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COLOR XEROGRAPHY

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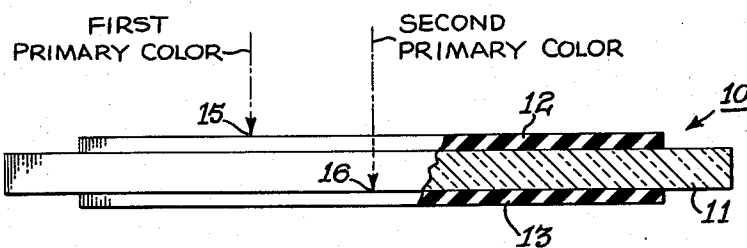


Fig. 1

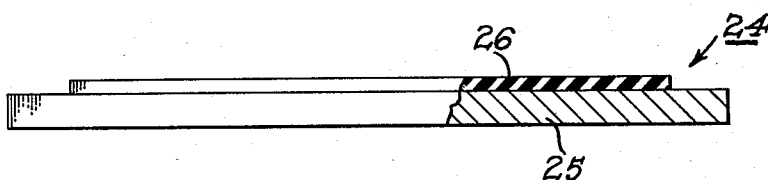


Fig. 2

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COLOR XEROGRAPHY

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2 Claims. (Cl. 96—1)

This invention relates in general to xerography and in particular to the xerographic reproduction of color images.

In the art of xerography it is usual to record and reproduce by electrical means a black and white copy of an original scene, document or the like. Such xerographic reproduction has been brought into commercial use for the making of line copy images and, to a certain extent, for continuous tone reproduction. At the present time, however, there is no system commercially available for producing colored xerographic prints. It is, therefore, an object of the present invention to provide means, method and apparatus for the production of full colored xerographic prints.

It is a further object of the invention to provide means, methods and apparatus for two or more color xerographic reproduction and for the addition of other colors thereto.

It is an additional object of the invention to provide a new method for reproduction of xerographic images corresponding to two primary colors of light.

It is a still further object of the invention to provide new color xerographic apparatus comprising a light sensitive xerographic member characterized by having two separate sensitive xerographic layers each selectively sensitive to exposure by means of a different primary color.

It is a still further object of the invention to provide new means, methods and apparatus for color xerography whereby a xerographic print or reproduction in two colors can be produced with a single exposure to light of mixed primary colors.

In accordance with the present invention, a plurality of photoconductive layers of selected conductive sensitivity to light of different primary colors are simultaneously exposed to a projected light image of mixed primary colors. For example, a plurality of photoconductive layers may be superposed, one on top of the other in laminated configuration, and a light image of mixed primary colors may be projected onto the array of photoconductors from one side thereof so as to pass selectively through the first of the photoconductors in reaching the last of the photoconductors. An electric field is applied through the photoconductive layers while they are exposed in this manner so as to produce a plurality of developable xerographic latent images which may be developed and superposed to form a two-color or full color xerographic reproduction.

The general scope and nature of the invention having been set forth, the invention is further illustrated in the following specification and in the drawings in which:

Fig. 1 is a diagrammatic view of a two-color xerographic plate illustrating its exposure to light of mixed primary colors;

Fig. 2 is a diagrammatic view of a xerographic plate adapted to record a third color.

In Fig. 1 there is illustrated a color xerographic sensitive member generally designated 10 comprising a transparent conductive support base 11 having on its one surface thereof a photoconductive insulating coating or layer

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12 characterized by sensitivity to a first primary color and on its opposite surface a photoconductive insulating layer or coating 13 characterized by sensitivity to a second primary color. As shown in the figure, the member can be exposed to light of mixed primary color from the side of the first layer 12 whereby light of a first primary color is incident on and conductively activates the layer 12 as illustrated at point 15, and a light of a second primary color is transmitted through said first photoconductive layer 12 and through the support 11 to be incident on and conductively activate layer 13 as illustrated at point 16.

The first photoconductive layer 12 comprises a thin layer of a material which is normally insulating and is conductively sensitive to light of one primary color to the substantial exclusion of sensitivity to a second primary color. It is characterized by the ability, in the absence of radiation of this first primary color, to accept and retain on its surface a usable xerographic charge potential and to selectively dissipate this charge potential upon the exposure of active radiation of the first primary color. This layer may comprise any photoconductive insulating material meeting these general characteristics. It has been found, for example, that a layer comprising zinc oxide particles dispersed in a solid insulating transparent binder such as a silicone resin, as disclosed in copending application Serial No. 311,546 by A. E. Middleton and D. C. Reynolds is characterized by being conductively sensitive to blue light and substantially insensitive to light of other primary colors. Thus, according to one embodiment of the invention, layer 12 may comprise a normally insulating material conductively sensitive to blue light and substantially insensitive to red and green light, such as, for example, a binder coating of zinc oxide, or of zinc selenide, zinc sulfide, mixed zinc sulfide-cadmium sulfide, or titanium dioxide. Other materials may be used such as, for example, binder coatings of other photoactive oxides, sulfides, silicates and selenides of cadmium, zinc, calcium, magnesium and the like, selected from those that are also characterized by appropriate sensitivity to a single primary color. Layer 12 may also be a vacuum evaporated coating of vitreous cadmium sulfide, which is a transparent yellow material conductively sensitive to blue light.

The second photoconductive layer 13 comprises a normally insulating layer conductively sensitive to light of a second primary color and optionally substantially insensitive to light of the remaining or third primary color. Thus, for example, if the first layer is conductively sensitive to a primary color other than blue, this second layer 13 may be a blue sensitive layer such as, for example, the zinc oxide binder layer mentioned hereinbefore. If, on the other hand, the first layer 12 comprises a zinc oxide binder layer as illustrated, then the second layer 13 is conductively sensitive to a second primary color, such as green or red. Illustratively, a layer of vitreous or amorphous selenium, preferably deposited on a conductive surface under vacuum and at a controlled temperature, is characterized by substantial sensitivity to green light and is substantially insensitive to red light. For example, a layer of vitreous selenium about 10 to 20 microns thick deposited in vacuum at a substrate temperature of about 40° to 60° C. is conductively sensitive to green light and virtually insensitive to red light; this layer is a preferred companion to the zinc oxide binder layer. Other suitable layers include binder coatings of mixed cadmium selenide-zinc selenide, mixed lead oxide-zinc oxide, and mixed mercuric sulfide-zinc oxide.

The conductive support 11, on which layers 12 and 13 are disposed, is a transparent conductive material such as, for example, conductive glass or transparent plastic having a conductive coating on each surface thereof, or

a composite member comprising two sheets of glass or plastic, each with a single conductive coating on its outwardly facing surface. In a preferred embodiment of the invention the glass may be tinted to absorb the primary color of sensitivity of layer 12. Thus, for example, if layer 12 comprises a zinc oxide binder coating then the glass member 11 desirably will be tinted so as to absorb substantially all the stray blue radiation that might be passed through photoconductive layer 12 and in this case layer 13 may permissibly be sensitive to blue as well as green light.

In operation of the device illustrated hereinbefore an electrostatic charge of about 150 volts is placed on each of layers 12 and 13 by suitable means such as for example the charging methods illustrated in Carlson Patent 2,588,599 wherein an ion source such as a corona discharge electrode may be passed across a surface to be charged. The voltage on the photoconductive layers as well as the polarity of the potential may be selected in accordance with best operating techniques and in accordance with the characteristics of the layers. In one presently preferred embodiment of operation, the first photoconductive layer comprises a binder coating of zinc oxide and the second layer comprises a vacuum evaporated vitreous or amorphous form of selenium. In this case the binder coating of zinc oxide is principally sensitive to blue light and is most satisfactorily operable when it has been sensitized by charging to make it of negative polarity. A selenium coating, on the other hand, is sensitive to green light and is most satisfactorily operable when sensitized by charging to positive polarity. Thus, in accordance with this operation, layer 12 is charged prior to exposure to a negative potential of 150 volts and layer 13 is charged prior to exposure to a positive potential of 150 volts. The plate as thus charged is exposed to a light image of mixed primary colors projected on to the plate from the side of a zinc oxide binder layer 12. The blue light thus is incident on layer 12 and is selectively absorbed by the layer causing it to be conductive in response to photon excitation whereby the negative charge on the layer is selectively dissipated by photoconductivity in accordance with and in proportion with the incident blue light. The remaining light image, including the primary color green is transmitted through layer 12 and through transparent support base 11 whereupon it becomes incident on layer 13. At layer 13 at least the green light incident on the layer similarly selectively dissipates the charge on this layer. Optionally, and as is the case in this illustrated embodiment of the invention, layer 13 may be insensitive to the third primary color whereby red light is immaterial in selective dissipation of charge on the layer. If desired, a suitable filter or dye may be incorporated as part of support base 11 to filter out the undesired or red component of the light or such a filter may be employed between the image source and the plate 10. Thus, the transparent plate 11 may be green so as to transmit substantially exclusively the primary color to which layer 13 is sensitive or a cyan filter may be employed between the image source and plate 10 to block the passage of red light. In this latter case base 11 may also contain a blue absorbing dye or filter. If transparent plate 11 is of composite construction a sheet of color filter material may be interposed between the elements thereof.

In addition to their function of completely blocking undesired primary colors either or both of the above described filter means may be chosen to partially absorb selected wavelengths to which the photosensitive layers are unduly sensitive thereby achieving more uniform response of the layers to the various wave-lengths of light comprising the primary colors to which the layers are intended to respond.

Upon completion of charging and exposing the blue electrostatic image on layer 12 and the green electrostatic image on layer 13 may be developed by suitable

means. For example, a powder of color complementary to the primary light of exposure and charged to polarity opposite to the polarity to that of the photosensitive layer may be passed across the surface of the layer to adhere selectively to the charged areas in proportion to the charge. In the case of layer 12 the blue image is developed with a yellow colored powder and the green image developed with a magenta powder. This development can be carried out by any suitable development methods, such as, for example, methods described in Carlson 2,297,691 and Carlson 2,221,776 or the methods of Wise 2,618,552. According to a preferred embodiment of xerographic development operations, the xerographic latent images were developed by placing them in a development zone with a closely spaced conductive surface or development electrode about $\frac{1}{40}$ -inch removed from the image surface and passing between the two surfaces a cloud or gas suspension of finely divided charged powder particles as shown in Landrigan et al. 2,725,304.

Where it is desired to develop a xerographic image by deposition of charged particles on the charged plate areas, this may be accomplished by maintaining the backing member of the xerographic plate and the development electrode at substantially the same electric potential. Where, on the other hand, it is desired to produce a reversal print in which developer particles are deposited on the relatively uncharged areas and the charged areas are maintained substantially free from deposit, this may be accomplished by biasing the development electrode at substantially the highest potential of such charged areas.

According to the example illustrated above, the first photoconductive layer 12 contains a residual charge image of negative polarity corresponding to the areas in which there is substantially no blue light incident on the layer. Accordingly, these areas are developed with yellow powder charged to positive polarity and caused to deposit on the image layer in the charged areas. The second xerographic image on layer 13 corresponds to positively charged areas formed in the same manner from an originally positively charged surface. These areas, therefore, are developed with negatively charged magenta powder particles which are introduced between the image layer and the development electrode. There are formed in this manner developed images of colors complementary to the two primary colors. These images are therefore transferred to a single support base, in register, to form a two-color xerographic print.

Image transfer may be accomplished by laying an image support layer, such as a sheet of paper, on the photosensitive coating, applying to the back of the layer as by a corona discharge device an electrostatic charge of the same sign as was used to charge the photosensitive coating and stripping the image support layer with the image now adhering to it from the photosensitive coating. Since the two images on the xerographic plate are in mirror image relation to each other they must either be transferred to opposite sides of a transparent support layer or one of them must be reversed before it can be superimposed upon the other. This may be done by transferring one image to a sheet of paper or the like by the method described above and transferring the second image to an intermediate support such as another sheet of paper or preferably a sheet of transparent plastic such as cellulose acetate. The side of the intermediate support bearing the second image is then laid on the first image and an electrostatic charge of sign opposite to that first used is applied to the back of the intermediate support, driving the second image onto the first. The intermediate support is then removed leaving the two images superimposed in register. The resulting image may be sprayed with clear lacquer to prevent smudging.

In Fig. 2 is illustrated a further photosensitive member by means of which the third primary color may be added to the xerographic system hereinbefore disclosed. Shown in Fig. 2 is a second xerographic plate generally

designated 24 comprising a conductive support base 25 and a photoconductive insulating coating or layer 26 sensitive to at least the third primary color. Thus, in the event that the plate illustrated in Fig. 1 is sensitive to the two primary colors, blue and green, then layer 26 is sensitive to the third primary color, red. Photoconductive materials which possess red sensitivity include, for example, silicon, tellurium, tellurium-selenium mixtures, and many photoactive materials of the so-called phosphor classes, including, for example, certain of the photoactive oxides, sulfides, selenides and silicates of cadmium, zinc, calcium, and the like. For example, in a preferred embodiment of the invention a xerographic plate was prepared by first evaporating onto a clean brass surface a 50 micron layer of substantially pure selenium at a backing plate temperature of about 60° C., followed by evaporating a 2 micron layer containing substantially 90 percent selenium and 10 percent tellurium, directly on the freshly deposited selenium layer without breaking the vacuum. The xerographic plate thus prepared was highly sensitive to red light.

This plate is charged to a positive potential of 150 volts and exposed through a red filter to the same light image of mixed colors as plate 10. In this manner only the third or red primary color is incident on the xerographic plate 24. There is thus formed a xerographic or electrostatic latent image corresponding to this third primary color and this image is developed in the same manner with developer material complementary to the primary color. Thus, in the case of the red image a cyan colored developer material is employed. This cyan image is then transferred to the support base in register with the images already thereon.

While there are innumerable combinations of wavelengths corresponding to any particular sensation of color, the terms blue, green and red have been used in accordance with the usual terminology of color photography to mean short, intermediate, and long wavelengths of visible light, respectively, and blue, green, and red filters or dyes are those which transmit the indicated portions of the spectrum to the exclusion of others. Similarly, yellow, magenta, and cyan dyes, filters, or pigments are those which selectively absorb the short, intermediate, and long wavelength portions respectively of the visible spectrum.

It will be obvious that numerous modifications may be made in the present invention without departing from the present scope thereof. For example, xerographic development may be carried out according to subtractive color principles with the use of colors complementary to the three primary colors or alternatively additive development may be employed with developers of the primary colors themselves. Thus, for example, added brilliance may be achieved through the use of a colored glass developer or the like.

In like manner, the photoconductors may be first charged to a desired electric potential and polarity and then placed in position as illustrated in Fig. 1. Alternatively, any or all of the photoconductors may be placed in position in an uncharged condition and a field applied thereto by means of an electric potential maintained between support member 11 and an adjacent plane electrode which must be transparent if it is to be used adjacent to layer 12. These and other modifications and variations will be within the scope of the present invention.

What is claimed is:

1. The process of color xerography comprising projecting a light image consisting of a pattern of light and shadow of at least a first and a second primary color onto and through a first photoconductive insulating layer adherent on a substantially transparent conductive member and onto a second photoconductive insulating layer adherent on the opposite side of said member while maintaining an electric field through said layers to form an electrostatic latent image thereon, said first photoconductive layer being conductively sensitive to light of at least

one first primary color and both substantially transparent to and substantially insensitive to light of at least one second primary color, said second photoconductive insulating layer being conductively sensitive to light of at least said second primary color, one of said photoconductive layers consisting essentially of a dispersion in a transparent insulating binder of a material selected from the group consisting of zinc oxide, cadmium sulfide, mixed zinc sulfide-cadmium sulfide, zinc sulfide, zinc selenide and titanium dioxide, and the other of said photoconductive layers consisting essentially of a material selected from the group consisting of vitreous selenium, a dispersion of mixed cadmium selenide-zinc selenium in a transparent insulating binder, a dispersion of mixed lead oxide-zinc oxide in a transparent insulating binder, and a dispersion of mixed mercuric sulfide-zinc oxide in a transparent insulating binder, developing said latent images with colored finely divided particles of colors complementary to said first and second primary colors respectively, and superposing the developed color image for the first primary color with the developed image for the second primary color on a common support layer.

2. The process of color xerography comprising projecting a light image consisting of a pattern of light and shadow of at least a first and a second primary color onto and through a first photoconductive insulating layer adherent on a substantially transparent conductive member and onto a second photoconductive insulating layer adherent on the opposite side of said member while maintaining an electric field through said layers to form an electrostatic latent image thereon, said first photoconductive layer being conductively sensitive to light of at least one first primary color and both substantially transparent to and substantially insensitive to light of at least one second primary color, said second photoconductive insulating layer being conductively sensitive to light of at least said second primary color, said transparent conductive member being substantially transparent to the primary color of photosensitivity of said second photoconductive insulating layer and substantially opaque to the primary color of photosensitivity of said first photoconductive insulating layer, one of said photoconductive insulating layers comprising vitreous selenium and the other of said photoconductive insulating layers comprising zinc oxide in a transparent insulating binder, developing said latent images with colored finely divided particles of colors complementary to said first and second primary colors respectively, and superposing the developed color image for the first primary color with the developed image for the second primary color on a common support layer.

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