electrically conductive layer **12** of the photosensitive element and the electrically conductive layer **24** of the transfer element form the outside of a sandwich. Between these two layers, in intimate contact with one another are the layer **14** of photoconductor containing the latent electrostatic image and the layer **22** of electrically insulating material. After these components have been brought together in the manner described, electrical contact is established between the two electrically conductive layers of the sandwich. As a result, the charge image redistributes itself so that one portion of the charge image splits off from the photoconductive material and attaches itself to the electrically insulating material, while the remainder of the charge pattern is retained by the photoconductor. The electrical connection between the two electrically conductive elements of the assembly may be either direct (as shown in Figure 1) or indirect, e.g., through ground (as shown in Figure 2). After a portion of the latent electrostatic image has been transferred to the electrically insulating layer, the electrical connection between the members of the sandwich is broken, and then the photosensitive element is separated from the other half of the temporary assembly. The charge image now present on the electrically insulating layer may be developed into a visible image in any known fashion, e.g., by any of the three techniques previously described. When proceeding in the manner described, it was found that a resolution of about 20 lines per millimeter was obtainable using selenium as the photoconductor and Mylar (polyester resin) on aluminum foil as the medium on which the visual image was developed. This was decidedly inferior to the resolution of 60 lines per millimeter obtainable by direct development on the selenium photoconductor.

It was observed that when the elements of the sandwich were brought together in total darkness, very small sparks were formed as they were pressed into intimate contact. This was believed to be due to a breakdown of the air in the space between the photoconductor and the electrically insulating material, due to the relatively high field strength induced as the sandwich was being assembled. As a result some spreading or fanning of the latent electrostatic image followed, with a corresponding

loss in resolution. To overcome this, and in an effort to improve the resolution obtainable, the process above described was modified in the following manner.

In the second embodiment it was found that a thin film 18 of a liquid having a relatively high dielectric strength applied to the photoconductive surface of the photosensitive element prior to charging said photoconductor decreased the loss in resolution reported above. Specifically, we have found that a liquid having a high dielectric strength and a relatively high resistance may be used to advantage to improve the charge transfer between the members of the sandwich and to inhibit charge breakdown across the gap between the photoconductor and the insulator to which a portion of the latent electrostatic image is to be transferred until the photoconductor and insulator are brought into closer proximity, than when they are separated by an air gap.

By way of comparison we have found that when the surface of the photoconductor is charged to a potential of between 100 and 600 volts (normal for selenium photoconductor) the transfer of the latent electrostatic image occurs when the photoconductor and insulator are about 0.005 to 0.010 inch apart with air as the medium between the surfaces. The resolution obtained under these conditions was 10–20 lines per millimeter. When a high dielectric strength liquid was substituted for air, the spacing between the photoconductor and insulator at which breakdown and consequently transfer occurred was found to be substantially diminished and the resolution obtainable was substantially increased. For example, with a silicone oil, the distance between the photoconductor bearing the latent electrostatic image and the insulator to which the image was to be transferred was reduced to between 0.001 and 0.003 inch before breakdown and charge transfer occurred and the resolution increased to between 30 and 60 lines per millimeter. Another advantage produced by substituting a high dielectric strength liquid for air as the medium through which charge is transferred from the photoconductor to the insulator resides in greater uniformity of transfer. Air exhibits a dielectric strength which varies widely with varying relative humidities and temperature. The high dielectric strength liquids used by us are not subject to this variation. Charging, exposure, assembly, electrical connection, separation and development are all carried out in the same manner as in the first embodiment. Owing to the closer spacing of the photoconductive material and the electrically insulating material, at the time of actual transfer of the charge, the latent electrostatic image is transferred to the electrically insulating material with less spreading along the surface and hence with a greater retention of resolution.

In still another embodiment (not illustrated) the charge is initially imparted to the surface of the electrically insulating material instead of to the photoconductor. The elements of the sandwich, including the high dielectric strength liquid, are then assembled and exposure of the photoconductor to a light pattern is accomplished by projecting the light and shadow image through a transparent electrically conductive support and onto the back of the photoconductive layer. Prior to exposure, of course, an electrical connection between the electrically conductive supporting layers on either side of the sandwich is effected so that appropriate pattern of charges is established when the photoconductive material becomes conductive.

In either of the modifications above described the film 18 of liquid high dielectric material may be applied either to the photoconductor or the transfer medium at any time in the process prior to assembly of the members of the sandwich. It has been found that the desired degree of resolution is obtainable with films of silicone oil of not more than about 100μ in thickness. One way of securing the required intimacy of contact between the elements of the sandwich is by pressure applied to the members of the assembly prior to and/or during the transfer of the charge pattern constituting the latent electrostatic image.

Having now described our invention in detail in accordance with the patent statutes, what we desire to secure by Letters Patent is set forth in the following claims.

We claim:

1. In a method of forming a reproduction of an object which comprises (*a*) forming a temporary assembly comprising (1) an electrically conductive material on which there is supported a photoconductive insulating material; (2) a thin film of an insulating liquid of a high dielectric strength overlying said photoconductive insulating material and (3) a solid dielectric material overlying said liquid film and supporting a second layer of electrically conductive material wherein at least one of said photoconductive insulating material and said solid dielectric material bears a uniform electrostatic charge on its surface, prior to forming said temporary assembly; (*b*) establishing an electrical connection between said two electrically conductive materials and simultaneously therewith exposing said electrically charged photoconductive insulating material to a pattern of light and shadow to thereby form an electrostatic image on the opposed surfaces of both of said photoconductive insulating material and said solid dielectric material, and (*c*) thereafter removing the photoconductive insulating material and its support and the liquid dielectric material from the image bearing surface of the solid dielectric material and thereafter (*d*) developing said electrostatic image on said dielectric material into a visible image by applying thereto a dispersion of electrostatically attractable particles; the improvement which comprises: limiting the thickness of said liquid dielectric material to less than 100 microns and providing no external potential in the electrical circuit between said electrically conductive members, whereby the charge image is transferred through said dielectric liquid solely under the electrical influence of the potential difference created during the formation of the latent image in the photoconductive insulating material.

2. The method of claim 1 wherein the thickness of the liquid dielectric material is decreased to substantially below 100 microns prior to exposure.

3. In a method of making a reproduction of an object in which a latent electrostatic image is produced on the surface of a photoconductor, wherein the electrostatic charges are distributed in a pattern characteristic of the original object to be reproduced and a corresponding image is transferred to the surface of an electrically insulating material on which it is subsequently developed into a visible image; which method includes: forming a temporary assembly of (1) the photoconductive insulating material bearing a latent electrostatic image, (2) an electrically conductive material, supporting the photoconductor, (3) an electrically insulating material having a high dielectric strength, and (4) a second electrically conductive material, adjacent the high dielectric strength material, and (5) a film of a liquid having a high dielectric strength, disposed between the photoconductor and the electrically insulating material; establishing an electrical connection between the two electrically conductive materials constituting the outermost members of the assembly; and thereafter separating the photoconductor and its electrically conductive support and the dielectric liquid from the high dielectric strength material bearing a reproduction of the latent electrostatic charge pattern originally present on the photoconductive insulating material; and thereafter developing a visible image from said reproduction; the improvement which comprises: effecting said latent image transfer without the application of any external applied potential by limiting the thickness of said liquid dielectric material to less than 100 microns prior to establishing the electrical connection between the two electrically conductive materials.

4. The method of claim 3 in which the thickness of the liquid dielectric material is decreased substantially below 100 microns prior to separating the members of the temporary assembly.

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