

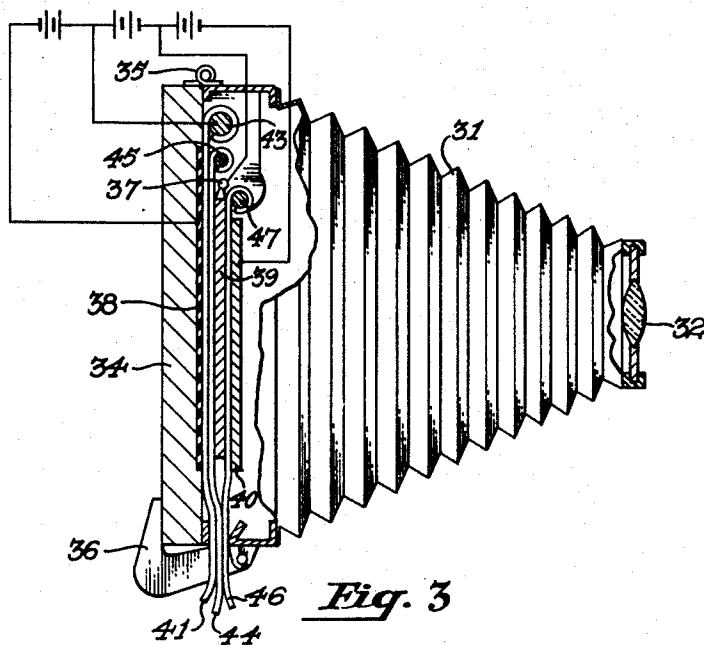
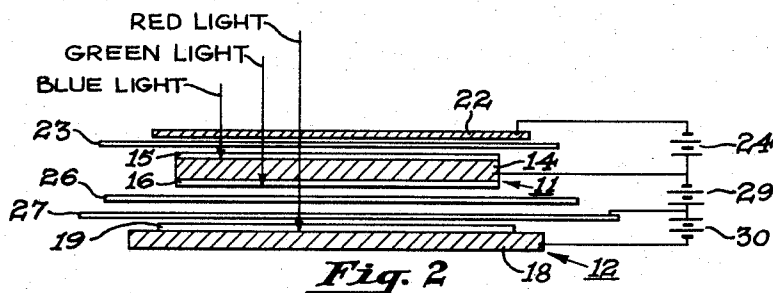
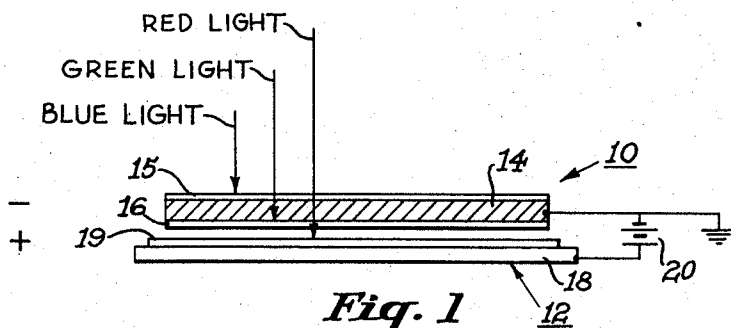
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COLOR XEROGRAPHY

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1

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COLOR XEROGRAPHY

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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 full 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, method and apparatus for three color xerographic reproduction.

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

It is a still further object of the invention to provide new means, method and apparatus for color xerography 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 one embodiment of an apparatus according to the present invention.

Fig. 2 is a diagrammatic view of apparatus according to another embodiment of the invention.

Fig. 3 is a diagrammatic view of a three-color xerographic camera.

In Fig. 1 there is illustrated a three-color xerographic system generally designated 10 comprising a first xerographic plate 11 and a second xerographic plate 12 arranged one above the other, in laminated or sandwich configuration. The first xerographic plate 11 comprises a transparent conductive support layer 14 having on one surface, such as, for example, its upper surface, a photoconductive layer 15 and on another surface, such as, for example, its lower surface, a second photoconductive layer 16. Positioned directly adjacent to this first plate

2

and with its surface spaced extremely closely to the first plate, is a second xerographic plate 12 comprising a conductive support surface 18 having on one surface such as, for example, its upper surface, a third photoconductive layer 19 positioned closely against the second photoconductive layer 16. A power supply 20 is operably connected to supply a potential difference between conductive members 14 and 18 with, optionally, one of these members being operably connected to ground potential.

The first photoconductive layer 15 comprises a thin layer of a material which is normally insulating and is conductively sensitive to light of one and substantially only one 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 electrostatic potential and to selectively dissipate this 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 in an insulating transparent binder is characterized by being conductively sensitive to blue light and substantially insensitive to light of other primary colors. According to a further embodiment of the invention, layer 15 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. Other layers, such as, for example, cadmium sulfide or binder coatings of other photoactive oxides, sulfides, silicates and selenides of cadmium, zinc, calcium, magnesium, titanium, and the like, including zinc sulfide, zinc selenide, mixed zinc sulfide-cadmium sulfide, and titanium dioxide, are also characterized by appropriate monochromatic sensitivity.

The second photoconductive layer 16 comprises a normally insulating layer conductively sensitive to light of a second primary color and substantially transparent 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 16 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 15 comprises a zinc oxide binder layer as illustrated, then the second layer 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 transparent to red light. Thus, for example, a layer of vitreous selenium about 10 to 20 microns thick deposited under vacuum conditions at a substrate temperature of about 40° C. to 60° C. is conductively sensitive to green light and permits passage through the layer of a large proportion of a red light component. Other green photoconductive layers include binder coatings of mixed cadmium selenide-zinc selenide, mixed lead oxide-zinc oxide, and mixed mercuric sulfide-zinc oxide.

The conductive support 14, on which layers 15 and 16 are disposed, is a transparent conductive material such as, for example, conductive glass having a conductive coating on each surface thereof. In a preferred embodiment of the invention the glass is tinted to a color complementary to the primary color of sensitivity of layer 15. Thus, for example, if layer 15 comprises a zinc oxide binder coating then the glass member 14 desirably will be tinted yellow so as to absorb substantially all blue radiation that is passed through photoconductive layer 15.

Positioned directly adjacent to the first xerographic plate 11 is a second xerographic plate 12 with its photo-

conductive layer 19 facing photoconductive layer 16. Desirably, the two xerographic plates are placed as close together as possible, first for the purpose of applying as intense as possible an electric field through layers 16 and 10 with a moderate potential difference between their conductive backing layers and, second, for the purpose of increasing the sharpness of focus on these two photoconductive layers. The space may vary from several microns to a moderately large fraction of an inch, such as $\frac{1}{8}$ or $\frac{1}{4}$ inch, but preferably is about $\frac{1}{100}$ to $\frac{1}{20}$ inch. The conductive backing member 18 may be any suitable conductive material as desired and may either be transparent or opaque so as to include conductive glass and metals, such as, for example, aluminum, brass, ferrous metals and the like, and to include flexible materials such as paper, conductive plastics and conductive metal foils and the like.

Disposed on the upper surface of layer 18 is a third photoconductive layer 19 which is sensitive to at least the third primary color of light. Thus, for example, if as illustrated, layer 15 is conductively sensitive to blue light and layer 16 is conductively sensitive to green light, then layer 19 will be conductively sensitive to at least red light. 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, the photoactive oxides, sulfides, selenides, tellurides and silicates of cadmium, indium, arsenic, mercury, zinc, calcium, and the like including indium triselenide, arsenic triselenide, mercuric sulfide and mixed zinc telluride-cadmium telluride. 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.

In operation of the device illustrated hereinabove, an electric charge of about 150 volts of negative polarity was placed on layer 15 by suitable means such as, for example, the charging methods illustrated in Carlson Patent 2,588,699 wherein an ion source such as a corona discharge electrode may be passed across the surface to be charged. Xerographic plate 11 was then placed in position above the second xerographic plate 12 at a space about $\frac{1}{100}$ " away from the second plate and the conductive backing members 14 and 18 were connected to the voltage source 20 to apply a potential difference of about 1,000 volts between the backing members. The potential difference may operably be either positive or negative, but in the specific example, xerographic plate 11 was about 1,000 volts negative with respect to xerographic plate 12. For this purpose, there were employed xerographic plates hereinbefore specifically disclosed, including a first plate having a first layer of zinc oxide in a transparent insulating binder and a second layer of selenium in conjunction with a second plate having a photoconductive insulating layer including a surface layer of mixed selenium and tellurium.

The three xerographic layers with the electric field applied therethrough were then simultaneously exposed to a three-color light image by projecting the image on the upper or first photoconductive layer 15. The result of the combined exposure and electric field caused electric charge to be carried through layer 15 in the areas at which blue light was incident to form at the surface of the layer a residual charge image of negative electric charge corresponding to the areas not receiving blue light. Simultaneously, the blue light was absorbed either by the absorption of photon energy necessary to the activation of this first photo-conductive layer, or by the yellow coloring in the glass plate 14. Thus, simultaneously with the

exposure of photoconductive layer 15 to blue light, there occurred the exposure of the second photoconductive layer 16 to combined red and green light. The exposure of this second layer to green light under the conditions of electric field caused electric charge to migrate through this layer to form on the surface of the layer a charge pattern corresponding to the areas of conductivity. Thus, there was formed a developable xerographic latent image on the second or selenium layer. The red light passed through the substantially red-transparent selenium layer without excessive absorption and had no detectable electrical effect on this substantially red insensitive selenium layer.

Thus, at the same time, the selenium layer in addition to forming a xerographic latent image, also absorbed the incident green light and transmitted the incident red light so that a pattern consisting substantially exclusively of red light emerged from the first xerographic plate to be projected on the second plate. In this manner, the third photoconductive insulating layer 19 received an incident pattern of red light corresponding substantially to the red light component in the original light image. Under the same influence of exposure of electric field this caused the formation of a third developable xerographic latent image on the surface of layer 19.

Upon completion of the steps of exposure to light and electric field, the three xerographic latent images were separately developed. This development can be carried out by any suitable development method, 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 $\frac{1}{40}$ " removed from the image surface and passing between the two surfaces a cloud or gas suspension of finely divided charged powder particles. 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. The method of and apparatus for such development of xerographic latent images is further disclosed in a co-pending application S.N. 244,556, now Patent No. 2,725,304, issued on November 29, 1955.

According to the example illustrated above, the first photoconductive layer 15 contained a residual charge image of negative polarity corresponding to the areas in which there was substantially no blue light incident on the layer. Accordingly, these areas were 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 16 corresponded to positively charged areas formed by the combined action of electric field and conductivity to draw electric charge to the surface. These areas, therefore, were developed with positively charged magenta powder particles which where introduced between the image layer and the development electrode, while the development electrode was biased to substantially the highest potential of the image layer. Similarly, the image on layer 19 corresponded to a pattern of red light in which the exposed areas contained the highest positive charge potential and this image layer, therefore, was developed under conditions similarly used for layer 16 with negatively charged cyan colored powder particles.

There were formed in this manner three developed images of colors complementary to the three primary colors.

5

These images were therefore transferred to a single support base, such as, for example, a base of dye transfer paper, in register, to form a three-color xerographic print. A sheet of moistened dye transfer paper was rolled against layers 15 and 19, causing the images thereon to adhere to the dye transfer paper. The image on layer 16, being in mirror reversed relation to the other images, was first electrostatically transferred to a sheet of cellulose acetate by laying the acetate on layer 16, passing a negative corona discharge electrode over the exposed surface of the acetate, and separating the acetate from layer 16. The cellulose acetate sheet was then rolled against the dye transfer paper to form the third superposed color image. The images may be protected from smudging or other mechanical damage by applying a coating of transparent lacquer.

In Fig. 2 is illustrated a second embodiment of the present invention. According to this embodiment, a xerographic plate 11 and a second xerographic plate 12 may optionally be the same plates as are of those in Fig. 1. A first plate 11 may comprise a transparent conductive support 14 bearing a first photoconductive layer 15 and a second photoconductive layer 16 of the type described in connection with Fig. 1. Similarly, the second xerographic plate 12 may comprise a conductive base 18 and a photoconductive layer 19 on its surface. Disposed above the first xerographic plate 11 is a transparent conductive electrode 22 such as, for example, a plate of conductive glass at least the lower surface of which is electrically conductive.

Positioned between the first xerographic plate 11 and the conductive electrode 22 is a transparent insulating sheet or web 23. The conductive electrode and the xerographic plate desirably are relatively movable toward each other so as to permit sheet 23 to be retained between the two members in relatively firm surface contact. A suitable power supply 24 is operably connected between the conductive member 14 of the xerographic plate and the conductive electrode 22 so as to apply an activating potential between the two members. This may, for example, be a potential on the order of about 750 volts.

Positioned between the lower surface of the first xerographic plate 11 and the upper surface of the second plate 12 are two transparent insulating sheets or webs 26 and 27, web 26 being positioned substantially in contact with the second photoconductive layer 16 and web 27 being substantially in contact with the third photoconductive layer 19. Desirably, one or both of the inner surfaces of the webs, or those surfaces that are in contact with each other, may be conductively coated with a transparent conductive coating so as to form a uniform conductive surface between and insulated from photoconductors 16 and 19. A suitable power supply 29 is connected between the first xerographic plate 11 and this intermediate electrode as formed by the surface of layer 26 or 27 and a second power supply 30 is connected between the same surface and the second xerographic plate 12. Each of these potential sources 24, 29 and 30, may be of a suitable voltage, such as, for example, about 750 volts, and the insulating sheets 23, 26, and 27 may be .001" Mylar, a polyester film made by DuPont.

In use and operation the parts of the apparatus illustrated in Fig. 2 are placed in position as illustrated and are pressed together into moderately firm contact, while the different potentials are applied to the conductive electrodes. Thus, a field is applied from the backing member 14 of the first plate through photoconductor 15 to and through sheet or web 23 and to electrode 22, thus applying a field from the photoconductor to the insulating web. Similarly, a second field is applied from this same backing plate through the second photoconductor 16 to and through sheet or web 26. Likewise, a third field is applied through photoconductor 19 to sheet or web 27. Under these conditions of applied electric field, the system is exposed to a three-color light image as in the case

6

of the apparatus and device illustrated in Fig. 1 to activate the first photoconductive layer with a pattern of light and shadow corresponding to a first primary color and to activate the second and third layers respectively with patterns of light corresponding to a second and a third primary color. There is formed in this manner on the three insulating webs 23, 26 and 27, developable xerographic latent images corresponding to the three primary colors, the images having relatively highly charged areas corresponding to those areas of highest intensity of light of the appropriate primary color and having relatively low potential on uncharged areas corresponding to the appropriate dark areas.

The resulting three xerographic latent images were developed in the manner previously illustrated and were superposed to form a three-color xerographic print.

In Fig. 3 is illustrated a camera operable according to the methods of Fig. 2. As illustrated, there is a camera housing, including, for example, bellows 31 supporting exposure means such as a lens 32 with suitable shutter mechanism as is conventional in the camera art. Positioned to make a light seal with the bellows is a rear panel 34, operably mounted on a hinge 35 and secured by a catch member 36. Mounted on a hinge 37 adjacent to the back panel is a xerographic plate 39 adapted to be positioned closely adjacent to the back panel. Positioned in front of plate 39 is a transparent conductive electrode 40. On the inside surface of rear panel 34 is a photoconductive layer 38. Passing between this photoconductive layer and the xerographic plate 39 is a first insulating web 41 held on a conductive feed roll 43 and a second web 44 from a feed roll 45. The surface of web 41 which contacts web 44 is coated with a transparent conductive coating. A third web 46 held on a conductive feed roll 47 passes between the xerographic plate 39 and the electrode 40. These three webs pass out of the camera housing through a slit having at least one cutting or tearing edge 41.

In accordance with Fig. 2, it is observed that the xerographic plate 39 has a first photoconductive layer facing the lens, this layer corresponding in properties and function to layer 15 of Fig. 2. Similarly, on the opposite side of the plate 39 is a second layer corresponding in characteristics and functions to layer 16. Similarly, the photoconductive layer 38 on the back plate 34 corresponds in properties and functions to layer 19 of Fig. 2 and may, if desired, be a removable xerographic plate. Suitable power supply means are operably connected to the conductive surfaces through the conductive feed rollers as shown in Fig. 3.

In use and operation the camera of Fig. 3 is suitably aimed and focused and the shutter mechanism is released while operating electric potentials are applied to the electrode members. This results in the formation of developable xerographic latent images on the three webs. The image bearing webs are then withdrawn through the exit slit where they may be torn or cut. These image bearing sheets are light insensitive and may, therefore, be developed in suitable external apparatus.

It will be obvious that numerous modifications may be made in the present invention without departing from the present scope thereof. For example, there have been illustrated methods, means and apparatus for the formation of the xerographic latent image directly on the xerographic plates and alternative methods and apparatus for the formation of these latent images on adjacent insulating members. It will be obvious also that suitable filter layers may be employed where necessary, in the event that the photoconductive layers themselves do not fully absorb light of the primary color to apply their sensitivity. Thus, for example, a selenium layer is substantially opaque to all incident light except red light. If, however, a different green sensitive photoconductor is applied which transmits appreciable green light, it may be necessary or desirable to place between

layer 16 and 19 an appropriate green absorbing filter layer which may be in the form of a permanent overcoating on layer 16 or alternately in the form of a red dye or the like incorporated in either film 26 or 27 of Fig. 2. Likewise, the conductive base plate 14 of the first xerographic plate may be appropriately colored so as to absorb light of the first primary color, or alternately, a separate filter layer may be employed between layers 15 and 16. Similarly, xerographic developments 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, one or all of 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 adjacent electrode. Thus, the conductive backing members 14 and 18 of the two xerographic plates may be such field generating members and electrode 22 may be another. Similarly layers 16 and 19 may be exposed to form an electrostatic latent image thereon by first retaining between the two layers in firm surface contact a sheet of transparent insulating material which has previously received an electrostatic charge on each of its surfaces.

What is claimed is:

1. A single step exposure method for three-color xerography to form images developable with electroscopic marking material comprising positioning in contacting laminar configuration first a first transparent conductive electrode, second a first electrically insulating sheet, third a first xerographic plate including a transparent conductive support a first photoconductive insulating layer coated on one surface of said support and contacting said first insulating sheet and a second photoconductive insulating layer coated on the opposite side of said transparent support member, fourth a second electrically insulating sheet contacting said second photoconductive insulating layer, fifth a third electrically insulating sheet in surface contact with said second insulating sheet, and sixth a second xerographic plate including a conductive support member and a photoconductive insulating layer coated thereon contacting said third insulating sheet, said first photoconductive layer being conductively sensitive to light of substantially only a first primary color and substantially transparent to light of other primary colors, said second photoconductive insulating layer being conductively sensitive to light of a second primary color and substantially transparent to light of a third primary color and said third photoconductive insulating layer being conductively sensitive to light of a third primary color, applying a voltage between said transparent conductive electrode and the transparent conductive support member of the first xerographic plate and between said transparent conductive support member and the support member of the second xerographic plate, and projecting a light image to be reproduced onto said transparent conductive electrode while said voltages are maintained to thereby form an electrostatic latent image corresponding to a different primary color on each of said three insulating sheets.

2. The process of color xerography comprising projecting a light image consisting of a pattern of light and shadow of three primary colors onto and through a first photoconductive insulating layer adherent on a substantially transparent first conductive member and onto a second photoconductive insulating layer adherent on the op-

posite side of said member and onto a third photoconductive insulating layer facing and adjacent to said second photoconductive insulating layer and adherent on a second conductive member while maintaining an electric field through said layers to form electrostatic latent images thereon, said first photoconductive insulating layer being conductively sensitive to light of one primary color and both substantially transparent to and substantially insensitive to light of a second and third primary color, said second photoconductive insulating layer being conductively sensitive to light of a second primary color and both substantially transparent to and substantially insensitive to light of a third primary color, said third photoconductive insulating layer being conductively sensitive to light of the third primary color, one of said photoconductive layers being a dispersion in an insulating binder of a material selected from the group consisting of photoconductive oxides, sulfides, silicates and selenides of cadmium, zinc, calcium, magnesium, and titanium, another of said photoconductive layers being selected from the group consisting of vitreous selenium, a dispersion in an insulating binder of mixed cadmium selenide-zinc selenide, a dispersion in an insulating binder of mixed lead oxide-zinc oxide, and a dispersion in an insulating binder of mixed mercuric sulfide-zinc oxide, and the other photoconductive layer being selected from the group consisting of tellurium-selenium mixtures, and photoconductive phosphors selected from the group consisting of photoconductive oxides, sulfides, selenides, tellurides and silicates of cadmium, indium, arsenic, mercury, zinc, and calcium, developing each of said latent images with colored finely divided particles of colors complementary to said first, second and third primary colors respectively and superposing the developed colored images on a common support layer.

3. The method of claim 2 in which one of said photoconductive layers comprises vitreous selenium, another of said photoconductive layers comprises zinc oxide in an insulating binder, and the other photoconductive layer comprises a tellurium selenium mixture.

4. The method of claim 1 in which one of said photoconductive layers comprises vitreous selenium, another of said photoconductive layers comprises zinc oxide in an insulating binder, and the other photoconductive layer comprises a tellurium-selenium mixture.

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