

[54] X-RAY COLOR ELECTROPHOTOGRAPHY

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1971, abandoned.

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[58] Field of Search 96/1.2; 117/17.5; 250/315,
250/315 A

[56]

References Cited

UNITED STATES PATENTS

2,817,598	12/1957	Hayford	117/17.5
2,859,352	11/1958	Sugarman, Jr.	250/315
3,057,720	10/1962	Hayford et al.	96/1.2

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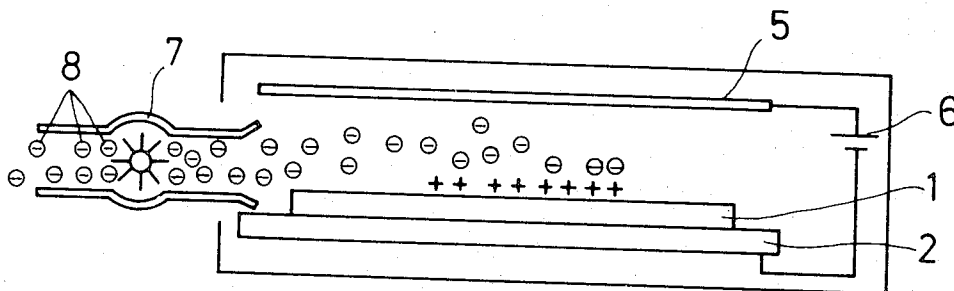
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[57]

ABSTRACT

An electrostatic latent image formed on a photoconductive layer by means of X-ray electrophotography is divided into at least two regions by the degree of electrostatic potential, said regions being represented by different colors after being developed by depositing a different color developer powder on each of said regions.

7 Claims, 8 Drawing Figures



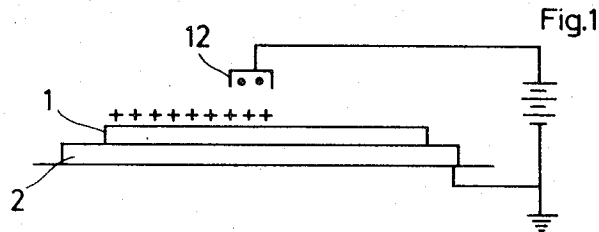


Fig. 1

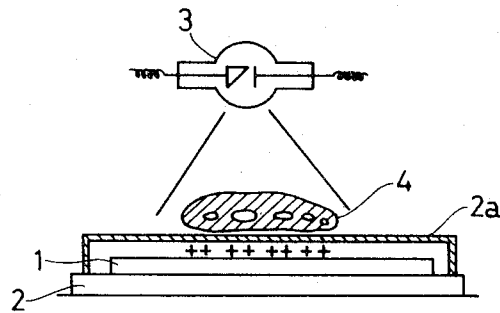


Fig. 2

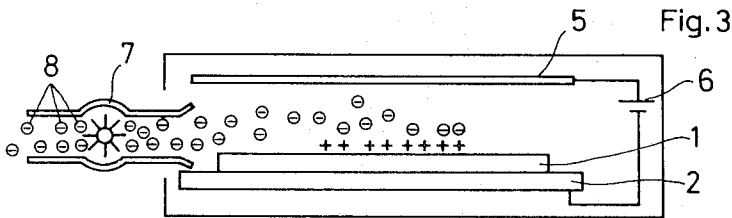


Fig. 3

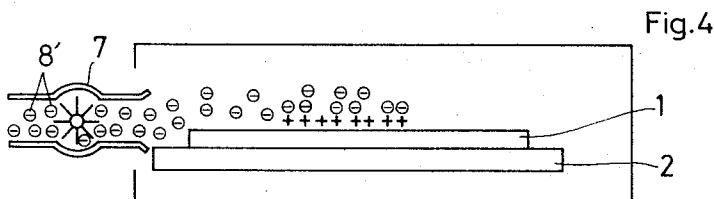


Fig. 4

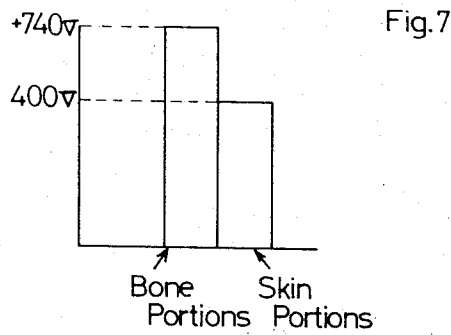
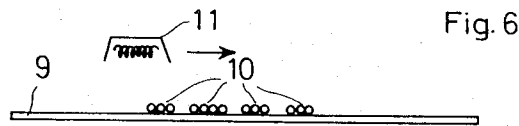
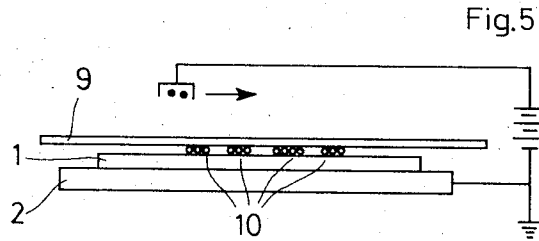
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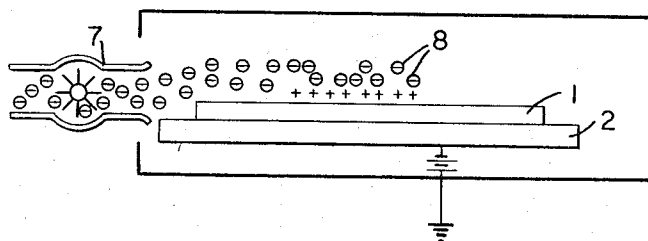


Fig. 8

X-RAY COLOR ELECTROPHOTOGRAPHY

This application is a continuation-in-part application of my application, Serial No. 130,820, filed April 2, 1971, now abandoned which claims the priority of Japanese Application 29052/1970 filed Apr. 7, 1970.

The present invention relates to an X-ray photography in which the image reading capability can be extremely enhanced by coloring an X-ray electrophotograph with two or more colors.

According to the X-ray electrophotography in the prior art, a photo-sensitive plate prepared by depositing amorphous selenium onto an aluminum base plate through evaporation within a vacuum was charged by corona discharge in a dark space, shielded from a visible light, loaded with a subject to be photographed thereon, and then irradiated with X-rays. The X-rays passed through the subject irradiate the selenium surface with doses at the respective portions which are reduced as the absorption at the corresponding subject portions increases. Since the surface potential of the selenium is decayed depending upon the amount of doses of the X-rays at the respective portions, an electrostatic latent image of the internal structure of the subject may be formed on the selenium surface.

At this stage of processing, if developer powders bearing an electric charge of opposite sign to that of the electrostatic latent image are dispersed on the selenium layer, then the developer powders are attracted to said selenium surface at a density corresponding to the magnitude of the surface potential at the respective portions, whereby the latent image can be visualized.

After this visualized image has been electrostatically transferred to a transfer sheet, if it is fixed by a means of a heat or a solvent vapor, a permanently preservable X-ray image can be obtained.

Heretofore, the developer powders were monochromatic powders of the order of 5 to 20 μ in size and colored black, blue or white, and consequently, the reading of the image has been done on the basis of the difference in density at the various portions.

In the X-ray electrophotography, the contrast of the finished image is far weaker than that of a silver salt emulsion film. However, on the other hand, due to the edge effect which is inherent to the electrophotography, the edges of the subject were developed distinctly, so that an easily readable image was obtained. In other words, upon reading the image, mainly the contour of the subject has been watched rather than reading the image of the subject on the basis of the difference in density.

As described, although it is possible to identify the contour of the subject by means of the developer of only one color, the present invention has made an improvement in that said contour is further emphasized with the difference in color so as to be identified more readily.

More particularly, the present invention has enhanced the image reading capability by dividing the image into a plurality of sections depending upon the difference in the surface potential caused by the difference in the dose of absorbed X-rays, one section being deposited with developer powders of two or more colors while the other section being deposited with those of only one color, and by making the internal structure within the subject clearly distinguishable on the basis of

the difference in color caused by the color mixing principle.

These and other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a schematic view illustrating the step of charging the surface of the photo-sensitive plate with a corona discharge,

FIG. 2 is a schematic view illustrating the step of irradiating the subject placed on the cassette containing the photosensitive plate according to the present invention,

FIGS. 3 and 4 are schematic views illustrating the successive steps of developing the latent electrostatic image on the photosensitive plate according to the present invention,

FIG. 5 is a schematic view illustrating the step of electrostatically transferring the developed visible image onto a separate transfer sheet.

FIG. 6 is a schematic view illustrating the step of fixing the transferred visible image by thermal means, and

FIG. 7 is a diagram showing a potential distribution formed on the selenium surface after the X-ray irradiation,

FIG. 8 is a schematic view illustrating the step of negatively charging the aluminum plate for selectively depositing the developing powder.

Referring now to the accompanying drawings, reference numeral (1) designates a selenium layer deposited onto a thin aluminum plate (2) by evaporation. Reference numeral (2a) designates a cassette cover plate for enclosing the charged photo-sensitive plate (1), (2). Reference numeral (3) designates an X-ray tube, numeral (4) designates a subject to be photographed, numeral (5) designates an opposite electrode to be opposed to the selenium layer (1) and is connected with the aluminum plate (2) through a power supply (6) upon developing, numeral (7) designates a developer device according to the powder cloud method, numerals (8) and (8') designate developer powders, numeral (9) designates a transfer sheet for transferring an image (10) thereto, numeral (11) designates a heat source for fixing the image (10), and numeral (12) designates a corona discharge device for charging the selenium layer (1).

Now examples of the X-ray color electrophotography according to the present invention will be described hereinafter.

EXAMPLE 1

On the surface of an aluminum plate (2) of 1.4 mm in thickness, is deposited a selenium layer (1) of 160 μ in thickness by evaporation. This selenium layer (1) is charged in a dark space with a corona discharge as shown in FIG. 1 so that the surface potential may attain +1000V. After the charged photo-sensitive plate (1), (2) has been enclosed by the cassette cover plate (2a), a hand articulation portion (4) is placed on said cassette cover plate (2a) as shown in FIG. 2, and irradiated with X-rays of 70 KV peak in tube voltage and 100mA in tube current for 0.14 seconds at a distance of 1m from the X-ray tube (3). Then the surface potential of the selenium layer (1) is reduced to 740V at the portions corresponding to the bones and to about 400V at other portions corresponding to the vessels, skins, etc. Diagrammatically representing the potential distri-

bution of such an electrostatic latent image, it shows a potential distribution as illustrated in FIG. 7. In other words, between the portions for the bones and the remaining portions, there exists a potential difference of about 340V.

Here, as a method for developing this electrostatic latent image to visualize the same, the powder cloud method of blowing type is employed. In the first step of development, the opposite electrode (5) is disposed apart from the selenium layer (1) by 1 cm as shown in FIG. 3, a bias voltage of +600V being applied thereto, and the latent image is developed by means of negatively charged blue developer powders (8). Then, the blue developer powders (8) are hardly attracted by the selenium surface portions where the surface potential is lower than 600V, while they are attracted only by the portions at a potential higher than 600V such as, for example, the portions corresponding to the bones. Next, in a developer device without the opposite electrode (5) (See FIG. 4), the latent image is developed by means of negatively charged red developer powders (8'). Then said red developer powders are attracted by every portion of the latent image having a positive potential. Subsequently, this visible image (10) is transferred onto a transfer sheet (9) by any known process as illustrated in FIG. 5, and then the developer powders (8) and (8') are respectively heated and thus fixed by means of the heat source (11). Therefore, the portions corresponding to the bones are doubly developed by both the blue developer powders and the red developer powders, resulting in violet images, while other portions such as corresponding to the vessels, skins, etc. are developed only by the red developer powders. Consequently, identification based on colors is enabled, and this results in remarkable enhancement of the image reading capability in comparison to the identification based on only the difference in density in the prior art.

EXAMPLE 2

On the surface of an aluminum plate (2) of 1.4 mm in thickness, is deposited a selenium layer (1) of 280μ in thickness by evaporation in a vacuum. This selenium layer (1) is charged in a dark space so that the surface potential may attain +2,500V. Then, a lower leg injected with 76percent Urograffin as a shadow making agent into the vessel is placed on the cassette cover plate (2a), and irradiated with X-rays of 80 KV peak in tube voltage and 300 mA in tube current for 0.1 seconds at a distance of 1 m from the X-ray tube (3). Then, the surface potential at the selenium layer portion corresponding to the vessel portions containing Urograffin which most hardly passes the X-rays, becomes 1,680V, the portions corresponding to the bones take a potential of 1,370V, and other portions corresponding to the skins take a potential of 1,050V. In case that the electrostatic latent image having such a potential distribution is developed by making use of the opposite electrode (5) similarly to the Example 1, at first a voltage of +1500V is applied to the opposite electrode and the latent image is developed by means of black developer powders. Then the developer powders are attracted only by the portions at a potential higher than +1,500V mostly corresponding to the vessels containing the shadow making agent. Next, the voltage applied to the opposite electrode is lowered to +1,200V and the latent image is developed by means

of blue developer powders. Then said blue developer powders are attracted by the portions at a potential higher than +1,200V, that is, by the portions corresponding to the vessels and the bones. Finally, the latent image is developed by means of red developer powders without applying a voltage to the opposite electrode. Then the red developer powders are attracted by all the image portions having a positive potential.

In the X-ray electrophotograph finished through the three consecutive steps of development by means of three kinds of developer powders as described above, the image reading capability can be extremely enhanced, because the different portions are discriminated by color in such manner that the portions corresponding to the vessels are black, the portions corresponding to the bones are violet and the portions corresponding to the skins are red. If this visual image is fixed after transferred to a transfer sheet, then a preservable image can be obtained.

The present invention contemplates to cause different colors of developer powders to be selectively attracted by the selenium layer by making use of the difference in surface potential thereof, and the method for development consists of the steps of providing an opposite electrode (5) as opposed to the selenium layer (1), properly selecting the bias voltage applied to said opposite electrode (5) in accordance with the potential on the selenium surface, and making a given color of developer powders to be attracted by the portions of said selenium surface (1) corresponding to said potential. Therefore, the various internal organizations of the subject to be photographed can be transferred and fixed as colored selectively and separately. From such reasons, it is enabled to transfer the various internal organizations of the subject as distinguished, if desired, by various different colors, so that the present invention achieves excellent functions and advantages in that it enables easy image reading with respect to the portions of the human body for which it has been heretofore difficult to read the X-ray images.

EXAMPLE 3

On the surface of an aluminum plate of 1.4 mm in thickness, is deposited a selenium layer of 160μ in thickness by evaporation. This selenium layer is charged in a dark place with a corona discharge as illustrated in FIG. 1 so that the surface potential may attain +1000 V. After that, the selenium layer is irradiated with X-rays in the same manner as in Example 1. Then, the surface potential of the selenium layer is reduced to 740 V at the portions corresponding to the bones and to about 400 V at other portions corresponding to the vessels, skins, etc. The fact indicates that there exists a potential difference of about 340 V between the portions for the bones and the remaining portions. The latent image is visualized by blowing powder cloud thereto. At that time, the aluminum base plate (2) is applied with a potential of -600 V and the latent image is developed by means of negatively charged blue developer powders (8) as illustrated in FIG. 8. Then, the blue developer powders are attracted by the selenium surface portion the surface potential of which is higher than 600 V. Next, the potential applied to the aluminum base plate is taken away and the whole surface of the latent image is treated by means of negatively charged red developer powders. Then, said red developer powders are at-

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tracted by every portion of the latent image having a positive potential. The image is then transferred and fixed onto a transfer sheet as shown in Example 1. Thus, the portions corresponding to the bones are in violet image, while other portions are in red image. This results in remarkable enhancement of the image reading capability in comparison with the identification based on only the difference in density as in the prior art.

While we have described above the principles of our invention in connection with specific apparatus, it is to be clearly understood that the description is made only by way of example and not as a limitation to the scope of our invention as set forth in the accompanying claims.

What is claimed:

1. A method of producing a multi-color X-ray electrophotograph comprising:

charging a photoconductive layer of an X-ray sensitive plate comprising a base and the photoconductive layer,

exposing the charged photoconductive layer to X-rays which have passed through an object to be electrophotographed such that an electrostatic latent image is formed on said photoconductive layer, said image having regions of reduced charge density in accordance with the concentration of exposing X-rays,

injecting a first color developer powder onto the surface of said photoconductive layer, said first powder having an electrical charge of sign opposite to that of the photoconductive layer,

applying an electrical force to said first powder, said force having a magnitude less than the magnitude of the force which the regions of maximum potential exert on said first powder whereby said first powder is deposited only on those regions of said photoconductive layer which exert a force greater than the applied force,

injecting a second differently colored developer powder onto the surface of said layer, said second powder having a charge of the same sign as said first developer powder,

adjusting the magnitude of said applied force to a

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magnitude lower than the magnitude of the force exerted on said second powder by the region on the photoconductive layer having the next highest potential such that said second powder is deposited on all regions of said photoconductive layer which exerts a greater force on said second powder than said adjusted applied force.

2. The method according to claim 1 wherein said photo conductive layer is exposed to said X-rays only once for each multi color electrophotograph.

3. The method according to claim 2, wherein said method further comprises providing a development electrode, placing said first development powder between said electrode and said surface of the photoconductive layer, and the electrical force is applied to said first powder by impressing a potential on said electrode such that said potential has a sign opposite to that of said first powder and exerts on said first powder said electrical force which has a magnitude less than the magnitude of the force which the region of maximum potential exerts on said first powder.

4. The method according to claim 2, wherein the step of applying the electrical force on said first powder comprises impressing a potential on the base such that said potential has the same sign as the sign of said first powder and exerts on said first powder said electrical force which has the magnitude less than the magnitude of the force which the region of maximum potential exerts on said first powder.

5. The method according to claim 3 wherein the step of adjusting the magnitude of the applied force comprises lowering the potential on said electrode to a level lower than the potential on the next highest potential region of said photo conductive layer.

6. The method according to claim 4 wherein the step of adjusting the magnitude of the applied potential comprises lowering the magnitude of the potential impressed on said base to a level lower than the potential on the next highest potential region of said photo conductive layer.

7. A multi-color X-ray electrophotograph produced by the method according to claim 1.

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