United States Patent [19]

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[11] **3,898,082**

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[54] **METHOD OF MAKING A TRANSPARENCY OF A COLORED IMAGE IN A MAGNETO-ELECTRIC PRINTING SYSTEM**

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[52] **U.S. Cl.** .... **96/1.2**; 96/1 R; 96/1.4; 117/17.5; 360/56; 346/74 ES; 346/74 P; 346/74 M; 355/4

[51] **Int. Cl.**[2] **G03G 13/22**

[58] **Field of Search** .... 96/1 R, 1.4, 1.2; 117/17.5

[56] **References Cited**

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[57] **ABSTRACT**

A transparency of a colored image is produced on a light-transmitting recording element, comprising a photoconductive layer and a tricolor mosaic filter layer, by a single-exposure method wherein (a) the photoconductive layer is uniformly charged electrostatically and uniformly covered with magneto-electric particles; (b) a magnetic field of a strength just insufficient to remove the particles from the photoconductive layer is applied adjacent to the particles; and (c) the photoconductive layer is exposed through the tricolor mosaic filter, while in the magnetic field, with a light image of the colored image to be produced.

1 Claim, 6 Drawing Figures

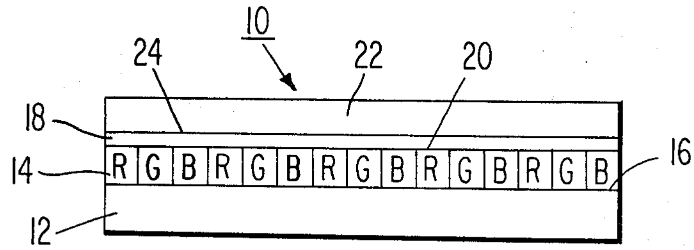

Fig. 1.

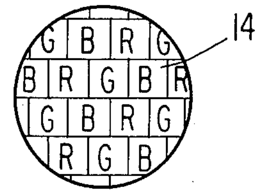

Fig. 2.

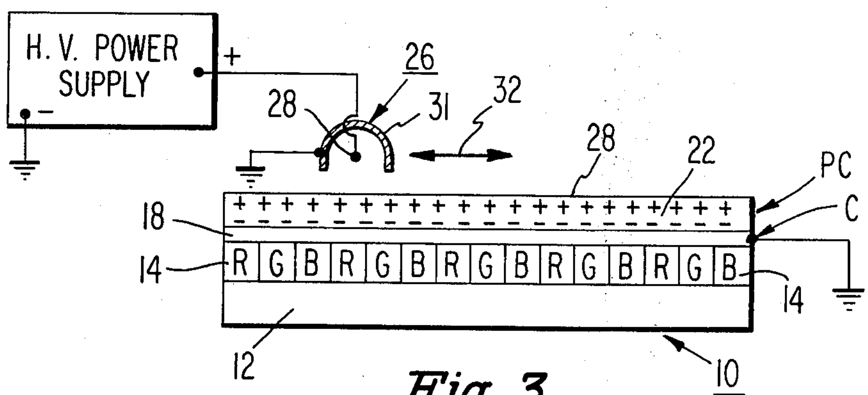

Fig. 3.

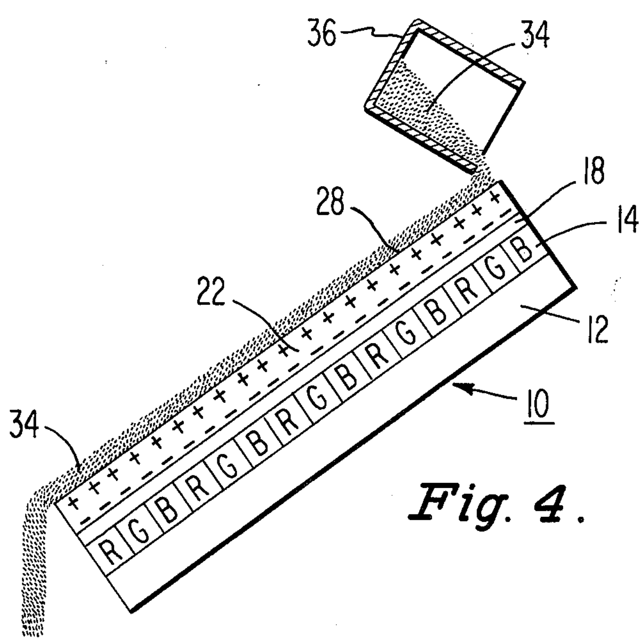

Fig. 4.

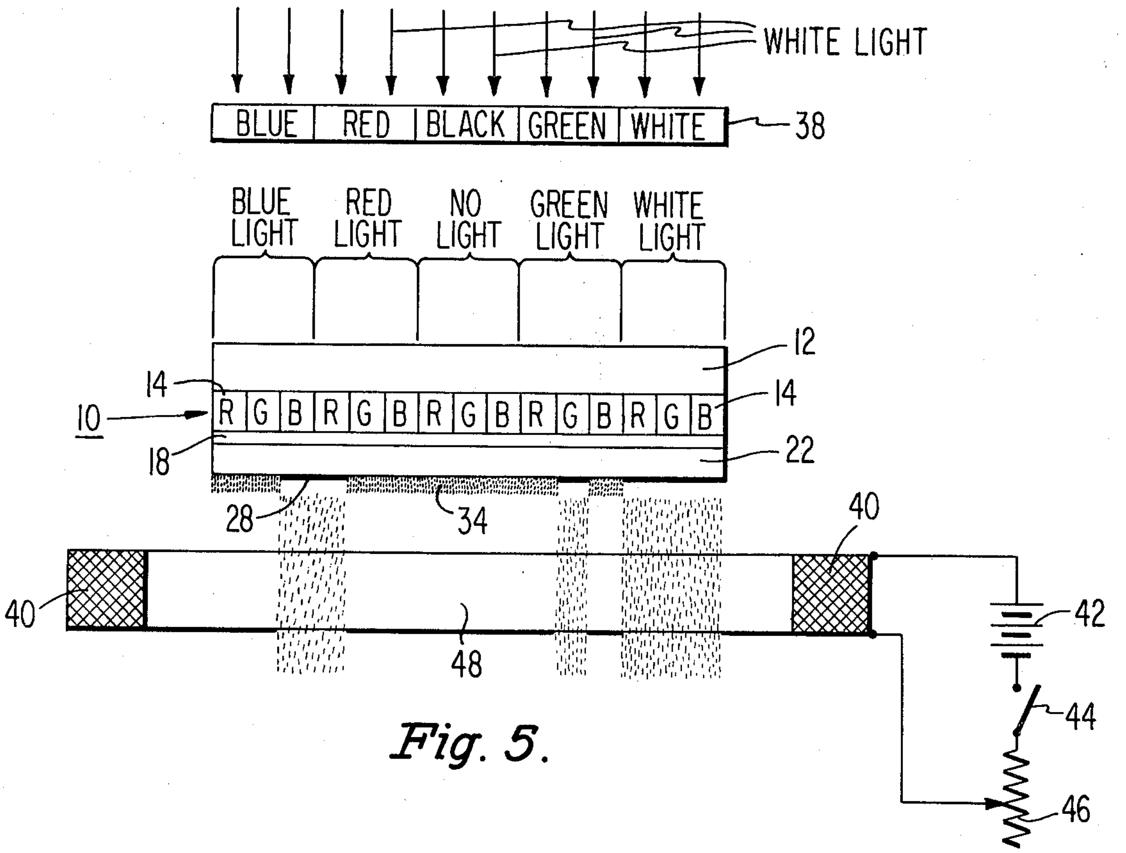
WHITE LIGHT
BLUE
RED
BLACK
GREEN
WHITE
38
BLUE LIGHT
RED LIGHT
NO LIGHT
GREEN LIGHT
WHITE LIGHT
12
14
R G B R G B R G B R G B R G B
14
10
18
22
28
34
40
40
40
42
48
44
46

Fig. 5.

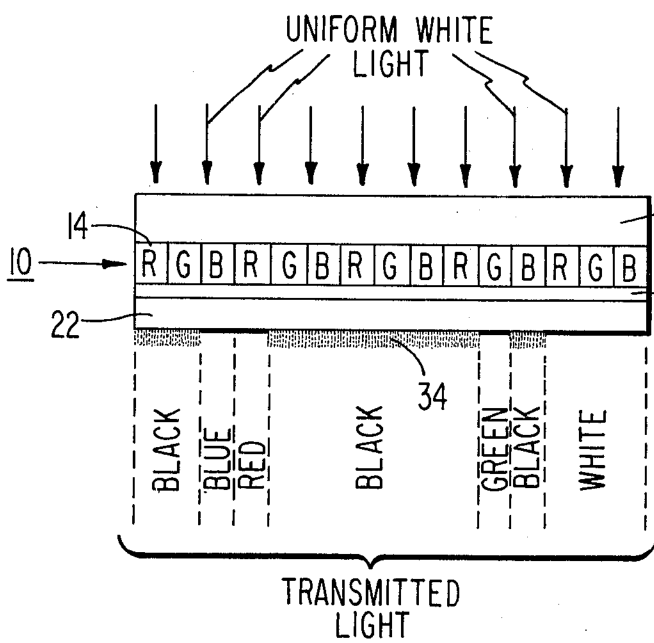
UNIFORM WHITE LIGHT
12
14
R G B R G B R G B R G B R G B
10
18
22
34
BLACK
BLUE
RED
BLACK
GREEN
BLACK
WHITE
TRANSMITTED LIGHT

Fig. 6.

METHOD OF MAKING A TRANSPARENCY OF A COLORED IMAGE IN A MAGNETO-ELECTRIC PRINTING SYSTEM

BACKGROUND OF THE INVENTION

This invention relates generally to the art of electrostatic printing in color, and, more particularly, to a method of making a transparency of a colored image in a magneto-electric printing system. The novel method is particularly suitable for making transparencies of colored images, with a single exposure, on a light-transmitting recording element that may be viewed immediately and erased easily, if so desired.

It has been proposed, in U.S. Pat. No. 3,458,309 issued to J. Gaynor, to provide color transparencies by an electrophotographic method wherein a light-transmitting recording element, including a tricolor mosaic filter layer and a photoconductive layer, is elestrostatically charged; and the recording element is exposed to a colored light image to form a latent electrostatic image which is subsequently developed with electroscopic particles. While this prior-art method is satisfactory for many applications, the colored image produced cannot be monitored and its development controlled easily during the development thereof. Also, the developed colored image cannot be erased with the same apparatus used to develop the image with the particles.

It has also been proposed to use magnetic toner particles in an electrostatic printing system, and to effect a removal of the magnetic toner particles from a recording element with the aid of a magnetic field. While such a method is satisfactory for certain applications, it leaves something to be desired in others because the magnetic field does not always completely overcome the electrostatic field between the recording element and the magnetic toner particles; and some of the magnetic toner particles adhere tenaciously to the recording element, thereby preventing their complete removal.

In accordnace with the novel method, a transparency of a colored image on a light-transmitting recording element is produced with the aid of magneto-electric particles in a manner whereby the colored image may be visually monitored during its formation; and the image can be viewed, when formed, without removing the color transparency from a combined exposure, development and viewing station. Alternatively, the magneto-electric particles may be erased from the recording element, if so desired, with the same apparatus used for developing the recording element, and without the necessity of removing the recording element from the exposure, development, and viewing station.

SUMMARY OF THE INVENTION

The novel method of making a transparency of a colored image on a light-transmitting recording element, comprising a photoconductive layer and a tricolored mosaic filter layer, comprises the steps of: (a) charging the photoconductive layer uniformly, (b) covering the charged photoconductive layer uniformly with magneto-electric particles, (c) applying a magnetic field adjacent to the uniformly toned photoconductive layer, the magnetic field being of a strength just insufficient to remove the particles from the photoconductive layer, and (d) while in the magnetic field, exposing the uniformly covered photoconductive layer through the filter layer with a colored light image of the colored image to be produced on the color transparency.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a sideelevational view of a light-transmitting recording element used in the novel method;

FIG. 2 is a schematic view of one form of a tricolor mosaic filter layer viewed in the direction of light-transmission; and

FIGS. 3, 4, 5, and 6 are schematic illustrations of the recording element, shown in FIG. 1, in sequential operations of being electrostatically charged, covered with magneto-electric particles, exposed, and viewed, respectively, in accordance with the novel method.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawings, there is shown a light-transmitting recording element **10** of the type used in the novel method. The recording element **10** comprises a light-transmitting substrate **12**, a tricolored mosaic filter layer **14** on a major surface **16** of the substrate **12**, a light-transmitting, electrically conductive layer **18** on a major surface **20** of the filter layer **14**, and a photoconductive layer **22** on a major surface **24** of the conductive layer **18**.

The light-transmitting substrate **12** may be rigid or flexible and may comprise a light-transmitting material, such as glass or a flexible plastic material, such as "Mylar" or "Cronar" (E. I. DuPont De Nemours Co., Wilmington, Del.). The electrically conductive layer **18** may comprise a lighttransmitting, thin film of a metal, such as aluminum or chromium, for example, or a transparent layer of tin oxide and/or indium oxide.

The photoconductive layer **22** should be responsive to all of the colors in the visible spectrum and comprises a photoconductive layer of a light-transmitting material of the type described in U.S. Pat. No. 3,484,237, for "Organic Photoconductive Compositions and Their Use in Electrophotographic Processes," or in the aforementioned U.S. Pat. No. 3,458,309, both patents being incorporated herein by reference. A light-transmitting recording element comprising a layer of dye-sensitized particulate zinc oxide in a resin binder may also be used.

The filter layer **14** may comprise a multiplicity of systematically, or randomly, arranged minute colored areas of a substantially equal number of each of three primary colors, designated as R, G, and B for the colors red, green, and blue, respectively. The elemental colored areas of the filter layer **14** illustrated in FIG. **2** are in a regular geometric pattern. A separate minute area of a primary color is provided for each elemental area of the image to be formed on a color transparency. Examples of the filter layer **14** and their method of manufacture are described in the aformentioned U.S. Pat. No. 3,458,309 and U.S. Pat. No. 3,413,117, and are included herein by reference. Color filter layers, having a more or less statistically random distribution of irregularly shaped primary colored areas are described in the aformentioned patents. In any case, the maximum transverse dimension of each separate color R, G, or B area should be less than about 0.005 inch.

In the novel method, means are provided to electrostatically charge the photoconductive layer **22**, in darkness, with a uniform electrostatic charge. To this end, the conductive layer **18** of the recording element **10** is connected to a source of reference potential, such as ground, and a corona discharge device **26** of the type commonly used in the electrophotographic printing art, is disposed between the outer major surface **28** of the photoconductive layer **22** of the recording element **10**. The corona discharge device **26** has a corona generating element **28**, such as a thin wire, connected to the positive terminal of a high-voltage, unidirectional power supply **30**. The negative terminal of the power supply is connected to ground, as is the shield **31** of the corona discharge device **26**. The high voltage power supply **30** is capable of providing at least 5,000 volts, and the corona discharge device **26** is adapted to be moved over the recording element **10** in the directions of the double-headed arrow **32** to provide the photoconductive layer **22** with a uniform electrostatic charge. With the corona discharge device **26** connected as shown in FIG. **3**, the surface **28** of the photoconductive layer **22** is charged positively, in darkness. It is also within the scope of the present invention to charge the surface **28** negatively.

The uniformly charged surface **28** of the photoconductive layer **22** is next covered, in darkness, uniformly with magneto-electric particles **34**, as shown in FIG. **4**. The magneto-electric particles **34** are attracted electrostatically to the electrostatically charged surface **28**. The magneto-electric particles **34** comprise particles of magnetic material that may, or may not, be coated with a thermoplastic adhesive of any desired color. By the term "magneto-electric particles" as used herein, is meant particles of materials that are capable of being moved by both a magnetic field and an electric field, either separately or concurrently. The magneto-electric particles **34** may comprise nickel, cobalt, or iron particles, for example, capable of being moved by a magnetic and/or an electric field. The average diameter of the magneto-electric particles **34** is not critical and may be between 5 and 30 microns. The magneto-electric particles **34** do not necessarily have to be spherical in shape. Suitable magneto-electric particles **34** for the novel method are described in U.S. Pat. Nos. 3,526,191; 3,106,479; and 3,093,039, for example. The magneto-electric particles **34** need not have an electroscopic charge thereon because electrostatically neutral magneto-electric toner particles **34** are attracted to a charged surface by what is believed to be electrostatic induction.

The magneto-electric particles **34** may be applied to the surface **28** by cascading them over the surface **28** from a container **36** held over an inclined recording element **10**, as shown in FIG. **4**. Other means of applying the magneto-electric particles **34** uniformly to the surface **28** may be employed, such as by passing the uniformly charged recording element **10** through a trough of magneto-electric particles **34**.

Means are provided to expose, at an exposure station, the uniformly covered recording element **10** with a single exposure of a colored light image of the image desired on the color transparency to be formed by the recording element **10**. To this end, a colored light image as, for example, from a color transparency **38**, such as a photographic "Kodachrome" slide transparency, is projected (by directing white light onto the transparency **38**) through the substrate **12**, the color filter layer **14**, and the conductive layer **18** onto the photoconductive layer **22**, as shown in FIG. **5**. The colored image on the tranparency **38** may comprise blue, red, black, green, and white portions, as indicated in FIG. **5**. The projected blue, red, and green portions of the image of the transparency **38** will pass through blue, red, and green areas, respectively, of the tricolor mosaic filter layer **14** of the recording element **10**. Any black portions of the transparency **38** will not pass through any of the colored areas of the filter layer **14**; and the projected white light of the transparency **38** will pass through each of the red, green, and blue areas upon which it impinges on the filter layer **14**. The primary component colors of a color other than a primary color are transmitted through the appropriate primary colors of the filter layer **14**.

A magnetic field of a strength just insufficient to remove the particles **34** from the surface **28** of the recording element **10**, in the absence of any exposure of the recording element **10**, is disposed adjacent the surface **28**. Thus, an electromagnet **40** in the form of a toroid (illustrated in FIG. **5** in cross section) is disposed adjacent to the surface **28** to provide a substantially uniform magnetic field just insufficient to remove the magneto-electric particles **34** from the surface **28** in the absence of any exposure of the recording element **10**. The electromagnet **40** is energized from a suitable source **42** of electrical energy, such as a battery, connected through a single-pole single-throw switch **44** and a rheostat **46**. The proper strength of a desired magnetic field adjacent to the surface **28** of the photoconductor **22** is obtained by closing the switch **44** and adjusting the rheostat **46**. When the photoconductive layer **22** is exposed by light from the colored image of the transparency **38**, the electrostatic attraction between the magneto-electric particles **34** and the photoconductive layer **22** at the exposed portions is reduced; and the affected magneto-electric particles **34** are removed from the exposed areas of the photoconductive layer **22** by the magnetic field, as shown in FIG. **5**. The amount of magneto-electric particles **34** that are removed by the exposure of any elemental area of the photoconductive layer **22** is proportional to the intensity of light of the exposure thereat.

The exposure and development (selective removal of some particles **34** from the surface **28**) of the recording element **10**, at the developing station, as shown in FIg. **5**, may be monitored by an observer viewing the image being formed on the surface **28** by looking through the opening **48** in the toroid of the electromagnet **40** during the exposure process. When the image formed on the surfaces **28** of the recording element **10** appears to be fully developed, (by the formation of selective, light-transparent areas on the surface **28**), the exposure may be extinguished, as by turning off the white light that projects the colored image from the transparency **38** onto the recording element **10**, and/or by opening the switch **44** and removing the magnetic field from adjacent the surface **28**. The colored image being developed on the surface **28** may also be monitored by projecting the image as it is formed, during the exposure period, onto a screen (not shown) with a suitable optical system (not shown.

The developed recording element **10** is a transparency of the colored image projected onto it from the transparency **38**; and this colored image may be viewed, like any photographic transparency, by directing uniform white light through the developed recording element **10**, as shown in FIG. **6**. The magneto-electric particles **34** may be fixed to the surface **28** of the recording element **10** by spraying a transparent adhesive onto the magneto-electric particles **34**. If the magneto-electric particles **34** are coated with a thermoplastic material, they may be fixed to the surface **28** by heating them to melt the thermoplastic coating so that the particles **34** may adhere to the surface **28**.

In accordance with the novel method, unfixed magneto-electric particles **34** can be removed easily from the recording element **10** after the image defined thereby has been viewed and it is desired to reuse the recording element **10**. Thus, the particles **34** can be removed from the surface **28**, at the combined exposure, developing and viewing station, as shown in FIG. **5**, by increasing the strength of the magnetic field of the electromagnet **40**, as by adjusting the rheostat **46** so as to send more current through the electromagnet **40**. The strength of the magnetic field may be increased so that all the magneto-electric particles **34** are pulled from the surface **28** without removing the recording element **10** from the exposure station. The removal of the magneto-electric particles **34** may also be enhanced by exposing the recording element **10** with white light, preferably through the filter layer **14**, so as to increase the photoconductivity of the photoconductive layer **22**. This procedure reduces the electrostatic attraction between the magneto-electric particles **34** and the photoconductive layer **22** so that the particles **34** may be removed easily by the magnetic field.

I claim:

1. A method of making a transparency of a colored image on a light-transmitting recording element comprising a color-sensitive photoconductive layer and a tricolor mosaic filter layer, said filter layer comprising a multiplicity of systematically, or randomly, arranged minute colored areas of a substantially equal number of each of three primary colors, and a separate minute area of a primary color being for each elemental area of said colored image, said method comprising the steps of:

charging said photoconductive layer uniformly with an electrostatic charge,

covering said charged photoconductive layer uniformly with magnetic particles,

applying an adjustable magnetic field adjacent to said uniformly covered photoconductive layer, said magnetic field being adjusted to a strength just insufficient to remove said particles from said photoconductive layer,

exposing said uniformly covered photoconductive layer, while in said magnetic field, with a colored light image of the image desired on the transparency, to reduce the electrostatic attraction between the exposed portions of said photoconductive layer and certain magnetic particles thereat, and to remove said certain magnetic particles from said photoconductive layer by said magnetic field, whereby said colored image may be viewed by light transmitted through said recording element,

said adjustable magnetic field being applied adjacent said uniformly covered photoconductive layer with an electromagnet in the form of a toroid having an unobstructed opening therein, and observing said photoconductive layer through said unobstructed opening in said toroid during the step of exposing said photoconductive layer, and removing said certain magnetic particles whereby to monitor the development of the image on said transparency.

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