United States Patent

Fantuzzo

[15] **3,702,483**

[45] **Nov. 7, 1972**

[54] **COLOR RENDITION METHOD**

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[73] Assignee: **Xerox Corporation,** Stamford, Conn.

[22] Filed: **Dec. 23, 1970**

[21] Appl. No.: **100,982**

[52] **U.S. Cl.**....**346/74 ES,** 101/DIG. 13, 178/5.4 CD, 355/4

[51] **Int. Cl.** **G03g 15/04,** G03g 15/08, H04n 1/46

[58] **Field of Search**.346/74 ES; 355/4; 101/DIG. 13; 178/5.4 CD

[56] **References Cited**

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3,045,644	7/1962	Schwertz	346/74 ES X
3,060,020	10/1962	Greig	101/DIG. 13
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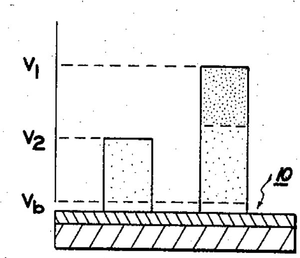
[57] **ABSTRACT**

A simple xerographic color process is herein disclosed for reproducing functional color. An original, containing color information, is recorded on a charged photoreceptor so that each function color found in the original is registered thereon at a discrete charge density level. The plate is then transported through a developing station containing a plurality of developing units, the units being equal in number to the number of functional colors found in the original. Each developing unit has an electrical control means operatively associated therewith to control development whereby only color components recorded at or above a predetermined potential are developed within the unit. The recorded images are developed in a descending order of magnitude whereby different and distinct colors are produced for each color component recorded on the photoconductive element. The final color rendition is transferred, in a single operation, to a sheet of final support material.

12 Claims, 5 Drawing Figures



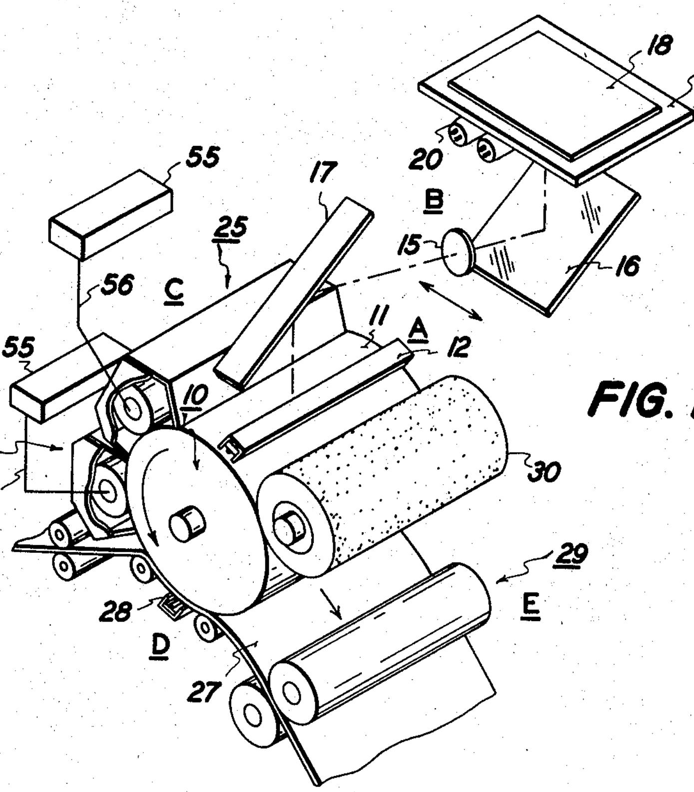


FIG. 1

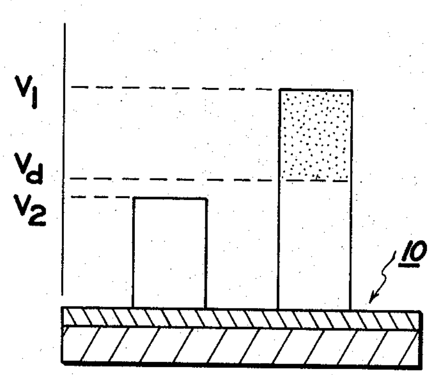


FIG. 4

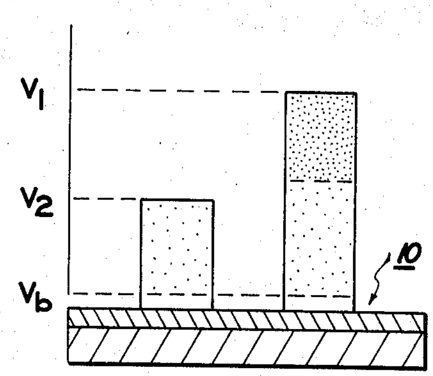


FIG. 5

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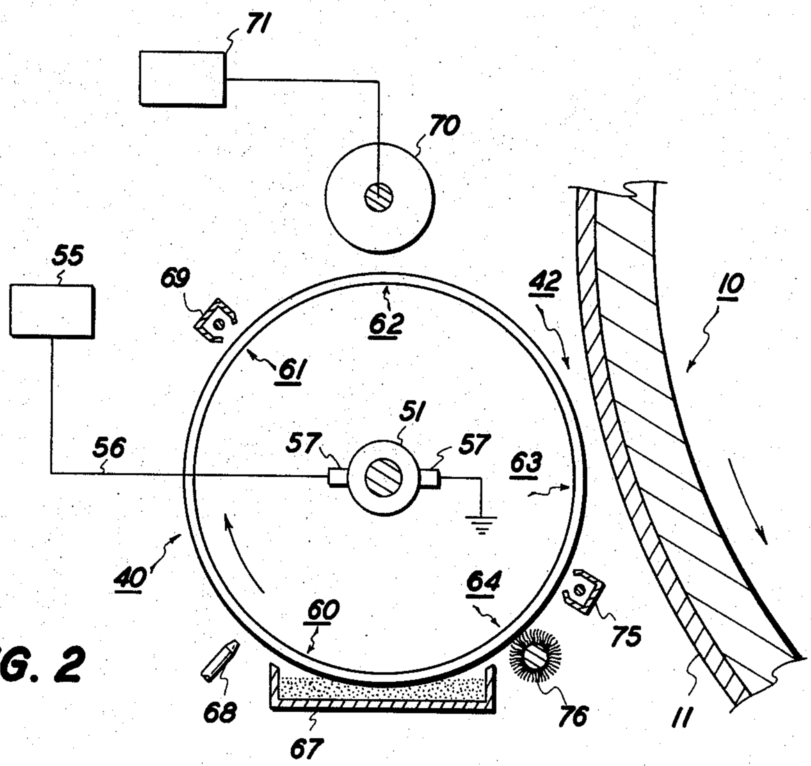
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FIG. 2

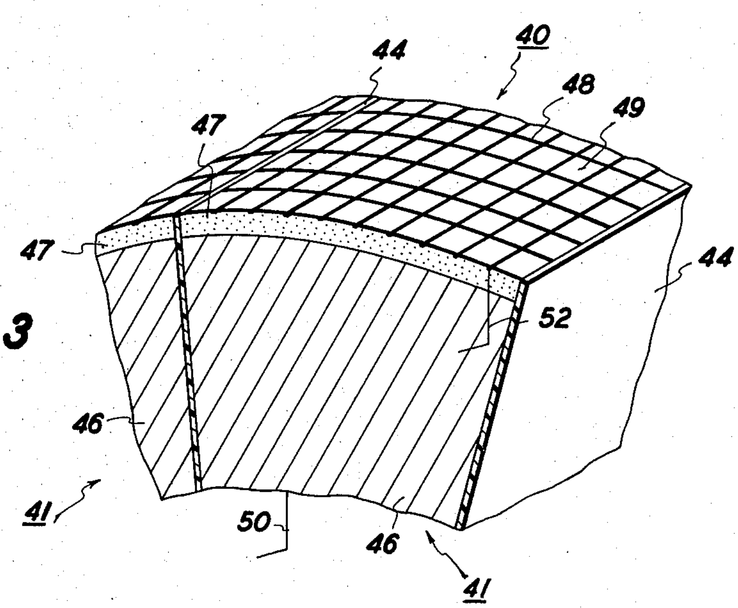
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FIG. 3

COLOR RENDITION METHOD

This invention relates co color copying and, in particular to a simple and efficient means for producing color copy.

More specifically this invention relates to a color process suitable for use in xerography. Basically, in conventional xerography, a photosensitive plate, consisting of a photoconductive coating placed upon a conductive backing, is uniformly charged and the plate then exposed to a light image containing original subject matter to be reproduced. Under the influence of the light image, the charge on the photoconductive member is selectively dissipated in the light struck regions thereby producing a latent electrostatic image of the original. The charged latent electrostatic image is then developed, or made visible, by bringing oppositely charged, finely divided, electroscopic marking particles into operative communication with the plate in a manner so that the charge particles are attracted into the imaged regions. After development, the visible image is transferred to a final support material, such as paper or the like, and the image affixed thereto to form a permanent record of the original.

The basic xerographic process can be adapted to produce full color reproductions by using well known subtractive color printing techniques. It is conventional, in the xerographic subtractive system, to first color separate the original into the primary color components of red, green and blue. Each component is then used to record a separate latent electrostatic image on the surface of a photoconductive plate and the images are developed using toners containing colorants that are the complements of the primary colors recorded. The recorded red, green and blue color components are developed with toner containing the colorants of cyan, magenta and yellow. Each developed image is individually transferred to a sheet of final support material to create a full color rendition of the original. Because of inherent limitations found in most known colorants, it is generally necessary to employ costly and complex masking and/or balancing techniques to achieve a faithful color reproduction. Furthermore, because of the number of exposure and transfer operations involved, registration is also a problem in this type of system.

Any disadvantages that might be associated with the subtractive color printing process are certainly offset by the quality of the full color renditions produced. However, because the method is relatively costly and complex, it does not readily lend itself to use where only one or two functional colors are to be reproduced.

Howell, in U. S. Pat. 3,094,429, discloses a relatively simple xerographic process for reproducing a two color original. In this system, a special recording head is employed to selectively image a zinc oxide sheet to record the two color components as latent electrostatic images possessing distinct charge densities. Selective development of each color component is achieved by sequentially applying different size toner particles to the image retaining sheet. The larger particles are applied to the sheet first. Because of their size, the large toner particles are only attracted and held in those regions containing the more dense images so that these regions are developed to the exclusion of the less dense regions. Upon completion of the first development step, the smaller toner particles are applied to the sheet and

development of the less dense images accomplished. Color differentiation is accomplished in this process simply by adding different colorants to the toner materials involved. Although the Howell process does eliminate the registration problems associated with most subtractive color systems, it nevertheless requires special input apparatus and, because it involves contact image development, color contamination is an ever present problem.

It is therefore an object of this invention to simplify color copying.

A further object of this invention is to reduce the number of processing steps required to produce a color copy.

A still further object of this invention is to eliminate the need for special recording means when xerographically reproducing a color copy.

Yet another object of this invention is to minimize color contamination in a xerographic color copying device.

A still further object of this invention is to provide a color copier capable of rapidly and efficiently reproducing functional colors.

These and other objects of the present invention are attained by means of an automatic reproducing device adapted to continually pass a photoconductive plate through a series of processing stations. An original, containing discernable color information is used to expose the uniformly charged photoconductive plate whereby each color component found in the original is recorded at a discrete charge potential. The plate is then passed through a developing station containing a plurality of developing units equal in number to the number of discernable colors found in the original. Electrical control means are operatively associated with each of the developing units so that only color components recorded at or above a predetermined potential are developed within the unit. The recorded images are developed in a descending order of magnitude whereby different and distinct colors are produced fir each color component recorded on the photosensitive element.

For a better understanding of the present invention as well as other objects and further features thereof, reference is had to the following detailed description of the invention to be read in connection with the accompanying drawings, wherein:

FIG. 1 is a schematic view in perspective showing an automatic xerographic reproducing machine embodying the teachings of the present invention;

FIG. 2 is an enlarged end view, in partial section, illustrating one of the developer units employed in the apparatus shown in FIG. 1;

FIG. 3 is a partial sectional view illustrating the construction of the donor roll employed in the developing apparatus shown in FIG. 2;

FIGS. 4–5 are graphic representations diagrammatically illustrating the characteristics typifying the color developing operations utilized in the automatic reproducing machine shown in FIG. 1.

Referring now specifically to FIG. 1, there is shown a schematic illustration of an automatic xerographic reproducing device for producing color copy from an original utilizing the teachings of the present invention. As will become apparent from the disclosure below, the instant invention is well suited for use in a wide variety of applications and the teachings herein embodied are not necessarily restricted to the particular machine environment disclosed. Basically, the xerographic reproducing apparatus employs a rotatably mounted drum **10** having a photoconductive surface **11** thereon. The photoconductor is preferably formed of a photosensitive material that exhibits a relatively panchromatic response to visible light.

The drum is arranged to move in the direction indicated to transport the photoconductive surface thereon sequentially through a series of processing stations. The first processing station in the direction of drum rotation is a charging station A containing a corona generator **12** similar to that disclosed by Vyverberg in U.S. Pat. No. 2,836,725. The corona generator is arranged to extend transversely across the drum and serves to uniformly charge to a relatively high potential, the photoconductive surface thereon.

The charged photoconductive surface is next transported through an exposure station B including a moving lens **15** interposed between an object mirror **16** and an image mirror **17**. The original input scene information, which is in this case carried upon an original document **18**, is stationarily supported upon a viewing platen **19** and successive incremental areas thereon illuminated by means of a moving lamp assembly **20**. The lens element **15** is adapted to scan the illuminated areas and to focus the reflected light image therefrom through the mirror system onto the moving photoconductive drum whereby the drum is imaged. For further information and features concerning this type of scanning system, reference is had to U.S. Pat. No. 3,062,094.

Following the recording of the input scene information, the drum is advanced through a developing station C that includes two individual developer units **25** and **26**. As will be explained in greater detail below, each of the developing units is arranged to apply a toner containing a predetermined colorant to the imaged drum surface to develop the recorded original input scene information.

After development, the now visible image is moved to a transfer station D wherein the image is transferred electrostatically to a web **27** of final support material by means of a conventional transfer corotron **28** similar to that disclosed in the previously mentioned Vyverberg patent. In operation, the web of final support material is transported through the transfer station at the same peripheral speed as the moving drum surface by means of the cooperating feed roll as provided to prevent the image from being smeared.

After transfer, the image bearing web of final support material is transported through an image fixing station E. Here, the sheet is delivered between the nip of a pair of cooperating roll members which coact to deliver sufficient heat and pressure energy to fix the color toner images to the support sheet. The heat pressure fixing device disclosed herein is similar to that described by Hudson in U.S. Pat. No. 3,256,002.

The last processing station in the direction of drum rotation is a drum cleaning station F wherein a rotatably mounted fibrous member **30** is positioned adjacent to the photoconductive surface. The brush is arranged to rotate in the direction indicated so as to drag the brush fibers into moving contact with the drum surface to remove residual toner particles found thereon after the transfer operation.

Although any suitable development technique may be employed in the practice of the present invention, it is preferred that the systems have the capability of providing relatively low background development in order to minimize color contamination. The term "background", as herein used, refers to those areas in the original containing no input scene information. Inadvertantly, unwanted toner particles are sometimes randomly deposited in these background areas during development which results in dirty or poor quality copy being produced. In a multi-color system, as herein disclosed, background development leads to color contamination.

A "transfer" development technique is employed in the preferred embodiment of the present invention. In transfer development, a uniform layer of finely divided toner material is first coated upon the surface of a donor member and the member brought into operative communication with the image bearing photoconductive element. The photoconductor and the donor are separated from each other within the development zone by means of a finite air gap. The air gap is of a sufficient width to prevent the toner particles supported on the donor member from contacting the photoconductive surface as the members move through the development zone. This out-of-contact development is accomplished by transferring the toner particles across the air gap. The predominant mechanism by which the particles are activated, that is, removed from the donor surface, and attracted into the imaged photoconductive regions is the electrostatic force field associated with the latent electrostatic images. Consequently, little or no toner is inadvertently deposited in the background areas.

Referring more specifically to FIG. **2**, there is illustrated the developing mechanism typically contained within each of the developing units **25** and **26**. In this system, the individual toner particles are initially uniformly loaded upon a cylindrical donor member **40** and the donor moved continuously adjacent to the photoconductive drum surface **10** through a development zone **63**. The donor member and the photoreceptor are positioned so that they are separated by a finite air gap **42**, the air gap being typically within a range of between 0.001 and 0.010 inches.

The donor member is basically formed of a plurality of longitudinally extended segments **41** as illustrated in FIG. **3**. Each segment is electrically isolated from the other by means of dielectric strips **44** whereby each segment is capable of independentally supporting a discrete charge potential thereon. Each segment is formed upon a conductive metallic substrate **46**, preferably being of aluminum, over which is placed a thin dielectric enamel coating **47**. A conductive grid network **48**, in turn, is placed over the insulating coating in a manner wherein the outer surface of each segment is broken into a multitude of discrete dielectric islands **49** surrounded by the conductive grid material.

In practice, each of the segmented conductive substrates **46** are connected, via electrical connector **50**, to a biasing source (not shown) and the substrates placed at a reference potential which, in this case, is a ground potential. Each of the individual grid segments **48**, however, are operatively connected to a control means **51** by means of wire **52** provided. The control means **51** consists of a series of commutators mounted upon donor roll shaft **53** which are arranged to divide the periphery of the donor roll into a number of distinct electrical regions. Typically, each electrical region is governed by means of a biasing source **55**, acting through wire **56** and brushes **57**, which serves to place the grid segments passing therethrough at a predetermined potential.

In this particular embodiment, the segmented donor roll member is arranged to pass through five distinct electrical regions. These regions include, (1) a toner loading and agglomerate removing zone **60**, (2) a toner charging zone **61**, (3) a toner doctoring zone **62**, (4) a developing zone **63** and, lastly, (5) a donor roll cleaning zone **64**.

Initially, the donor roll is passed through the toner loading and agglomerate removal zone **45** in which is contained a housing **67**. The housing is adapted to place a quantity of negatively charged toner particles in contact with the surface of the moving donor member. The grid segments passing through this electrical region are placed at a relatively high bias potential, approximately +350 volts so that the donor roll attracts and supports, in a charged state thereon, a layer of toner particles. Positioned adjacent to the donor member, immediately downstream from housing **67**, is a vacuum manifold **68**. The manifold extends transversely across the donor surface and has a plurality of uniformly spaced suction nozzles machined therein that are supported a short distance from the donor roll surface. Sufficient negative vacuum is drawn through the manifold to pull toner agglomerates and loosely adhering toner particles from the donor surface providing for a relative uniform toner coating. It has been found that surface protrusions in the toner layer cause unwanted background development and thus degrade the quality of development.

Located between the vacuum means and the development zone **63** is a toner charging zone **61** wherein the bias on the donor grid is reduced to a reference or ground potential. Within the charging zone is located a corona generator **69** that is adapted to spray a uniform negative corona charge upon the toner particles supported on the donor roll surface whereby each toner particle is placed at substantially the same charge level. Controlling the uniformity of the toner coating and the uniformity of charge on the toner particles places the developing system in a condition whereby background development is held to a minimum.

Not all agglomerates or loosely held toner particles, which might be transferred into the background regions during development, are removed by the vacuum means. In order to further prevent the unwanted background development from occurring, a dummy development system is herein provided within electrical zone **62**. Herein, a biased dummy roll member **70**, preferably having a relatively smooth surface is arranged to be conveniently rotated at approximately the same peripheral speed of the donor roll member. The roll is biased, by means of a suitable biasing source **71**, to approximately background potential, typically somewhere between +100 and +200 volts. To further establish the dummy development zone, the outer periphery of dummy roll **70** is supported a distance equal to air gap **42** from the roll and the segmented grids passing through this region are placed at approximately the same potential as applied thereto within the development zone **63**. By creating a dummy development zone in this manner, any toner particles that might normally be attracted into the background regions during the actual development operation will be deposited on the surface of the dummy roll.

After rendering the donor roll agglomerate free, the evenly distributed, uniformly charged, toner material is then presented to the imaged photoconductive surface within the development zones **63** wherein transfer development is accomplished. As will be explained in greater detail below, the potential applied to the donor grid within this electrical region is such as to hold the threshold potential, that is, the potential at which toner particles supported on the donor member are both activated and attracted into the imaged areas on the drum surface, at a predetermined level.

After the donor member had given up the needed toner in the development process, the residual toner remaining thereon is transported on the donor roll surface to the donor roll cleaning zone **64**. Herein, the donor grid potential is reduced to the reference or ground level and the donor roll surface treated with corona from AC corona generator **75**. The AC corona generator serves to neutralize the charge on the toner particles. After neutralization the residual toner is readily swept from the donor roll surface by means of a brush member **76**, and the removed toner particles exhausted from the system.

To produce a color copy in the present apparatus, the original **18** to be reproduced is placed upon the viewing platen **19** (FIG. **1**) and the rotated photoconducting drum surface exposed to a flowing light image of the information contained therein. The original document preferably contains colors or hues that are capable of selectively discharging the photoconductive surface to discrete charge density levels due to the reflective characteristics of the original input images. As a general rule, the photoconductor will be discharged to a greater degree in those regions irradiated by light reflected from the original containing less dense, or light, colors and to a lesser degree by the reflected dark colors. Black images are therefore generally recorded as latent images having the greatest charge density. The white images are recorded at a relatively low charge density and the other colors will range somewhere between the blacks and whites. Alternately, it is also quite feasible to produce a latent image consisting of predetermined charge densities by using an original containing input scene information of one color. This is achieved by controlling the density or light absorbing characteristics of the original.

The operation of the present invention will be explained in reference to an original containing input scene information formulated of two discrete colors. The photoconductor, upon exposure, records the input scene information at two distinct charge levels with each charge corresponding to a color found in the original. In effect, therefore, the input scene information recorded on the photoreceptor contains both input scene information and color information. In practice, those images recorded at the higher image potential are developed first with a toner material containing a first colorant while the images recorded at the lower potential level are developed next employing a toner containing a second colorant. Developer units **25** and **26** (FIG. **1**) employing the transfer development apparatus herein described, are provided for this purpose.

Developer unit **25**, which is arranged to initially act upon the rotating photoconductive drum surface, applies toner material of a first color into the more highly charged imaged areas. To accomplish this result, the segmented grids associated with the donor roll are biased as they pass through the development zone **63** (FIG. **2**) to a potential somewhere between the two recorded image potentials found on the photoconductive drum surface, and preferably to a potential slightly higher than the lowest recorded image potential. By placing an electrical bias on the donor member in this manner, an electrical control field is established within the development zone between the photoconductor and the donor member capable of regulating both the activation and attraction of toner particles from the donor member into the imaged areas. With the grid of the donor roll so biased, that is, at a potential greater than the lower recorded image potentials, the images recorded at a higher potential will be developed to a first color and the images recorded at a lower potential will remain undeveloped.

The operation of the first developer unit is graphically illustrated in FIG. **4**. As shown, the dark or more dense images found in the original are recorded on the photoreceptor surface **10** as images of a relatively high potential V_1. The lighter colored or less dense images found in the original are similarly recorded at some lower potential, herein referred to as V_2. By setting the bias on the donor roll grid to a threshold potential V_d that is somewhere between V_1 and V_2, only those images, recorded at the higher image potentials, that is, the darker colored or more dense images, will be developed with the first color toner.

Subsequent to the first development step, the image drum surface is advanced into a second developing unit **26**. Here, the bias potential placed on the grid of the donor roll is reduced to approximately the background potential on the photoconductor as the roll passes through the developing zone. Normally, background potential will vary somewhere between +100 and +200 volts. The second developing unit is arranged to apply toner containing a second colorant to those imaged areas on the plate surface that are recorded at potentials higher than the background potential.

The second developing step is graphically illustrated in FIG. **5**. As can be seen, by reducing the bias potential from V_d to a background potential V_b places the second developer unit in a condition to apply the second color toner to the images recorded at the lower potentials. However, it also should be noted that there also remains some residual voltage in those previously developed regions and this voltage, in some cases, may be sufficient to activate the toner and attract it into the previously developed regions. Therefore, as the photoconductive moves through the second development zone, toner particles might be activated and deposited in both the previously developed and more developed region on the drum **10**.

In one mode of operation it is contemplated that the images recorded at the higher potential be developed using a black toner while the images recorded at the lower image potential be developed using a toner containing one of the primary colors, as for example, red, blue, green or the like. This may of course result in some of the toner of a primary color being deposited over the previously developed black images during the second developing operation, giving the black image a slightly tinted appearance. However, in most cases where the primary color is applied over the black this tinting is not particularly disturbing to the eye and can be tolerated. A second mode of operation can be also employed in the practice of the present invention. Here, the two toner materials involved contain colorants capable of being subtractively mixed during the second developing operation to render two distinct color images in the final copy. For instance, the first colorant applied to the photoconductor could be a yellow toner which would then be overdeveloped during the next subsequent developing step with a magenta containing colorant to render a red. By setting the developer biases of the first unit at a level considerably above the lower record voltage it is possible to assure that sufficient overdevelopment will be achieved to accomplish the desired color mixings.

In the above disclosure, there is described a preferred method for simply and efficiently creating a color copy from an original employing a single exposure and a single transfer operation. For the sake of convenience, reference has been made throughout the specification to developing the images on the photoconductive surface with a negatively charged toner material. It should be understood, however, that this description relating to the specific charge relationships involved is not intended to limit the present invention. For instance, it is quite possible to utilize oppositely charged toner material which, of course, would call for a similar change in the relationship of all other charges and potentials involved. Therefore, all references to either positive or negative potentials in this particular disclosure are considered as merely defining a relationship and it should be clear that the teachings of the present invention can be practiced as long as these relationships are maintained.

While this invention has been described with reference to the structure disclosed herein, it is not confined to the details as set forth and this application is intended to cover any modifications or changes as may come within the scope of the following claims.

What is claimed is:

1. In a process wherein a latent electrostatic image formulated on an image retaining element is developed by bringing electroscopic marking particles of the same charge polarity opposite to that of the latent image into operative communication with said element, the method of producing a color copy including

recording a latent electrostatic image comprising more than one color component by recording each color component to be reproduced at a discrete potential level of the same polarity on said image retaining element forming said latent image,

sequentially developing, in a descending order of magnitude, each recorded color component with an electroscopic marking powder of the same charge polarity containing a predetermined colorant corresponding to each recorded color component whereby the color component recorded at the highest image potential is developed first, and

electrically regulating each development sequence to allow toner brought into operative association with said image retaining element to be attracted into the imaged regions that are recorded at or above a predetermined potential and to preclude the toner from being attracted into other regions whereby each color component is developed to render a different and discrete color.

2. The method of claim **1** wherein each developed colorant is arranged to subtractively mix with other subsequently developed colorants to produce a predetermined resultant color.

3. The method of claim **1** further including the step of simultaneously transferring the developed color components of the latent image to a final support material subsequent to the last development sequence.

4. The method of claim **3** further including the step of fixing the simultaneously transferred developed color components of the latent image to the final support material.

5. Apparatus of the type wherein a latent electrostatic image formulated on an image retaining element is developed by bringing oppositely charged electroscopic marking particles of the same polarity into operative communication with said element, the apparatus including

means to form an electrostatic latent image to record input scene information on said image retaining element comprising more than one color component recorded at discrete potential levels of the same polarity,

a plurality of developing units, each unit being arranged to sequentially act upon the image retaining member to bring into operative communication therewith electroscopic marking powder of the same charge polarity containing a predetermined colorant corresponding to each color component and

means to electrically regulate each developing unit to allow toner brought into operative association with said image retaining element to be attracted into those image regions recorded at or above a predetermined potential and to preclude the toner from being attracted into other regions whereby each recorded color component is developed to render a different and discrete color.

6. The apparatus of claim **5** wherein the developing units are arranged to subtractively mix the colorants to produce predetermined color in the composite image formed by the plurality of color components.

7. The apparatus of claim **5** further including means to simultaneously transfer the developed color components of the latent image to a final support material.

8. The apparatus of claim **7** further including means to fix the transfer color images to the final support material.

9. In a xerographic reproducing apparatus of the type having means to uniformly charge the surface of a moving photoconductive member to a uniform potential, the apparatus further including

means to expose the charged photoconductive member to a light image to record latent electrostatic images thereon at least at two discrete potential levels of the same polarity,

first developing means to develop the latent electrostatic images recorded at the higher of the two potential levels to the exclusion of those images recorded at the lower potential levels using a first toner of like charge polarity containing a first colorant, and

second developing means to develop those images recorded at said lower potential level in the presence of the previously developed images using a second toner of the same charge polarity as said first toner containing a second colorant.

10. The apparatus of claim **9** wherein said fist and second developing means include a donor member uniformly coated with electroscopic marking particles and being arranged to move in close proximity with the image retaining element whereby the particles are transferred from said donor member to the imaged regions on said element, and

biasing means associated with said donor member to electrically regulate the development process to allow toner brought into operative association with said image retaining element to be attracted into imaged regions recorded at or above a predetermined potential.

11. The apparatus of claim **10** wherein said donor member of the first developing means is biased to a potential in a range between the first and second image recorded potential.

12. The apparatus of claim **11** wherein the donor member associated with said second developing means is biased to a potential between the background potential and the image potential of the lowest recorded image on said image retaining element.

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