Nov. 11, 1969 J. W. WEIGL ET AL 3,477,846

XEROGRAPHIC CHARGE TRANSFER PROCESS

Original Filed Dec. 28, 1962 3 Sheets-Sheet 1

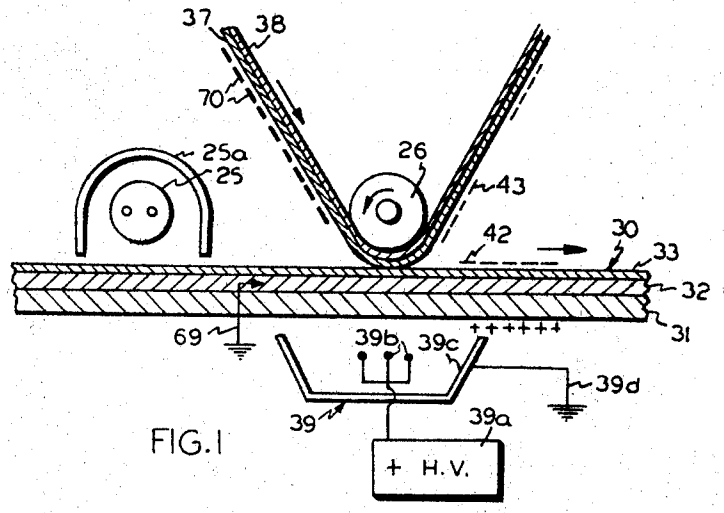


FIG. 1

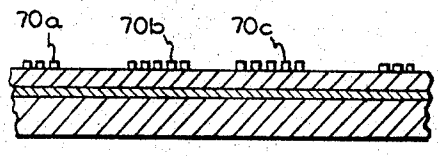


FIG. 2

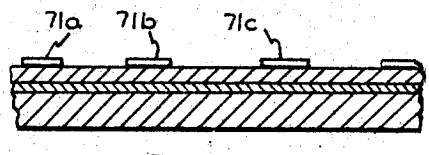


FIG. 3

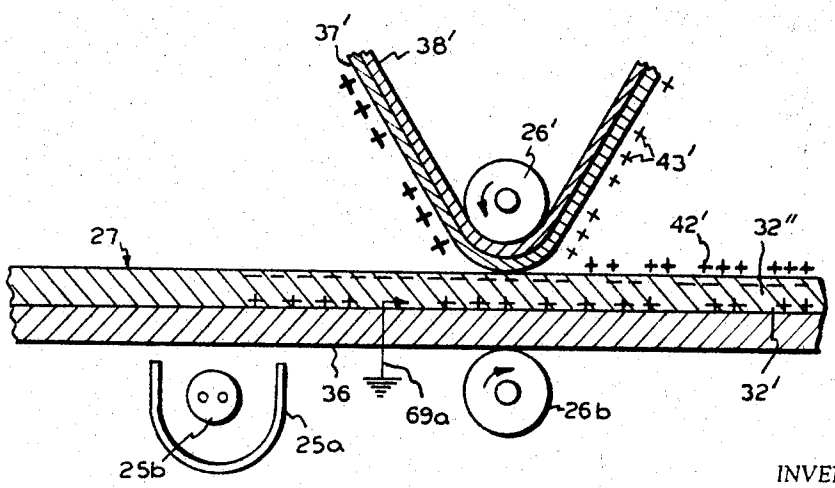


FIG. 4

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XEROGRAPHIC CHARGE TRANSFER PROCESS

Original Filed Dec. 28, 1962 3 Sheets-Sheet 2

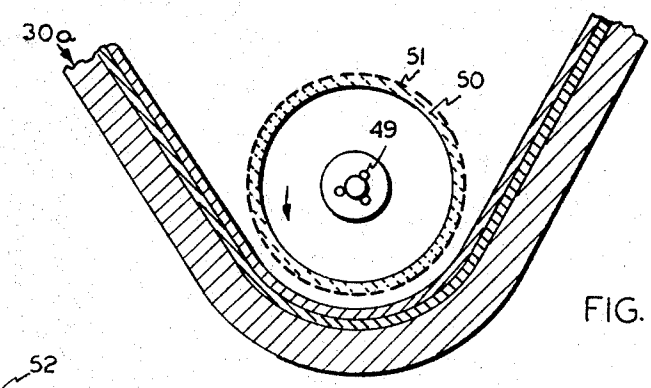


FIG. 5

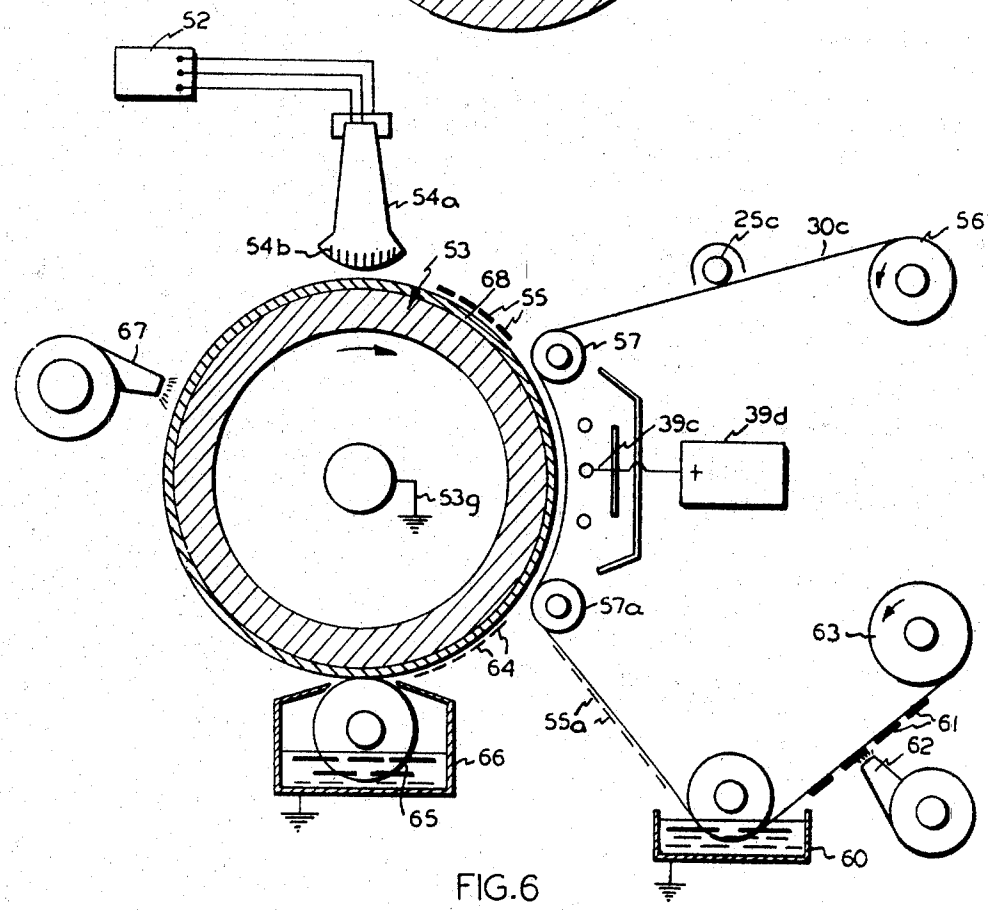


FIG. 6

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XEROGRAPHIC CHARGE TRANSFER PROCESS

Original Filed Dec. 28, 1962 3 Sheets-Sheet 3

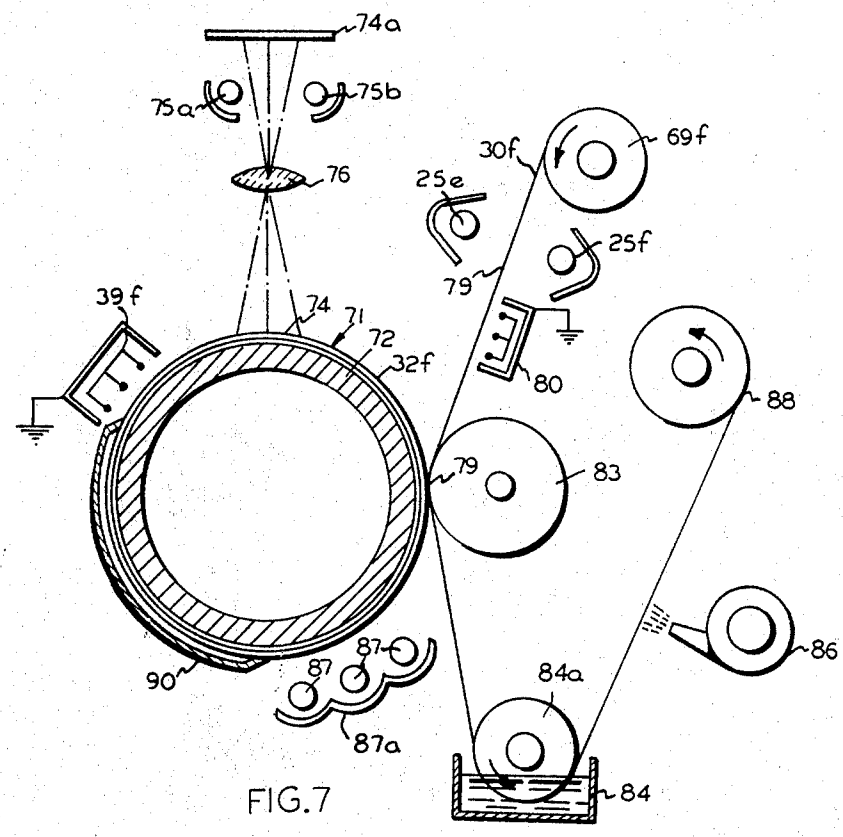


FIG.7

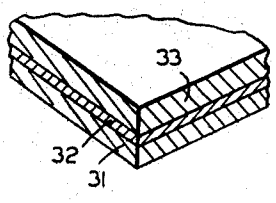


FIG.8A

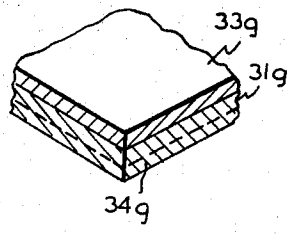


FIG.8B

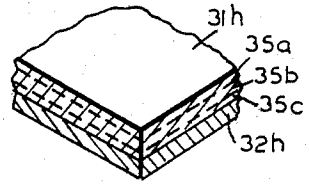


FIG.8C

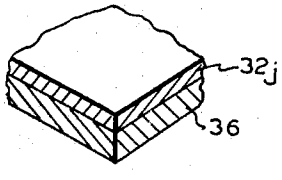


FIG.8D

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XEROGRAPHIC CHARGE TRANSFER PROCESS

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Continuation of application Ser. No. 247,903, Dec. 28, 1962. This application May 1, 1967, Ser. No. 635,266

Int. Cl. G03g 13/22

U.S. Cl. 96—1

6 Claims

ABSTRACT OF THE DISCLOSURE

Process for electrostatic recording in which a receiving or transfer sheet having a normally insulating photoconductive layer on a non-conductive support, is subjected to irradiation so as to cause an inner stratum of the sheet consisting of at least part of the photoconductive layer to become temporarily conductive, contacting an insulating surface of the sheet with a record sheet bearing an electrostatic latent image and applying an overall charge of a polarity opposite to that of the latent image to the rear of the receiving sheet so as to transfer the latent image from the record sheet to the front surface of the receiving sheet.

This application is a continuation of application Ser. No. 247,903, filed Dec. 28, 1962, now abandoned.

The present invention relates to a xerographic charge transfer process and materials therefor, i.e. to an electrostatic process for photographic reproduction and printing and to the sheet material and the equipment for carrying out the process. It has particular application to that general form of electrophotography disclosed, for example, in Carlson, U.S. Patent 2,297,691 (Oct. 6, 1942). More specifically, it relates to an improved material, process and apparatus for electrostatic charge image transfer.

In the conventional xerographic process, a photoconductive layer, backed by a support which is electrically conductive, is employed. The support is charged or maintained at a selected potential and its normally insulative photoconductive layer is given a uniform charge at a different potential. The photoconductive layer is then exposed to an actinic radiation pattern. An electrostatic latent image is formed in the photoconductive layer. This image may be rendered visible by means of an electroscopic powder which is differentially attracted (or repelled) by charged and uncharged areas of the image. The powder, or most of it, is normally transferred by contact to a suitable receiving sheet and affixed thereto. Residual powder may be cleaned off the xerographic plate so that the latter may be reused. Atlernatively, if desired, in special cases the powdered image may be permanently fixed on the xerographic plate itself. However, the xerographic plate is normally reused many times, being relatively expensive.

While the xerographic process is capable of producing excellent photocopies, it has some operational drawbacks. For example, it is extremely difficult to clean off excess powder without scratching or otherwise marring or injuring the delicate photoconductive coating. Plate life tends to be limited by mechanical and electrical failure resulting from powder abrasion. Various schemes

and devices have been proposed to provide gentle but effective and automatic cleaning, attesting to the difficulties encountered.

In an alternative form of xerography, known sometimes as charge transfer xerography, to which the present invention is particularly applicable, the electrostatic image charge pattern, i.e., the latent image, is partially transferred to a thin resinous insulating layer coated or otherwise applied onto a support sheet. The support is at least slightly conductive. This charge pattern transfer is accomplished by bringing the original electrostatic latent image and the receiving surface into firm physical contact with each other while applying an electrostatic field across the interface. The field is applied in such a direction as to transfer an appreciable or substantial fraction of the charge pattern from the photoconductor surface to the receiving insulator. The charge pattern is then rendered visible by development with an electroscopic powder, commonly called a "toner" powder. The powder particles, suitably charged, may be applied from suspension in air or in insulating liquids, or possibly by other means. This process has the advantage of avoiding entirely the deleterious effects of powder transfer and clean-up of the original xerographic plate. This process is described by S. A. Hawk et al. in P.B. 131,336, published by O.T.S., U.S. Department of Commerce, 1956.

The charge transfer process just described is normally practiced by using, as backing sheet material, white paper sheets coated with a clear resin layer. The latent image transferred to the web is developed with black or deeply colored toner powder.

In still another form of the xerographic process, a latent image charge pattern is simultaneously formed and transferred to the receiving sheet. This sheet has a dielectric surface and is backed by an electrically-conductive layer. See for example, Walkup, U.S. Patent 2,833,-930.

In the conventional charge transfer process, as described in the prior art, e.g., by Hawk et al., as cited above, certain practical difficulties are encountered. A main one of these arises from the fact that the base conductivity of resin-coated white paper varies so widely, with changes in humidity, for example, as to be quite unreliable. In order to be effective for charge pattern transfer, the resin surface layer should have high resistivity, not less than 10^9 and preferably 10^{12} ohm/square cm., whereas the backing sheet or layer should be relatively conductive with resistivity and not greater than 10^8 and preferably less than 7 ohms/square. The desired conductivity properties in the backing layer allow the image charge to travel or shift freely opposite the dielectric layer so as to conform to the surface charge pattern. When relative humidity drops to 25% or less, ordinary white paper does not have sufficient conductivity to perform satisfactorily.

It is of course possible, in principle, to use papers or other supports which have been rendered conductive by means of applied conductive materials. For example, paper may be coated very lightly with a partially transparent layer of vacuum evaporated metal and then overcoated with a suitable dielectric layer. Such materials, however, are generally too expensive for most commercial purposes when xerography must compete with other reproductive processes. Proposals to add humectants and antistatic agents have not been particularly successful,

especially when relative humidity becomes very low, e.g., around 15% or less.

Anti-static agents also are unsuccessful in film base types of supports. Other treatments have not been satisfactory for yielding white or translucent backing material for the xerographic transfer sheets as they are conventionally used.

In principle, xerographic equipment, suitably enclosed, could be humidified internally to stabilize the conductivity of the paper. In practice, however, this has not been found to be feasible. Various difficulties, including spillage, arc-over and internal corrosion arise.

Hence, it appears that the prior art lacks any satisfactory solution to the problem of rendering white paper bases reliably conductive for xerographic charge transfer purposes, particularly when the ambient relative humidity drops below 20 to 25%.

In addition, all presently known transparent and translucent film bases are insulators. Lack of an economical, clear semi-conductive layer or anti-static coating or impregnant for such bases has precluded this use. Resinous coated film bases apparently cannot be or have not been successfully used in xerography.

There is, therefore, a great need for novel xerographic image receiving papers or films which have desirable and necessary stable conductive properties under all reasonable conditions. At the same time they must be economical in cost and this rules out the use of expensive permanently conductive or semi-conductive sub-layers. Opaque layers also must be avoided where they would interfere with exposure to light and the finished product must have an aesthetic appearance. The present invention meets this need. It involves not only the needed improvement in sheet material, but also improvements in the process and apparatus to be employed with the improved sheet material.

It is, therefore, a prime object of this invention to produce aesthetically attractive, economical xerographic image-receiving sheets.

Another object is to provide a process whereby these sheets, or sheet materials, may be used to form excellent images by the charge-transfer process under a wide range of ambient conditions of temperature and humidity.

Still another object is to design simple and effective apparatus to carry out the process.

An additional object is to devise simple means and ways by which several varying types of existing xerographic apparatus may be modified or converted for use with the sheet material and the process of this invention.

Still further objects and advantages will become apparent upon consideration of the detailed description which follows.

In general terms, the invention consists of the substitution of preilluminated and, therefore, temporarily semi-conductive photoconductive layers for the conductive bases of the prior art. The receiving sheet is given a preliminary illumination by actinic radiation at a sufficient level of exposure to activate it. The surface conductivity of the photoconductor itself is rendered sufficiently conductive to exceed the minimal conductivity level 10^{-8} or 10^{-7} mho/square which is required for movement or adjustment of the image charge during the time that the charge transfer takes place. Hence, the receiving sheet must be coated first with a photoconductor. This photoconductor is such as will retain an appreciable fraction of its photoconductivity for at least the brief period of time required to transport the sheet from the preillumination station to the point where it makes contact with the laten image-bearing member. It is not necessary, however, that the imparted conductivity be permanent. While various photoconductors may be employed, an excellent example is zinc oxide produced by the French process. This material exhibits a strong "memory effect." It remains semi-conductive for as much as several minutes after the preillumination treatment. Also, French processed zinc oxide is relatively inexpensive; it is white and attractive in appearance and it is easy to handle. For these reasons, it is the preferred photoconductor for the transfer sheets of this invention. The process of this invention, however, is not limited to the use of zinc oxide and other light colored and translucent photoconductors may be employed, provided they exhibit a sufficient level and persistence of conductivity to be useful in the transfer charge process.

Although light colored and translucent photoconductors are well known, per se, they have not heretofore been used for xerographic transfer sheet coatings. As far as applicants are aware, they have not been preilluminated to form discrete layers which are temporarily at least semi-conductive. They have been used for photoelectric detectors. When irradiated by a pattern of actinic radiation, they have been used for electrophotography and also have been used in television cameras and the like.

In charge transfer xerography, it is necessary to have base conductivity only during the recording and optionally during the development steps. It does not matter whether the base is conductive prior to, or after, processing. Hence, a temporarily conductive layer is entirely sufficient for the purposes of this invention. By inducing a temporary, semi-conductive state in a photoconductive layer by means either of prior or even simultaneous actinic illumination, the material becomes useful in the process. All that is required is that the semi-conductivity persist during the image recording process.

Many of the conductive layers used in the prior art have necessarily included dark or metallic conductive pigments or they have involved the use of expensive evaporated metallized layers or the like. Photoconductors may be white or colored, opaque or translucent or transparent, depending on what is most convenient, economical, and aesthetically attractive. Many effective photoconductors are inherently inexpensive and may be applied by well-known methods. For present purposes, the conductors which are useful should be capable of giving a conductivity in excess of 10^{-8} mho/square under conditions of practical illumination. Many photoconductors, besides zinc oxide, retain much of this photo-induced semi-conductivity for some period after activation by actinic illumination. Hence, several practical photoconductors which have a sufficient "memory" of prior illumination are available. The memory should be sufficient to give a convenient time period between the pre-illumination and the actual image transfer steps. In the case of zinc oxide, for example, it is generally sufficient to preilluminate between 1 and 10 or 15 seconds prior to the xerographic image transfer. This assumes that the transfer is to follow quite immediately. The photoconductors may be applied to or incorporated in any desired layer or substrate. For example, they may be placed on parchment, paper and/or upon resinous film bases of all kinds as may be desirable.

The dielectric overcoatings which are to be applied may include a wide variety of insulating resins. These may be pigmented, if desired, provided the pigments are insulating materials such as mica, silica, or titania, and they may be applied as continuous films by coating from solvent or aqueous solutions. They may be applied from latices or sols or by casting or by extrusion of hot melts as well as by other means known in the art. The dielectric coating should have a thickness in the same range as is used in conventional paper-backed xerographic charge transfer sheets. This range may vary from $\frac{1}{10}$ to 2 thousandths of an inch and preferably is around 0.0005". Either the backing or the dielectric overcoating, when the latter is used, must be sufficiently translucent to allow effective actinic preillumination of the photoconductive layer of the transfer sheet, i.e., light must be permitted to come in from one side or the other to activate the photoconductor when this is sandwiched in between the paper and the dielectric overcoating.

done by means of a cathode ray tube **54***a* which has a face pierced by a multiude of conductors in the form of very fine wires, indicated at **54***b*. The pattern is determined by a suitable electronic facsimile input device **52**. The latter forms no part of the present invention.

As indicated at **53***g*, the drum **75** is suitably grounded. It is provided with an outer layer which is the thin dielectric coating, for example, 0.5 mil of an insulating resin. This is indicated at **68**. As the recording drum is rotated past the cathode ray tube **54***a*, it carries upon its surface a negative charge pattern indicated by the heavy negative symbols **55**. A charge receiving sheet **30** of the same type as that shown in FIGS. 1 and 2 and 8A is unrolled from a supply reel **56** and passes over guide rollers **57** and **57***a*. These hold them so that the dielectric covered surface **33***c* of sheet **30***c* is preilluminated by a fluorescent "black light" lamp **25***c*. A corona discharge device **39***c* is connected to a source of high positive voltage **39***d*. The preferred voltage is about 8000 volts. This applies a strong transfer field to attract negative charge from the drum to the receiving sheet. The transferred charge pattern shown by the lighter negative marks **55***a* is carried under another roller **59** through a tray of liquid toner **60**. Here a visible pattern, indicated at **61**, is developed, conforming to the latent image **55** on the roller and image **55***a*, which is picked up by transfer. The liquid is dried to leave a residuum, by passing it over a hot air blast **62**, and it proceeds to the windup roll **63** for storage.

Meanwhile, the residual charge indicated at **64** on the drum **53**, is wiped off by means of a sponge roller **65**, which rotates in a grounded tray containing conductive liquid **66** such as methanol. The drum is rendered charge receptive by drying off the remaining fluid when it passes by the hot air dryer **67**.

Hence, in the manner just described, the image which is first formed on the drum by the cathode ray tube transmitting intelligence or other data from the electronic facsimile input device, is transferred as a latent image to the surface of the web or record strip **30***c*. This record is made visible and fixed and meanwhile, the drum is cleaned off and returns to pick up another charge so that the process can be carried out continuously.

Referring now to FIG. 7, which represents in cross-section, a continuously operative xerographic printer using sheets corresponding to FIGS. 1, 2 and 8A, a set of corona wires **39***f* deposits a charge upon a rotatable xerographic drum **71**. Drum **71** consists of a metallic cylinder **72** covered with a uniform film **32***f* of a photoconductive insulator. The photoconductor **32***f* then receives a pattern of actinic radiation at an exposure station **74**. This exposure consists in taking a subject **74***a*. By means of light sources **75***a*, **75***b*, and a suitable optical system, such as lens **76**, the image from **74***a* is projected onto the drum. In this manner, for example, a portion of a document may be projected for copying onto the drum **71**.

A receiving sheet **30***f*, of the same general type as in FIGS. 1, 2 and 8A, is unrolled in the form of a continuous web from supply roller **69***f* and is uniformly preilluminated by passage between a pair of actinic lamps **25***e* and **25***f*. The web is then pressed into intimate contact with the charged and pattern-wise exposed photoconductive layer **32***f*. A corona pre-charging station **80** of conventional design may be used between the pre-illumination **79** and the transfer point **81** to improve the efficiency of the charge transfer. The dielectric coating of the transfer sheet is pressed into intimate temporary contact with the photoconductive layer **32***f* of drum **71** at the bite point **81**, between the drum **71** and a platen roller or presser **83**. By this means, a portion of the charge pattern on the drum is transferred to the sheet **30***f*. As the web **30***f* separates from the drum surface, it is passed through an immersion device **84** under roller **84***a*, led past a dryer such as a hot air blower **86**, and finally rerolled on the receiving roller **88**. The latent image-bearing section of the photoconductive layer **32***f* is illuminated uniformly by actinic radiation from three tubular lamps **87** in a reflector system **87***a*. This is done in order to destroy the residual charge pattern left on the drum. The drum is shielded to keep it dark for a portion of its rotation allowing residual photoconductivity to decay. This permits re-use of the drum. The dark shield is indicated at **90**.

Now referring to FIGS. 8A, 8B, 8C and 8D, the various types of record sheets will be explained. The material of FIG. 8A corresponds to FIGS. 1, 2 and 3 and has already been described as comprising the base member **31** which may be either paper or plastic filmbase coated with a sub-layer of photoconductor **32**, specifically zinc oxide, and an overlayer of a suitable dielectric **33**. FIG. 8B shows ordinary paper **31***g* impregnated on one side with a photoconductor material **34** and coated on the other side with an insulating layer **33***g*.

In FIG. 8C, there is shown a thin filmbase **31***h* which acts as its own dielectric, the several layers of potential difference being shown at **35***a*, **35***b* and **35***c*. On one side, this filmbase is coated with the photoconductive layer **32***h*.

FIG. 8D shows a translucent base of arbitrary conductivity **36**, which may be imparted to it in any desired manner. This is coated on one side with the photoconductive insulating layer **32***j*.

It will be obvious that any of the sheets or sheet materials just described may be used in any of the methods or forms of apparatus illustrated in the preceding figures. In appropriate cases, the film may be reversed or turned upside-down to conform to the requirements of the specific method being applied.

Obviously, a number of variations are contemplated as being equivalents of those actually described herein and it is intended to cover such so far as the scope of the following claims permit.

We claim:

1. A process for electrostatic photographic image recording which comprises irradiating a receiving sheet having a photoconductive normally insulating layer on a non-conductive support so as to render an interior layer of said sheet consisting of at least part of said photoconductive layer temporarily conductive while the exterior of said sheet remains essentially insulating, forming a latent electrostatic image on the surface of a recording sheet and contacting the image-bearing surface of the latter with an insulating surface of said receiving sheet while the temporary conductivity of said interior photoconductive layer persists and applying an electrostatic charge of polarity opposite to that of said latent image on the opposite surface of said receiving sheet, said latent image being transferred by such contact to the contacted surface of the receiving sheet.

2. A process as defined in claim **1**, wherein said photoconductive layer is a surface layer of said receiving sheet, the irradiation thereof being effected through the support so as to render only an inner stratum of the photoconductive layer temporarily conductive.

3. A process as defined in claim **1**, wherein the transferred latent image on said receiving sheet is developed by application of finely-divided electrostatic toner to the contacted surface of said receiving sheet, and the resulting visible image fixed thereon to render it permanent.

4. A process as defined in claim **1**, wherein said receiving sheet includes an insulating surface layer superposed on the photoconductive irradiated layer.

5. A process as defined in claim **1**, wherein said charge of opposite polarity to the latent image of the record sheet is deposited simultaneously on the opposite surface of said receiving sheet with the contact between the record sheet and the receiving sheet.

6. A process as defined in claim **1**, wherein irradiation of said receiving sheet is effected in the form of a halftone pattern.

(References on following page)

There are two important advantages which are gained by carrying out the xerographic charge transfer with transfer sheets of the type described. Where these have insulating backings or pre-coats covered by dielectric receiving surfaces, there is a more uniform and far more effective charge transfer, especialy under dry ambient conditions. This is believed to be due to the uniform and reliable high conductivity of the backing which may be induced by actinic illumination according to the present invention. The activation permits the charge transfer potential to be applied primarily across the substantially uniform thin and resistive insulating layer of the dielectric film. The latter is in effect the dielectric of a parallel plane condenser whose "plates" are the charged surface of the latent image-bearing member on the one hand, and the temporarily semi-conductive backing of the dielectric receiving layer, on the other hand. Referring now to the accompanying drawings:

FIG. 1 shows a system for employing the new charge receiving sheets illustrating both how the negative charge pattern may be transferred and how the sheet is pre-illuminated;

FIG. 2 shows the appearance of the sheet after the transfer charge has been developed by immersion in a positively-charged dark toner powder so as to form dark deposits on previous negatively-charged areas;

FIG. 3 shows in section, the appearance of one form of such a sheet after fixing the toner powder;

FIG. 4 illustrates a different form of sheet with the step of preillumination and charge transfer being shown graphically. Parts of the showing are in section;

FIG. 5 shows diagrammatically, an alternative form of the preillumination process, parts being shown in section;

FIG. 6 shows schematically a continuously operative electrostatic recording device for transferring electrostatic patterns, using the sheet material of this invention;

FIG. 7 is a schematic representation, showing parts in cross-section, of a continuously operative xerographic printer, operating on sheets of the preferred form of this invention; and

FIGS. 8A, 8B, 8C and 8D are fragmentary representations of various forms of sheets made according to the present invention and designed particularly for charge transfer.

Referring first to FIGS. 1 and 8A, there are here shown suitable base sheet materials **30**, which may be either in the form of separate sheets or a continuous web, indicated at **31**. This base material is coated with a sub-layer of a photoconductive material **32**, zinc oxide being preferred for this purpose. It is also overcoated with a suitable dielectric layer **33**. This dielectric layer is preferably a synthetic resin of suitable type having high dielectric or insulating properties.

As the charge receiving sheet **30**, comprising layers **31**, **32**, and **33**, passes through the apparatus to the right, as seen in FIG. 1, it first is subjected to a pre-illumination treatment by the device **25** which may comprise one or more fluorescent lamps with a suitable reflector **25***a*. Being thus rendered partially conductive in the layer **32**, the sheet **30** passes beneath a roller **26** which presses composite strips **37** and **38**, the former bearing a latent image, against the sheet **30**. The latent image, of course, is not visible, but is indicated by the heavy dashes **70**. As the assembly moves on to the right, the image has been transferred at least in part, as indicated by the moderately heavy dashes **42**, leaving residuary charges on the sheet **37**, as indicated by the light dashes **43**. The layer **38** may be a conductive layer such as a metal band whereas the charge receiving layer **37** is, of course, a relative insulator, but one having photoconductive properties.

The sheet **30** has its photoconductive layer grounded, as indicated at **69** and this may be accomplished by a brush which contacts an edge portion of the layer **32**.

A charge imparting device is indicated generally at **39** and comprises a high voltage generator **39***a*, the necessary electrodes **39***b* and the shield or reflector **39***c* which is grounded as indicated at **39***d*.

After the sheet **30** moves past the charge transfer point, its lower surface has received charges which are opposite to those of the pattern which is to be transferred. As shown in FIG. 1, these charges are indicated by the + marks. In those areas where the pattern **70** has been transferred wholly or in part from sheet **37** to sheet **30**, corresponding latent images have been formed. By subjecting the sheet **30** now to contact with charged colored particles of powder or the like, the image may be made visible and this is indicated by the characters **70***a*, **70***b*, **70***c* in FIG. 2. These characters may be fixed by fusing the powder or by setting them with an adhesive as indicated at **71***a*, **71***b* and **71***c* in FIG. 3.

Now referring to FIG. 4, there is shown a simpler charge receiving sheet, indicated generally at **27**, which is first preilluminated and then subjected to the image transfer operation. A source of intensely absorbed actinic radiation, such as the fluorescent lamp **25***b*, irradiates the charge receiving sheet **27** through its backing. This backing **36** can be either fibrous paper or a film base, but it should be sufficiently transparent or translucent that light can pass through it to activate the photoconductive layer.

In the case of zinc oxide, when this is used as the photoconductive layer, radiation of 3200 to 3900 angstrom units wavelength is over 90% absorbed in the first 0.05 mil thickness at the bottom of the photoconductive layer **32**. The whole layer is preferably from 0.3 to 0.6 mil thick so only the lowest 15–30% of the photoconductive thickness is rendered temporarily semi-conductive. The other 70–85% of the layer remains substantially insulating. As a result of this, the photoconductive layer itself assumes the form of a sort of "built-in" pair of conductive and insulating layers and these are indicated at **32'** and **32''**, respectively. Layer **32'** is grounded as indicated at **69***a* and at the same time the upper layer **32''** is effective to detain the charge pattern, which is transferred from the member **37'** which is fed under roller **26'** into contact with the record sheet **27**. As in the case of FIG. 1, the original record sheet **37'** is preferably backed by a conductive metal backed by a conductive metal backing **38'**. The charge in this case is indicated as being positive and the pattern in the form of a latent image is transferred to the surface of the sheet **27**. The pattern is indicated by the small crosses **42'** and the residual pattern on the original sheet is indicated by the light crosses **43'**. A backing roller **26***b* may be used to support this sheet **27** in intimate contact with the original record **37'**.

Referring now to FIG. 5, there is shown an alternative form of the preillumination step and apparatus. This should be compared with FIGS. 1 and 4. A suitable source of actinic light, indicated at **49**, shines through the transparent cylinder wall **50**, which may be made of glass or other suitable transparent material. On the surface of this transparent cylinder is a dot pattern which, when superimposed on the image, will result in preparation directly of a half-tone plate which may be used for printing. The principles of the half-tone plate are well understood and need not be explained here. This preillumination process may be applied to the sheet indicated at **30***a*, which corresponds in general terms, to the sheet **30** of FIGS. 1 and 2. It is equally applicable to the type of sheet illustrated in FIG. 4. The super-imposed pattern is to be developed later in case the eventual record is to be used as a half-tone.

Referring now to FIG. 6, this is a schematic representation of a continuous system using sheets which may be like those of FIGS. 1, 2 and 3. An electrostatic charge is deposited patternwise on a recording drum **53**. This is

9

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