United States Patent [19]
Iwasa

[11] 3,926,627
[45] Dec. 16, 1975

[54] PROCESS FOR MAKING AN ELECTROPHOTOGRAPHIC IMAGE BY USE OF PHOTOCONDUCTIVE PARTICLES

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[22] Filed: **Mar. 21, 1974**

[21] Appl. No.: **453,421**

[30] **Foreign Application Priority Data**

May 7, 1973 Japan 48-50428

[52] **U.S. Cl.** .... **96/1 R; 96/1 SD**
[51] **Int. Cl.²** **G03G 13/22**
[58] **Field of Search** .... 96/1 R, 1.3, 1 SD

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Attorney, Agent, or Firm—Gerald J. Ferguson, Jr.; Joseph J. Baker

[57] **ABSTRACT**

An electric power image is obtained on either an insulating or conductive surface by use of photoconductive particles. Photoconductive particles are applied in a plurality of layers on a substrate having an insulating surface. The surface of the photoconductive particle layers is uniformly charged and exposed to imagewise light. By the exposure, the charges in the upper layers in the exposed area of the image are moved to the lower layers. The charges in the non-exposed area are neutralized by D.C. corona discharge in the reverse polarity or by A.C. corona discharge. The particles on the substrate are removed by air blow leaving only the particles in the lower layers of the non-exposed area which are electrostatically attracted by the insulating surface.

The particle image can also be formed on a conductive substrate by applying precharged photoconductive particles on the conductive surface and simultaneously exposing the charged particle layers to the imagewise light and neutralizing the charges by A.C. corona discharge. In this case, a positive particle image is obtained from a positive light image.

29 Claims, 12 Drawing Figures

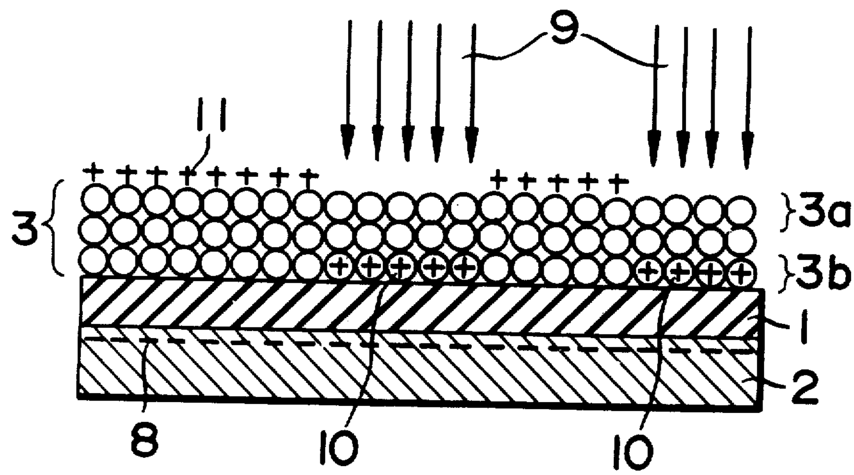


FIG. 1

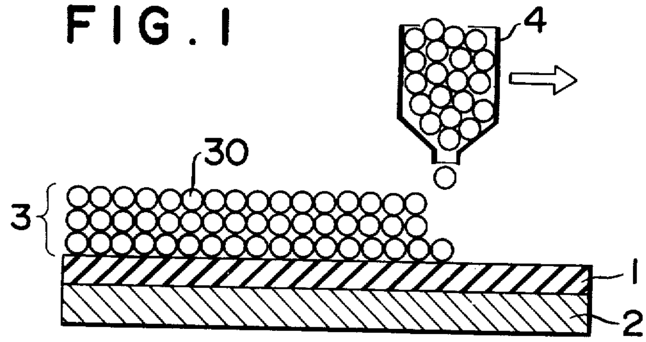


FIG. 2

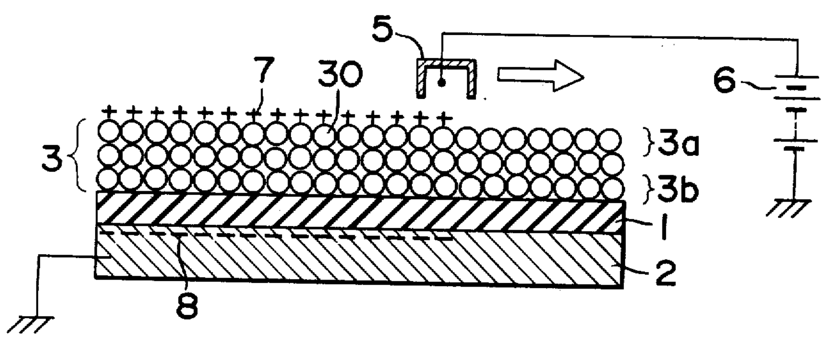


FIG. 3

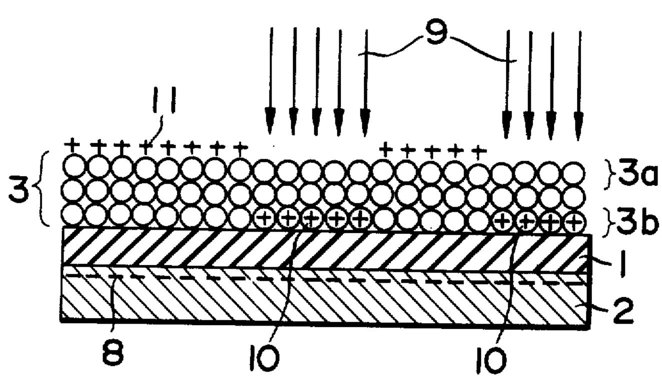


FIG. 4

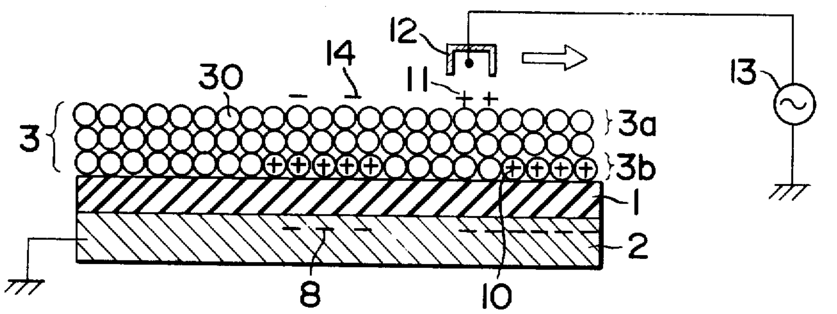


FIG. 5

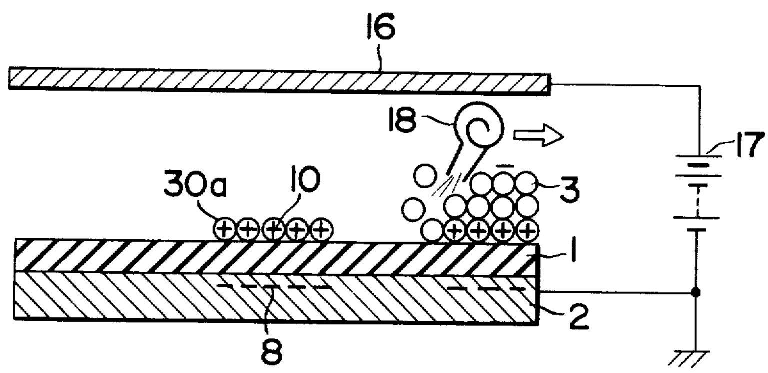


FIG. 6

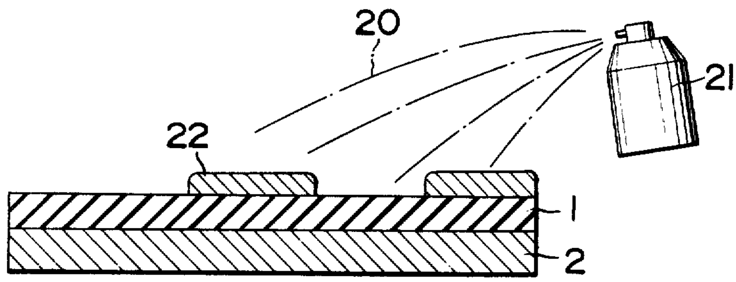


FIG. 7

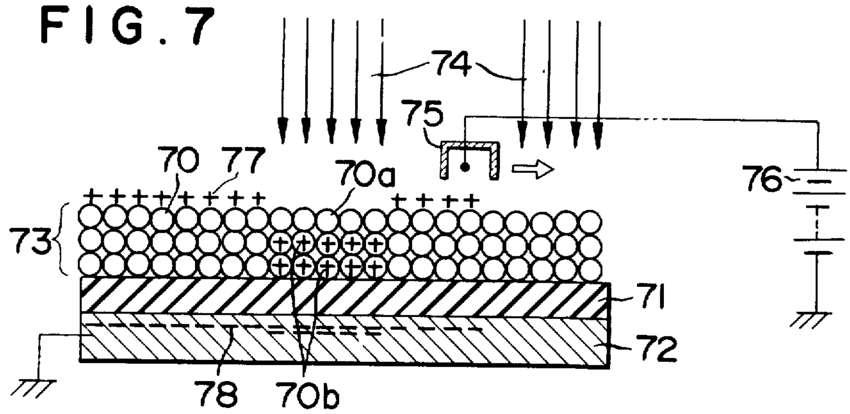


FIG. 8

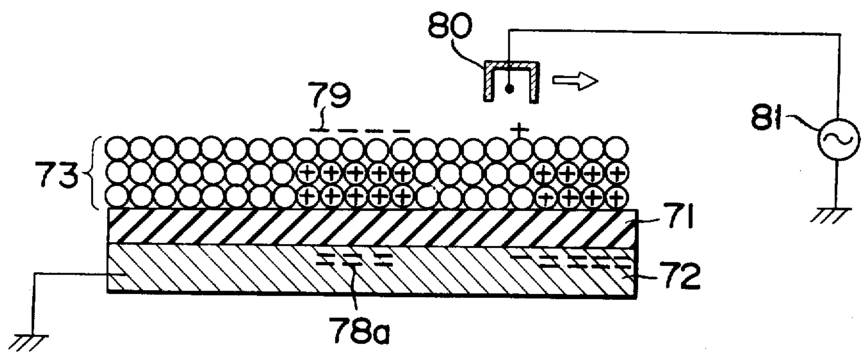


FIG. 9

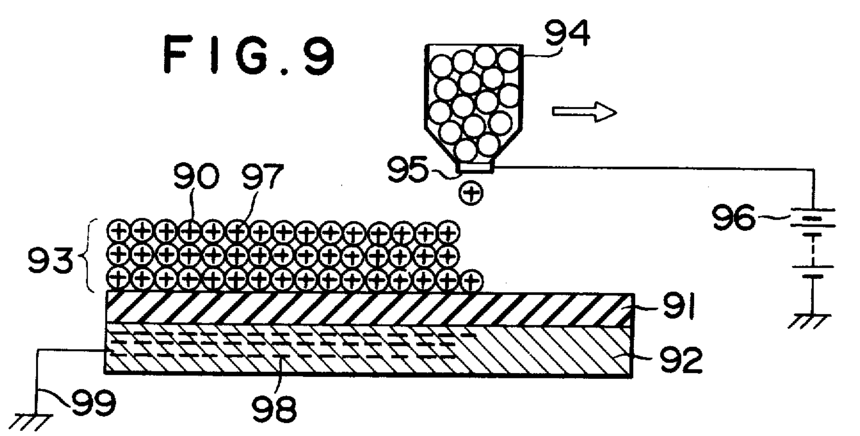


FIG.10

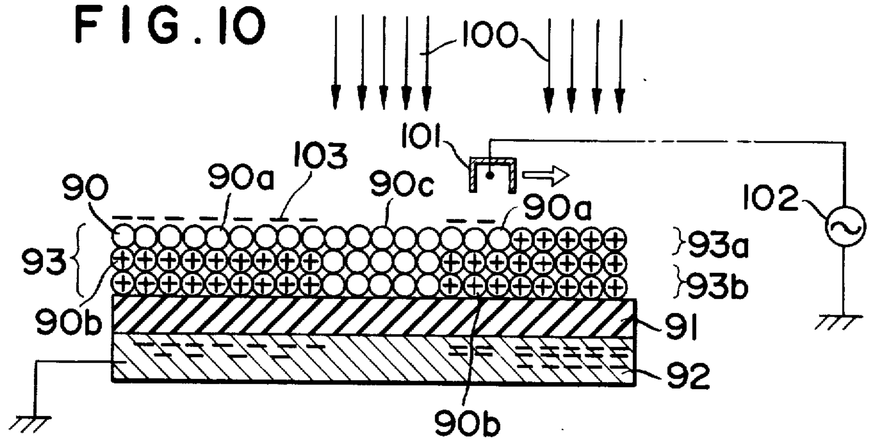


FIG.11

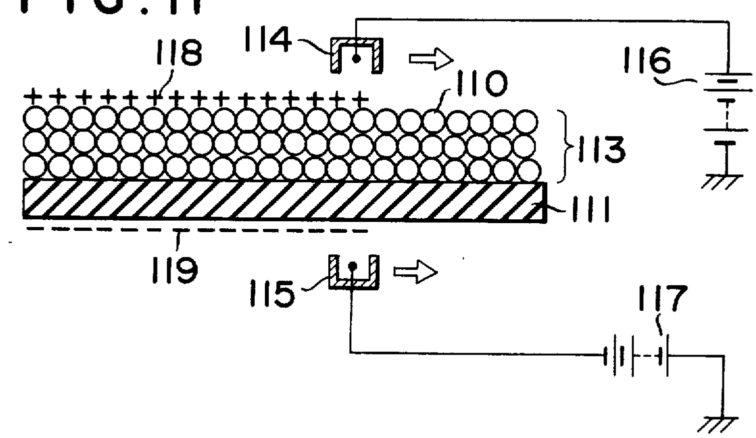
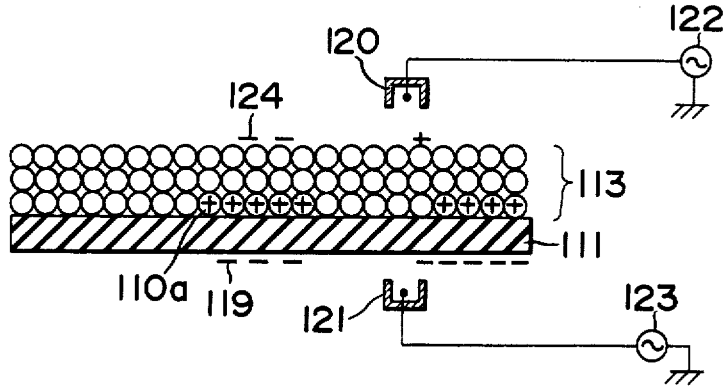


FIG.12



PROCESS FOR MAKING AN ELECTROPHOTOGRAPHIC IMAGE BY USE OF PHOTOCONDUCTIVE PARTICLES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a process for making an electrophotographic image by use of photoconductive particles, and more specifically to a process for making an electrophotographic image on an insulating substrate by use of photoconductive particles serving as developer particles.

The electrophotographic image forming process in accordance with this invention is also capable of forming a particle image on a conductive substrate by use of photoconductive particles. The photoconductive particles used in this invention are colored toner made of photoconductive material.

2. Description of the Prior Art

In the general electrophotographic process in which an electrophotographic image is formed on an electrophotographic plate or on a transfer paper, an electrostatic latent image is formed on a uniformly charged photoconductive surface by exposure to imagewise light. By exposure to the imagewise light, the charges in the exposed area of the image are neutralized and an electrostatic latent image is formed. Therefore, one surface of the photoconductive layer is required to be in contact with a conductive layer having surface resistance of not higher than about $10^{10}\Omega$ so that the charges may move away from the photoconductive layer in the exposed area.

Apart from the electrophotographic process in which a latent image is formed on the photoconductive layer disposed on a conductive substrate, it has heretofore been known in the art to form a particle image on a substrate by use of photoconductive particles. In one of the conventional processes of this type, the photoconductive particles are applied on a conductive substrate. This process is disclosed, for instance, in Japanese Patent Publication No. 22645/1963.

Another conventional process using the photoconductive particles as developer particles is disclosed in Japanese Patent Publication No. 9316/1972 filed by the same applicant. In this patent publication, it is disclosed that photoconductive particles are applied on an insulating substrate which is processed to have conductivity on the surface thereof.

As apparent from the above description of the prior art in electrophotography, it has heretofore been impossible to form an electrophotographic image directly on an insulating substrate unless it has a conductive surface.

SUMMARY OF THE INVENTION

In light of the above-described nature of the conventional electrophotographic process, it is the primary object of the present invention to provide a process for making an electrophotographic image directly on an insulating substrate with an insulating surface.

Another object of the present invention is to provide a process for making an electrophotographic image either on an insulating or conductive substrate by use of photoconductive particles applied on the substrate.

In accordance with the present invention, therefore, it becomes possible to form an electrophotographic image on any kind of image recording medium, conductive or insulating. Further, it will be understood that, in accordance with the present invention, it is possible to use an electrophotographic photosensitive layer insulated from conductive material.

In addition, it is still another object of the present invention to provide an electrophotographic image forming process in which a positive image can be obtained from either a positive or negative original.

Briefly summarizing, the process for making the electrophotographic image in accordance with the present invention comprises the steps of applying photoconductive particles on a substrate, uniformly charging the particles, exposing the particles to imagewise light to form an internal latent image in the particle layer, charging the surface of the particle layer in the reverse polarity to neutralize the charges on the surface of the particle layer, and removing the neutralized particles to leave only the charged particles attracted by the insulating substrate in the exposed area of the image. The developed image formed by selectively removing the particles is fixed by, for instance, a solvent fixing process.

In one variation of the process in accordance with the present invention, the uniform charging of the particles and the imagewise exposure are performed at the same time.

In another variation of the process in accordance with the present invention, the particles are charged before being applied on the surface of the insulating substrate and the imagewise exposure of the particle layer is performed simultaneously with the neutralization of the charges in the particles. In this variation of the invention, a positive image is obtained from a positive original.

In still another variation of the present invention, the electrophotographic image can be formed on an insulating substrate without a conductive base, In this variation, the uniform charging is performed by use of a pair of corona discharging electrodes of opposite polarities. Further, in neutralizing the charges, there is used a pair of A.C. corona discharging electrodes located one on either side of the insulating substrate.

It will be understood by those skilled in the art that the process for making an electrophotographic image in accordance with this invention is applicable not only to the dry type copying machine but also to a variety of recording machines including, for example, an electrostatic print marking system by which lines are marked on a steel plate utilizing the electrostatic recording principle for facilitating the marking work in the shipbuilding industry.

As for the photoconductive material used for the photoconductive particles, a variety of photoconductive materials including sulfides, oxides and selenides of zinc, cadmium and the like can be used. The photoconductive material is dispersed in a binder resin and processed so as to be chargeable in either positive or negative porality. For example, zinc oxide, mercury sulfide, lead sulfide, tellurium compound, titanium dioxide, cadmium sulfide, and cadmium sulfide-carbonate are effectively used. Organic photoconductors such as metal-free phthalocyanine and polyvinylcarbazole can be used as the material for the photoconductive material.

As for said binder in which the photoconductive material is dispersed, any resin which can be used for the ordinary electrofax photosensitive layer can be used. The resins which can be used as the binder are, for example, alkyd resins, styrene-modified or acryl-modified alkyd, rosin-modified or phenol-modified alkyd, epoxy esters, terpene resins, buthylated melamine resins, copolymers of styrene and other copolymerizable monomers such as butadiene, acrylonitrile, acrylic acid ester and methacrylic acid ester, vinyl chloride and vinyl acetate copolymer, partially saponified copolymers of vinyl chloride and vinyl acetate, polyvinyl acetate, copolymers of vinyl acetate and other vinyl monomers such as crotonic acid, acrylic acid ester and ethacrylic acid ester, homo- and co-polymers containing acrylate or methacrylate and silicone resins.

In the process in accordance with the present invention, it is possible to use two or more kinds of photoconductive particles of different composition. The photoconductive particles of different composition present different spectral sensitivity. Accordingly, it becomes possible to form a multi-color image by use of two or more kinds of photoconductive particles mixed together and scattered on an image recording medium.

The photoconductive particles employed in the process in accordance with the present invention are preferably finely granulated powders having a size of not larger than 50 microns in diameter and particles not larger than 20 microns in diameter are particularly preferable. The size of the particles is determined in accordance with the desired quality of image, particularly the resolution of the image. In other words, the resolution of the image is determined by the upper limit of the size of the particles used.

As for the characteristics of the photoconductive particles, the particles must be able to maintain electrostatic charges in the dark for at least a period of time corresponding to the time of one cycle of the electrophotographic process which is not shorter than one minute after being subject to a high voltage of about several hundreds of volts. In contrast to their ability to maintain high voltage charges in the dark, the photoconductive particles are required to form a layer in which the charges are neutralized in response to exposure to activating illumination and the residual charge is lowered after the exposure to such radiation. From the viewpoint of commercial use of the electrophotographic process, it is desirable that the exposure time required be not longer than 30 seconds. Accordingly, the sensitivity of the particles to the radiation must be high enough to make an exposure time of longer than 30 seconds unnecessary. From the viewpoint of practical use of the photoconductive particles, the neutralization of the charges should preferably be completely made with an exposure time of about 0.001 to 10 seconds. With such a high sensitivity of the photoconductive particles to the exposure, it is possible to form the electrophotographic image with strobo flash light exposure.

The above and other features, advantages and objects of the present invention will be made more apparent from the following detailed description taken in conjunction with the accompanying drawings as described briefly hereinbelow.

BRIEF DESCRIPTION OF THE DRAWING

FIGS. **1** to **6** show a first embodiment of the process for making an electrophotographic image in accordance with the present invention, in which;

FIG. **1** is a sectional elevation showing the first step of the first embodiment of the process in accordance with the invention wherein photoconductive particles are applied on an insulating surface attached to a conductive electrode,

FIG. **2** is a sectional elevation showing the second step thereof wherein the particles are uniformly charged,

FIG. **3** is a sectional elevation showing the third step thereof wherein the particles are exposed to imagewise light to form a latent image therein,

FIG. **4** is a sectional elevation showing the fourth step thereof wherein the charges on the particle layer are neutralized,

FIG. **5** is a sectional elevation showing the fifth step thereof wherein the photoconductive particles are selectively blown away to form a visible particle image on the insulating surface,

FIG. **6** is a sectional elevation showing the last step thereof wherein the developed visible particle image is fixed on the insulating surface,

FIG. **7** is a sectional elevation showing the first step of an image forming process in accordance with the second embodiment of the present invention in which the uniform charging and the exposure to the imagewise light are performed simultaneously,

FIG. **8** is a sectional elevation showing the second step of the second embodiment of the invention in which the charges on the particle layer are neutralized,

FIG. **9** is a sectional elevation showing the first step of an image forming process in accordance with the third embodiment of the present invention in which the particles are applied on an image recording substrate simultaneously with the uniform charging thereof,

FIG. **10** is a sectional elevation showing the second step of the third embodiment of the present invention in which the exposure of the particles to the imagewise light and the neutralization of charges are performed simultaneously,

FIG. **11** is a sectional elevation showing one step of the fourth embodiment of the present invention in which no conductive electrode is used in contact with the insulating substrate and the particles are charged uniformly by use of a pair of corona discharging electrodes of opposite polarities, and

FIG. **12** is a sectional elevation showing another step of the fourth embodiment of the present invention in which the charges on the particle layer are neutralized by use of a pair of A.C. corona discharge electrodes located one on either side of the substrate bearing the particle layer.

PREFERRED EMBODIMENTS OF THE INVENTION

Referring to FIGS. **1** to **6** which show a first embodiment of the present invention, an insulating substrate **1** disposed on a conductive electrode **2** in contact therewith is used for recording an electrophotographic particle image thereon. The first step of the first embodiment is shown in FIG. **1**, in which a plurality of particle layers **3** consisting of a number of fine photoconductive particles **30** are formed on the surface of the insulating substrate **1** by use of a particle scattering device **4**. The conductive electrode is not absolutely necessary as understood from the descriptions hereinafter. The purpose of the provision of the conductive electrode **2** is to provide a grounded electrode for the charging process and a bias electrode for the development process. Therefore, the insulating substrate **1** is not always required to be integrally fixed to the conductive electrode **2**. The insulating substrate **1** may be placed in contact with conductive electrode 2 so as to be easily peeled off or it may simply be placed on the conductive electrode 2.

The photoconductive particle layers 3 are subject to an electric field created by a D.C. corona charger 5 which is impressed with a voltage by a D.C. source 6. Thus, the surface of the photoconductive particle layers 3 is uniformly charged. In the embodiment illustrated in the drawing, the photoconductive particles 30 are of p-type and accordingly are positively charged. In case of the n-type photoconductive particles, the polarity in which the particles 30 are charged is minus. The minus numeral 7 indicates the plus charges imparted to the surface of the photoconductive layers 3 and 8 indicates the nimus charges induced in the conductive base plate or the electrode 2.

The uniformly charged photoconductive layers 3 are exposed to imagewise light 9 of activating radiation. By the exposure of the photoconductive particle layers 3 to the imagewise light 9, the electric resistance of the photoconductive particles 30 in the exposed area is lowered and the electric charges in the upper layer 3*a* of the photoconductive particles 30 are moved to the lower layer 3*b* of the photoconductive particles 30. Thus, the charges in the exposed area are moved to the lower layer 3*b* of the photoconductive layers 3 as indicated at 10 and the charges in the non-exposed area remain in the upper layer 3*a* of the photoconductive layers 3 as indicated at 11 in FIG. 3.

Thereafter, as shown in FIG. 4, the photoconductive layers 3 are subject to A.C. corona charging in the dark by use of an A.C. corona charger 12 which is impressed with an A.C. voltage by a high voltage A.C. source 13 so that the surface charges 11 on the upper layer 3*a* of the photoconductive particle layers 3 are neutralized. The charges 10 remaining in the lower layer 3*b* of the particle layers 3 are not neutralized by the A.C. corona charging since these charges 10 are insulated by the photoconductive particles existing thereon in the upper layers of the particles. Thus, an electrostatic latent image is formed by the A.C. corona charging. As shown in FIG. 4 indicated at 14, there remain a small amount of charges of the polarity opposite to that of the internal charges 10 imparted to the particles in the lower layer 3*b* in the exposed area on the surface of the particle layers 3 above said internal charges 10. In the conductive base or electrode 2 attached to the insulating substrate 1 there also remain a small amount of charges of the polarity opposite to that of the internal charges 10 as indicated at 8.

The subsequent development step is illustrated in FIG. 5 in which the photoconductive particles 30 having no internal charges attracted by the charges 8 are blown away by an air blow. In removing the photoconductive particles 30 from the surface of the insulating substrate 1, a bias electrode 16 which is impressed with the voltage of the same polarity as that of the charges 10 imparted to the photoconductive particles 30*a* remaining on the surface of the insulating substrate 1 is located above the insulating substrate 1 with the particles 30*a* attached thereon. The bias electrode 16 serves as a development electrode. The bias electrode 16 and the conductive electrode 2 are connected to the opposite polarities of an electric source 17. Said air blow is made by a blower 18 moved laterally above the photoconductive particle layers 3. Thus, a particle image is formed on the surface of the insulating substrate 1 by the particles 30*a* remaining thereon. The photoconductive particles 30 which are blown off from the surface of the insulating substrate 1 are restored and used again for the subsequent cycle of the image forming process.

Said bias electrode 16 serving as a development electrode has the effect of increasing the attraction between the disposed 10 imparted to the plate attached thereto. particles 30*a* and the charges 8 remaining in the conductive electrode 2, whereby the range of allowance of the strength of said air blow for development is enlarged and the fog in the background of the image is reduced by making possible the blowing off of the particles with an air blow of great intensity. Particularly, if the insulating substrate 1 has a large thickness or the dielectric constant of the insulating substrate is large, it is desirable to use the bias electrode 16. It is of course possible, however, for the formation of the particle image by the air blow to be conducted without the bias electrode 16.

The particle image which is formed on the insulating substrate 1 by the photoconductive particles 30*a* sticking to the surface thereof by the electrostatic force is fixed by means of well-known fixing methods such as heating, solvent fixing and pressure fixing. An example of solvent fixing is shown in FIG. 6, in which a solvent 20 containing a component to soften the photoconductive particles is sprayed on the particle image formed on the insulating substrate 1 by use of spraying device 21. The particle image is fixed on the insulating substrate 1 as shown at 22 in FIG. 6.

In the above-described first embodiment of the invention, the scattering of the photoconductive particles 30 on the substrate 1, the uniform charging of the surface of the particle layers, the exposure to the imagewise light, and the A.C. corona charging are sequentially performed. It is, however, possible to form the particle image even if the uniform charging by a D.C. corona charger and the imagewise exposure are performed simultaneously. Such a variation will now be described in detail as the second embodiment of the present invention referring to FIGS. 7 and 8.

In this second embodiment shown in FIGS. 7 and 8, photoconductive particles 70 are applied on an insulating substrate 71 disposed on a conductive electrode 72 in a plurality of layers 73 by the same method as employed in the first embodiment shown in FIG. 1. The photoconductive particle layers 73 are subject to an imagewise exposure 74 and a uniform charging by a D.C. corona charger 75 impressed with a high D.C. voltage by a D.C. source 76 simultaneously. As well known in the art, the uniform charging is performed by laterally moving the D.C. corona charger 75 above the surface of the photoconductive layers 73. Consequently, the non-exposed portion of the photoconductive layers 73 is charged only on the surface thereof as indicated at 77. In the exposed area, the photoconductive particles 70*a* on the surface of the layers 73 are made conductive and the charges are moved to the internal or lower photoconductive particles 70*b*. In the conductive electrode 72, opposite charges 78 are induced.

After the electrostatic latent image is formed as described above and illustrated in FIG. 7, the particles 70 are subject to an A.C. corona charging as shown in FIG. 8 so that the surface potential of the photoconductive particle layers 73 may be made zero by neutralizing the charges on the surface thereof by use of an A.C. corona charger 80 connected with an A.C. source 81. On the surface of the photoconductive layers 73 in the exposed area, charges **79** of reverse polarity are induced so that the charges **77** on the unexposed area may be neutralized. After the surface charges **77** have been neutralized, the development and fixing are performed similarly to those of the first embodiment as shown in FIGS. **5** and **6.**

The above embodiments concern the image formation of in a negative-to-positive type system in which a positive image is formed on an insulating substrate from a negative light image. It is, however, possible to perform a positive-to-positive type image formation by conducting the imagewise exposure and the neutralizing corona charging simultaneously. Further, in accordance with this process of the invention, the image can be formed on any type of substrate, insulating or conductive. Such a variation of the invention will now be described in detail as the third embodiment thereof referring to FIGS. **9** and **10.** In accordance with this embodiment, the image can be formed on a conductive material having a partial insulating portion such as a steel plate having a partially coated portion covered with a dielectric coating like paint.

Referring to FIG. **9** in which photoconductive particles **90** are applied on the surface of an insulating substrate **91** disposed on a conductive electrode **92**, the photoconductive particles **90** are precharged before they are applied on the substrate **91.** In order to apply the precharged photoconductive particles **90,** a device **94** for applying particles **90** on the surface of the insulating substrate **91** is provided with a charger **95** mounted to the particle applying opening of the device **94** as shown in FIG. **9.** The charger **95** is electrically connected with a high voltage D.C. source **96.** The photoconductive particles **90** scattered on the surface of the insulating substrate **91** are imparted with a charge **97.** The charge **91** is for instance plus as illustrated in the drawing. The polarity of the charge **91** is of course determined in accordance with the kind of the photoconductive material used in the particles **90** as mentioned in said first embodiment. Charges **98** of opposite polarity are induced in the conductive electrode **92** attached to the insulating substrate. The conductive electrode **92** is grounded at least during the process of uniform charging as indicated at **99.**

After the photoconductive particles **90** are applied on the insulating substrate **91,** the particles **90** are exposed to imagewise light **100** as illustrated in FIG. **10.** The light **100** is of course of the wavelength which is capable of activating the photoconductive particles **90.** Simultaneously with the exposure to the imagewise light **100,** the photoconductive particles **90** are subject to A.C. corona charging by means of an A.C. corona charger **101** connected with an A.C. source **102** as shown in FIG. **10.**

By the simultaneous exposure and the A.C. charging, the photoconductive particles **90*a*** in the upper layer **93*a*** in the non-exposed area are neutralized of their charge and the particles **90*b*** in the lower layers **93*b*** in the non-exposed area are maintained to have the charge as illustrated in FIG. **10.** Further, the charge of the photoconductive particles **90*c*** in the exposed area is neutralized since the electric resistance thereof is lowered by the activating radiation of the imagewise light. It will be understood that the surface of the photoconductive particle layers **93** in the non-exposed area is provided with a small amount of compensating charges **103** so as to make the surface potential of the non-exposed area zero.

In accordance with this embodiment, the charges in the exposed area are neutralized. Therefore, a positive-to-positive image formation can be performed. The electrostatic latent image which has been formed by the above-described process can be made into a visible fixed image by the development and fixing process as mentioned in the foregoing embodiments.

In accordance with the above-described embodiment shown in FIGS. **9** and **10,** it is possible to use a conductive substrate instead of the insulating substrate **91.** Therefore, this embodiment is applicable to the formation of an electrophotographic image on either a conductive substrate or a conductive substrate with a dielectric portion.

It is known that the contrast of the image is generally in proportion to the quantity of charge imparted to the photoconductive material or substrate. In this invention, a plurality of layers of photoconductive particles are used and the charges remain in a plurality of layers of the particles in the second and the third embodiments as shown in FIGS. **8** and **10.** Therefore, an image of high contrast can be obtained by these embodiments of the invention.

Although the above-described embodiments employ an A. C. corona discharging device for neutralizing the charges remaining on the surface of the photoconductive particle layers, it is possible to use a D.C. corona charging device of the reversed polarity instead thereof. The polarity of the D.C. charging device for neutralization of the charges of course must be opposite to that of the D.C. corona charging device for uniformly charging the particles. In said embodiments, for example, the polarity of the D.C. corona charging device to be used for neutralization of the charge remaining in the photoconductive particles must be minus. In this case, the level of the second D.C. charging device should desirably lower than that of the first uniformly charging D.C. charging device.

Furthermore, it is possible to perform the image forming process in accordance with this invention without using a conductive electrode, although all the foregoing embodiments use the conductive electrode in contact with the insulating substrate on which the image is finally formed. Such a variation will now be described in detail as a fourth embodiment of the present invention referring to FIGS. **11** and **12.**

As illustrated in FIG. **11,** in the fourth embodiment of the present invention photoconductive particles **110** are accumulated in a plurality of layers on an insulating substrate **111** which is not disposed on a conductive electrode or the like. The surface of the photoconductive particle layers **113** and the back surface of the insulating substrate **111** are subject D.C. charging of the opposite polarities by means of a pair of D.C. corona chargers **114** and **115** which are connected with D.C. sources **116** and **117,** respectively. The surface of the photoconductive particle layers **113** and the back surface of the insulating substrate **111** are charged in the opposite polarities **118** and **119,** respectively. The result of this operation shown in FIG. **11** corresponds to the result of the uniform charging performed in the first embodiment as shown in FIG. **2.** Therefore, the exposure of the particles **110** to the imagewise light is conducted in just the same manner as that conducted in the third step of the first embodiment as shown in FIG. **3.** Thus, an electrostatic latent image is formed in the photoconductive particle layers **113.**

The formation of the latent image as described immediately hereinabove corresponds to the similar step in the first embodiment as shown in FIG. 3. In case of the second and third embodiments of the invention, the above modified step of forming the latent image on an insulating substrate which is not disposed on a conductive electrode can be performed in a similar way to that of the second and third embodiments. That is, the imagewise exposure in the variation corresponding to the second embodiment is performed simultaneously with the charging. Further, the imagewise exposure in the variation corresponding to the third embodiment is performed simultaneously with the neutralization of charges after the photoconductive particles which have been precharged by a charger provided in the particle scattering device are applied on the insulating substrate, and the back side of the insulating substrate is charged to the polarity opposite to that of the charges imparted to the particles.

The electrostatic latent image formed in the photoconductive particle layers **113** as described hereinabove is converted to a developable latent image by neutralization of the surface charges. In order to neutralize the surface charges formed on the photoconductive layers **113** and the insulating substrate **111**, a pair of A.C. corona chargers **120** and **121** connected with A.C. sources **122** and **123**, respectively, located on the opposite sides of the electrophotographic recording medium comprising the photoconductive particles **110** and the insulating substrate **111**. By the neutralization, the surface charges in the non-exposed area are all removed. Only in the exposed area, the charges remain in the lower layer of the photoconductive particle layers **113** as indicated at **110*a*** in FIG. **12**. Together with the internal charges **110*a*** remaining in the lower layer of the particles **110**, a small amount of charges **119** remain on the back surface of the insulating substrate **111**. Further, a small amount of charges **124** are induced on the surface of the upper layer of the photoconductive particle layers **113** as shown in FIG. **12**.

Now the present invention will be described with particular reference to several experimental examples to specifically disclose the invention with concrete data.

EXAMPLE I

As the photoconductive particles, "EPM photoner" made by Fuji Photo Film Co., Ltd. (photoconductive particles containing zinc oxide which is sensitized in the region of visible light and having an average diameter of about 50μ and a true specific gravity of about **1.53**) was used. As the insulating substrate, "metalmy" made by Toyo Rayon Co., Ltd. (hereinafter referred to simply as "metalmy") comprising a polyethylene terephthalate film having a thickness of 100μ (hereinafter referred to simply as "PET film") and an aluminium layer evaporated on one surface of the film was used. With these particles and the substrate, the first embodiment of the present invention shown in FIGS. **1** to **6** was carried out for testing the embodiment.

The "EPM photoner" was uniformly applied on the PET film side of the "metalmy." The amount of photoner applied on the substrate was varied from 70 to 140g/m^2. The voltage of the D.C. corona charging was varied from −3 to −6KV. The height of the corona charger (the distance from the layer of the "EPM photoner") was 2 to 3cm. The surface voltage of the charged layer of the "EPM photoner" was 100 to 400 volts.

The surface of the "EPM photoner " layer which had been charged as described above was exposed to imagewise light of 100 to 1000 lux sec illumination. Then, the surface of the "EPM photoner" was subject to A.C. corona charging. The A.C. corona charger was impressed with alternating current of 3KV. The A.C. corona charger was controlled to generate the same amount of positive and negative ions.

After formation of an electrostatic latent image as described above, the image was developed by air blow. The air blow speed was controlled to be 10 to 20m/sec on the substrate. The test was performed under the above-described conditions with and without a bias voltage.

In case of not using the bias voltage, a thin but sufficiently distinguishable particle image was obtained. On the other hand, in case of using a bias voltage of 10 to 500V/cm, a satisfactory particle image was obtained.

EXAMPLE II

As the insulating substrate, a PET film having a thickness of 125μ, a vinyl chloride plate having a thickness of 1 to 2mm, an acryl plate having a thickness of 1 to 2mm and other high molecular insulating materials as well as insulating films such as vinyl chloride and polystyrene having a thickness of 200μ and other insulating material having a thickness of 100μ to 2mm were used, and the first embodiment of the invention was carried out for testing the invention with these materials. As for the photoconductive particles, "EPM photoner" was used as in Example I.

Each of the above insulating substrates was in turn put into contact with a metal plate serving as a grounded electrode. After photoconductive particles had been applied thereon, D.C. charging, exposure, A.C. corona charging and development were performed under the same conditions as those in Example I. At the time of development, a bias voltage of 50 to 1KV/cm was used.

In each case, a satisfactory image was obtained.

EXAMPLE III

The exposure to the imagewise light and D.C. charging were simultaneously performed in accordance with the second embodiment of the invention. As the photoconductive particles, "EPM photoner" was used as in Example I. Further, as the insulating substrate, "metalmy" was used as in Example I. The scattering or application of the EPM photoner on the substrate, exposure and D.C. charging and A.C. charging were conducted under the same conditions as those in Example **1**. The electrostatic latent image which was formed by the above process was developed into a visible image by use of air blow. The air blow speed was set to 15 to 20m/sec on the substrate. The bias voltage was varied from 0 to 300V/cm. In each case, an excellent particle image of high contrast was obtained.

EXAMPLE IV

The exposure to the imagewise light and D.C. charging were simultaneously performed in accordance with the second embodiment of the invention, and the insulating materials used in Example II were used. Further, the insulating material was used in contact with a metal plate serving as a grounded electrode. As the photoconductive particles, "EPM photoner" was used as in Example II. The application of the "EPM photoner" on the substrate, the exposure, D.C. corona charging, and development were performed under the same conditions as those employed in Example III. The bias voltage was changed from 100 to 1KV/cm. In each case a fairly good image of high contrast was obtained.

EXAMPLE V

In accordance with the third embodiment of the invention, D.C. charging was applied to the whole layer of photoconductive particles and the exposure to the imagewise light and the A.C. corona charging were performed simultaneously. As the photoconductive particles, "EPM photoner" was used. The application of the photoner on the substrate, exposure, and A.C. corona charging were made under the same conditions as those employed in Exampe I. The surface potential of the EPM photoner scattered after precharging was 300 to 500 volts. As the insulating substrate, the same materials as those used in Examples I and II were used. Insulating materials other than "metalmy" were used in contact with a grounded metal plate. The speed of the air blow was varied from 14 to 22m/sec. The bias voltage was varied from 0 to 300V/cm in case of the "metalmy" and from 100 to 700V/cm for other materials.

In each case, an excellent particle image of considerably high contrast was obtained.

EXAMPLE VI

Similarly to Example V, particle images were formed on a conductive substrate in accordance with the third embodiment of the invention. As the conductive substrate, metal, paper containing an appropriate degree of moisture and other conductive materials were used. The surface resistance of these materials was not higher than $10^8\Omega$. As the photoconductive particles, "EPM photoner" was used as in the other examples. The application of the particles on the substrate, D.C. charging, and development were conducted under the same conditions as employed in Example V. The A.C. corona charging was performed with a voltage of 0 to 2KV. A bias voltage was not used.

In each case, an excellent image of particles was obtained with high contrast.

EXAMPLE VII

The test was performed in accordance with the third embodiment of the invention as in Example V. As the substrate, materials having a surface resistance of 10^{10} to $10^{12}\Omega$ and a thickness of 100μ to 1 mm were used. Resistances of this degree fall in the intermediate range between insulator and conductor. As the photoconductive particles, "EPM photoner" was used. The application of photoner on the surface of the substrate, D.C. charging, exposure and A.C. corona charging were conducted under the same conditions as those employed in Exampe VI. The conditions of development were also the same as those employed in Example VI. The substrates were used in contact with a metal plate which was grounded. The bias voltage was changed from 100 to 700V/cm.

In each case, a satisfactory image was obtained as in the other examples.

EXAMPLE VIII

Similarly to Example V, the test was conducted in accordance with the third embodiment of the invention. As the substrate, a metal plate was used. The metal plate was partially covered with an insulating high molecular coating having a surface resistance of $10^{15}\Omega$ or more. Further, another portion of the metal plate was covered with a coating containing graft carbon in styrenated alkyd resin having a surface resistance of 10^{10} to $10^{12}\Omega$. The thickness of these coatings was 10 to 15μ. Thus, three different parts were formed on a metal substrate, an insulating part, a non-coated conductive part and an insulating-conductive part.

Then, charged "EPM photoner" was scattered on the metal plate having three differently coated parts at a rate of $120g/m^2$. Thereafter, the metal plate was subject to A.C. corona charging at 3KV while being exposed to imagewise light of 250 to 600 lux sec. Then, the latent image was developed under the same conditions as those employed in Example V. The bias voltage employed was 200V/cm. As a result, very good particle images were obtained regardless of the characteristics of the surface of the metal plate.

EXAMPLE IX

The test was performed without a conductive base in accordance with the fourth embodiment. The photoconductive particles were scattered on the surface of an insulating substrate and a D.C. charger and an A.C. charger were used on the backside of the substrate to form an image in accordance with the fourth embodiment of the invention. The conditions of formation of the image were made the same as those employed in the foregoing Examples I to VIII. In the first charging with the D.C. corona charger, a D.C. voltage of 6KV was impressed and in the second charging with the A.C. charger, an A.C. voltage of 3KV was impressed. At the time of development, a bias voltage of 100 to 600V/cm was used.

A satisfactory particle image was obtained as in the other examples.

I claim:

1. A process for making an electrophotographic image by use of photoconductive particles comprising the steps of:
   - providing a plurality of layers of photoconductive particles on a substrate having at least an insulating upper surface,
   - providing a uniform charge to the upper part of the layer of said photoconductive particles,
   - exposing the layers of photoconductive particles to imagewise light to move the charges in the upper part of the layers to the lower part thereof in the area exposed to the light,
   - neutralizing from a charging means external to the substrate the charges on the outer surface of the layers in the area not exposed to the light, and
   - removing said photoconductive particles from the surface of said recording medium to leave the particles which received the charge moved from the upper part of the layers.

2. A process for making an electrophotographic image as defined in claim 1 wherein said uniform charging step is conducted by use of a direct current corona charging means.

3. A process for making an electrophotographic image as defined in claim 1 wherein said uniform charging step and said exposing step are conducted simultaneously.

4. A process for making an electrophotographic image as define in claim 1 wherein said step of removing the photoconductive particles is performed by blowing air against the surface of the substrate.

5. A process for making an electrophotographic image as defined in claim 1 wherein said insulating substrate is deisposed on a conductive base

6. A process for making an electrophotographic image as defined in claim 1 wherein said substrate is entirely insulating.

7. A process for making an electrophotographic image as defined in claim 6 wherein said uniform charging step is conducted by used of pair of D.C. corona charging means of opposite polarities respectively disposed on opposite sides of said substrate.

8. A process for making an electrophotographic image as defined in claim 7 wherein said neutralizing step is conducted by use of a pair of A.C. corona charging means respectively located on opposite sides of the substrate.

9. A process for making an electrophotographic image as defined in claim 7 wherein said neutralizing step is conducted by use of a pair of D.C. corona charging means respectively disposed on opposite sides of said substrate and of reverse polarities to those of said D.C. corona charging means used for uniformly charging the photoconductive layers.

10. A process for making an electrophotographic image comprising the steps of

providing a plurality of layers of charged photoconductive particles on a substrate;

exposing the layers of photoconductive particles to imagewise light;

neutralizing from a charging means external to the substrate all of the charges in all of the layers in the area exposed to light and substantially only the charges in the upper part of the layers in the area not exposed to light to form at the lower part of said layers an electrostatic latent image; and

removing said photoconductive particles from said substrate to leave the charged particles not neutralized in the lower part of said layers in the area not exposed to light.

11. A process for making an electrophotographic image as defined in claim 10 wherein said step of providing a plurality of layers of charged photoconductive particles on a recording medium comprises charging a number of photoconductive particles in a predetermined polarity, and applying the charged particles in a plurality of layers on a recording medium.

12. A process for making an electrophotographic image as defined in claim 11 wherein the uniform charging step and the step of applying the particles are conducted simultaneously.

13. A process for making an electrophotographic image as defined in claim 10 wherein said exposing step and said neutralizing step are conducted simultaneously.

14. A process for making an electrophotographic image as defined in claim 13 wherein said substrate is conductive.

15. A process for making an electrophotographic image as defined in claim 13 wherein said substrate is conductive.

16. A process for making an electrophotographic image as defined in claim 10 wherein said step of removing the photoconductive particles is performed by blowing air against the surface of the substrate.

17. A process for making an electrophotographic image as defined in claim 10 wherein said insulating substrate is disposed on a conductive base plate attached thereto.

18. A process for making an electrophotographic image as defined in claim 10 wherein said substrate is entirely insulating.

19. A process for making an electrophotographic image as defined in claim 18 wherein a D.C. corona charging means charges the back side of the insulating substrate to a polarity opposite that of the charges imparted to the particles.

20. A process for making an electrophotographic image as defined in claim 19 wherein said neutralizing step is conducted by use of a pair of A.C. corona charging means respectively located on opposite sides of the substrate.

21. A process for making an electrophotographic image as defined in claim 19 wherein said neutralizing step is conducted by use of a pair of D.C. corona charging means respectively disposed on opposite sides of said substrate and of reverse polarities to those of said D.C. corona charging means used for uniformly charging the photoconductive layers.

22. A process for making an electrophotographic image comprising the steps of

providing a plurality of layers of photoconductive particles on a substrate;

providing a uniform charge to at least the upper layer of said photoconductive particles;

exposing the layers of photoconductive particles to imagewise light;

neutralizing at least the charges on the outer surface of the layers in the area not exposed to light with neutralizing charges of a polarity opposite to that of the charges on the outer surfaces, said neutralizing charges being provided from a source external to said substrate to form at the lower part of said layers an electrostatic latent image corresponding to said imagewise light; and

removing at least those photoconductive particles in the non-latent image area from said substrate to leave the particles in said latent image area.

23. A process as in claim 22 where said substrate has at least an insulating upper surface and where said uniform charge is substantially restricted to the upper part of said layers of photoconductive particles, said exposing step causing the charges in the area exposed to light to move to the lower part of said layers and said neutralizing step occurring after said exposing step and not affecting said charges in the lower part so that said charges in the lower part hold their associated photoconductive particles to the substrate as the non-latent image area photoconductive particles are removed whereby a visible image corresponding to a reversal of said light image is formed on said substrate.

24. A process as in claim 23 where said substrate is disposed on a conductive lower layer, said conductive layer being grounded during said uniform charging step.

25. A process as in claim 23 where said substrate is entirely insulative, said photoconductive particles being disposed on one side of said substrate and charges having a polarity opposite that of said uniform charge being uniformly applied to the side opposite said one side during said uniform charging step.

26. A process as in claim 22 where substantially all of said layers of photoconductive particles are provided with said uniform charge, said exposing and neutralizing steps occurring simultaneously to neutralize the charges in the area exposed to light in all of said layers so that the reamining charges in the lower part of the

layers not exposed to light hold their associated photoconductive particles to the substrate as the non-latent image area particles are removed whereby a visible image corresponding to a positive reproduction of said light image is formed on said substrate.

27. A process as in claim **26** where said substrate is conductive.

28. A process as in claim **26** where said substrate comprises an insulative layer disposed on a conductive lower layer, said conductive layer being grounded during said uniform charging step.

29. A process as in claim **26** where said substrate is entirely insulative, said photoconductive particles being disposed on one side of said substrate and charges having a polarity opposite that of said uniform charge being uniformly applied to the side opposite said one side during said uniform charging step.

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