United States Patent

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[54] **ELECTROPHOTOLUMINESCENT PRINTING PROCESS**
12 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **355/67,** 355/133, 96/45.1
[51] **Int. Cl.** **G03b 27/54**
[50] **Field of Search** 96/45.1, 82; 355/80, 83, 133; 313/108

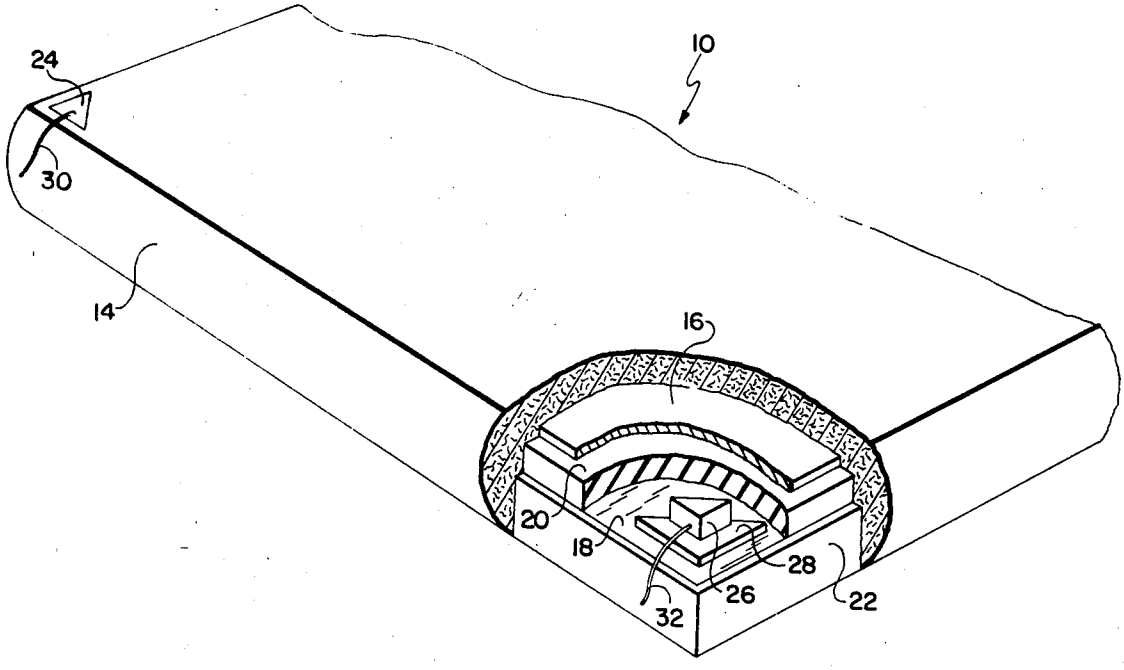
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ABSTRACT: Systems employing electrophotoluminescent panels to obtain reproductions of originals, which systems include the steps of exciting a layer of an electrophotoluminescent material optically and with an applied electric field to cause said material to emit visible light; eliminating said optical excitation while maintaining said electric field, whereby said material continues to emit visible light; and placing the subject matter to be reproduced in juxtaposition with said layer of material for a predetermined period of time sufficient to permit a significant imagewise differential in decay of luminescence of said material to form in said layer a positive reproduction of said subject matter, and, optionally may further include the steps of removing the electric field for a short period of time and then reapplying it whereby to obtain an image reversal wherein the positive image on the panel is converted into a negative image; and systems employing the same to obtain a photographic reproduction on a photosensitive element.



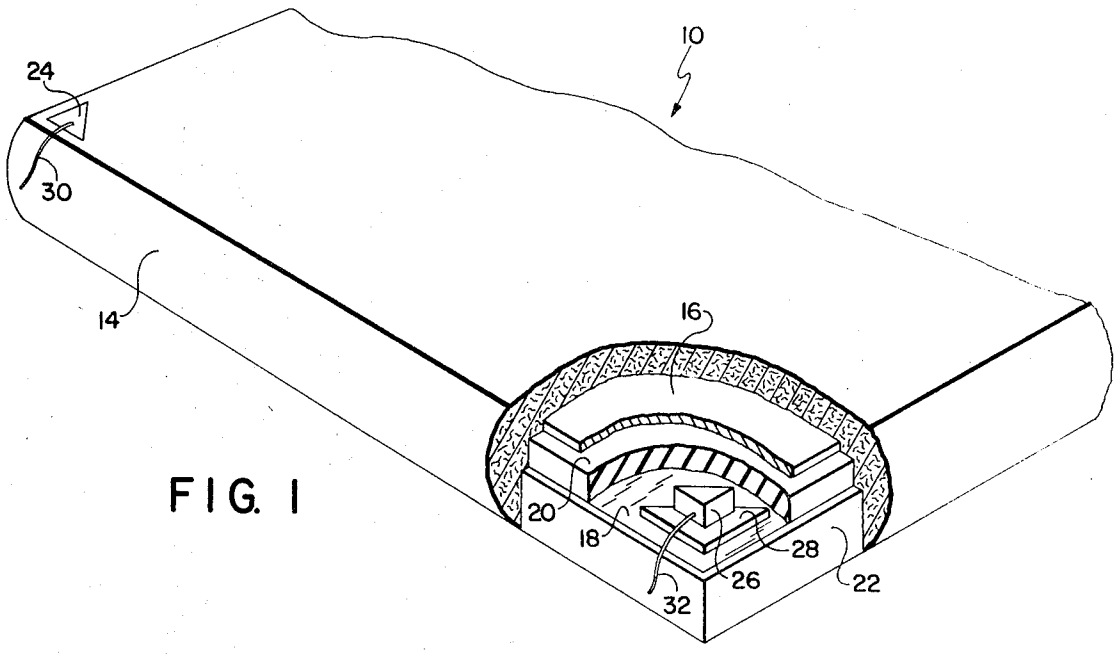


FIG. 1

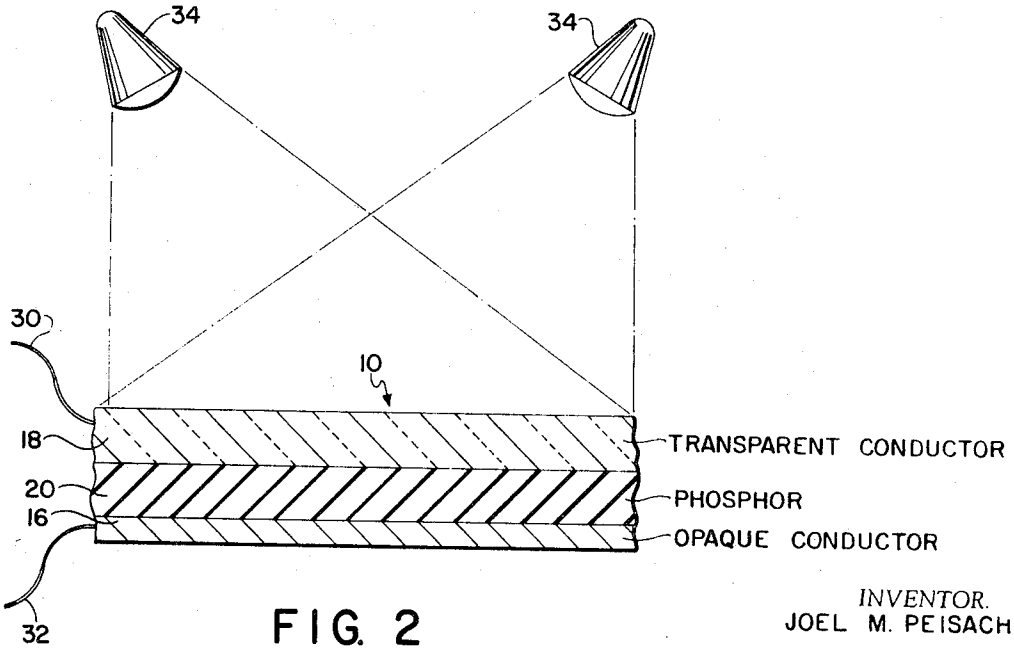


FIG. 2

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ELECTROPHOTOLUMINESCENT PRINTING PROCESS

BACKGROUND OF INVENTION

Various systems for generating visible light by excitation of a luminescent material or phosphor are known. In general, such systems employ one of three principles: photoluminescence; electroluminescence; or electrophotoluminescence.

Photoluminescence is the name given to the light emitted by phosphorus when excited optically, e.g., by ultraviolet light; it involves the transformation into visible wavelengths of invisible light having shorter wavelength.

On the other hand, electroluminescence and electrophotoluminescence are concerned with the effects of electric fields on the luminescent emission of phosphors. Electroluminescence refers to the light emitted by a suitable phosphor when an electric field is applied to it; whereas electrophotoluminescence pertains to light emission by a phosphor when an electric field is applied during or after excitation by optical means.

Electroluminescent or electrophotoluminescent materials have heretofore been arranged in elements, frequently called panels, which have been employed for various purposes, mainly in specialized forms of lighting. A typical panel includes the phosphor layer, typically a suitable phosphor embedded in a dielectric material, sandwiched between a pair of conducting sheets or electrodes, at least one of which is transparent. They may also include other layers contributing to the stability of the panel.

The present invention is directed to electrophotoluminescent panels of the foregoing general description and relates to the use of such panels in novel procedures for obtaining positive or negative visible images of a document or other subject matter.

SUMMARY OF THE INVENTION

According to one aspect of this invention positive images may be obtained on an electrophotoluminescent panel by subjecting the panel to excitation by an electric field plus invisible light to cause it to glow, removing the light and thereafter placing a document or other subject matter to be reproduced on the glowing panel for a given period of time, after which the subject matter is removed from the panel to reveal a positive reproduction thereof.

According to another aspect of the invention, negative images may be obtained by first forming a positive image in the aforementioned manner, thereafter turning off the current for a brief period of time and then reapplying the electric field to obtain an image reversal wherein the positive image is converted to a negative image.

In a still further aspect of the invention one or more copies of the aforementioned positive and/or negative images may be obtained by placing a photosensitive element in contact with the glowing imaging panel to expose this element and thereby obtain a latent image of the image on the panel, and thereafter developing the thus exposed element in known manner to form a visible image. The last-named aspect of the present invention is particularly significant in that it provides a document duplication or office copier device which requires no lens or optical system for obtaining one or more copies of the original.

As was mentioned previously, the present invention is directed to novel procedures for preparing positive or negative images and, more particularly, to novel processes employing an electrophotoluminescent panel to obtain such images.

A primary object of this invention, therefore, is to provide novel processes for obtaining visible images of a document or other subject matter.

Another object is to provide novel processes employing an electrophotoluminescent panel to obtain positive or negative images.

Still another object is to provide a novel document duplication device requiring no lens or optical system, which device may be employed to obtain, at the discretion or whim of the operator, a positive and/or a negative copy.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the process involving the several steps and the relation and order of one or more of such steps with respect to each of the others which are exemplified in the following detailed disclosure, and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings.

The present invention contemplates employing electrophotoluminescent panels such as those heretofore known in the art to obtain a positive image or reproduction, a negative one, or both.

As used herein and in the appended claims, the term "positive image" is employed in its ordinary photographic usage to define an image in which the highlight (white) areas and the shadow (dark) areas of the image correspond to that of the matter being reproduced; whereas a "negative image" refers to a reversed image in the sense that the highlight and shadow areas of the image are the reverse of those areas of the matter being reproduced.

The electrophotoluminescent panels employed in the practice of this invention may be any of those heretofore known in the art and accordingly the precise structure of such a panel per se comprises no part of this invention.

A typical such panel includes an electrophotoluminescent material in a thin layer sandwiched between a pair of conducting surfaces, at least one of which is transparent for viewing. Suitable electrophotoluminescent materials include phosphors of the zinc sulfide or selenide type with a relatively high copper content, e.g., about 0.1 percent by weight of copper, as the principal activator. The spectral distribution of the luminescent emission occurs generally in relatively broad bands, and depending on the method of preparation, three different colors are customarily prepared, namely blue, green or yellow. The blue and green phosphors may be obtained with copper in different proportions as the principal activator. The yellow phosphor may be obtained by using copper and manganese activators. The phosphor in a typical panel is embedded in a dielectric material, e.g., an organic resin or transparent enamel in a thin layer which, as heretofore noted, is sandwiched between two conducting sheets, at least one of which is transparent.

BRIEF DESCRIPTION OF DRAWING

FIG. 1 is a perspective view, greatly enlarged and with a section broken away, of an electrophotoluminescent panel for use in the present invention; and

FIG. 2 is a diagrammatic, fragmentary sectional view of the essential elements of a panel such as is shown in FIG. 1.

The typical construction of such a panel will be more readily understood by reference to the drawing and in particular to FIG. 1 wherein panel **10** is shown to include a thin layer **20** of an electrophotoluminescent phosphor embedded in a dielectric material, layer **20** being sandwiched between an opaque back conducting surface or electrode **16** and a front transparent conducting surface or electrode **18**. A protective insulating backing **14** is shown to be provided over the back and sides. A nonconducting glass wall sheet is also shown to be provided around the sides. Contacts **24** and **26** are in electrical contact with the transparent front and opaque rear conducting surfaces, respectively, as shown. An insulator **28** is shown to be associated with contact **26** to electrically insulate the contact from the front conducting surface to prevent shorting out. It will likewise be appreciated that contact **24** is electrically insulated or free from electrical contact with the rear conduct-

ing surface to prevent shorting out. Leads **30** and **32** extend from contacts **24** and **26** to a source of alternating current (not shown).

In a typical procedure for preparing the "sandwich" of an electrophotoluminescent cell for use in the aforementioned panel, a transparent conducting film of tin oxide is formed on a sheet of glass to provide the transparent conducting surface **18**. This may be done by spraying hot glass (about 500° C.) with stannic chloride. A suspension of the phosphor in a suitable resin or plastic dielectric medium is then sprayed on the conducting glass to a thickness of about 100 μ. A second backing electrode is then applied, e.g., by metallic evaporation or by spraying aluminum.

FIG. **2** illustrates schematically the use of such a panel. As shown therein, a pair of ultraviolet lights **34** are also provided. It will, of course, be appreciated that the number of ultraviolet lights is not essential and a single such source of UV light providing substantially uniform illumination over the surface of the panel is quite sufficient.

In operation, an electric field is applied during or after optical excitation to cause the panel to glow.

The present invention is predicated upon the discovery that positive or negative images may be obtained by certain process steps employing one of the aforementioned panels.

According to one aspect of the invention positive images are obtained by first exciting the panel by applying an electric field and exposing the panel to invisible light of shorter wavelength than visible light to cause the panel to glow, removing the optical excitation, and then placing a document or the like face down on the still glowing panel for a predetermined period of time, e.g., about 30 seconds. Upon removal of the document, a positive image is revealed. The exact reason for this behavior is not entirely clear and, while it is not wished to be restricted to any particular theory, it is however believed that the positive image is formed by a differential in luminescent intensity obtained as a function of the varying "-decay" of luminescence between the highlight (nonimage) and shadow (image) areas. Once the source or sources of excitation are removed, a "decay" or attenuation of luminescence normally occurs. Thus, where the optical excitation is removed, but the applied electric field is maintained, a decay and consequent loss of intensity of illumination uniformly over the entire surface of the panel would normally be anticipated. However, when the document is placed over the surface, light being reflected back from the areas of the document which are white or of a color which will reflect the visible light emitted by the panel materially reduces or inhibits the decay imagewise in these areas so that a positive image is formed in terms of the appreciably greater decay, i.e., appreciably lower intensity of luminescence, in areas corresponding to shadow areas of the document.

While reference has been made to the panel having an opaque rear conducting surface and consequent removal of the document to reveal the positive image, it will be apparent that the rear conducting surface may also be transparent, in which case the document need not be removed for viewing purposes, viewing being accomplished through the rear conducting surface.

It is also possible to obtain a positive image by applying the electric field, placing on the panel a document having nonimage areas transparent to UV light and image areas which will absorb UV light, and then subjecting the panel to optical excitation, e.g., to UV light, through the document. In areas of the panel corresponding to or below the image areas of the document where the exciting light is absorbed, the phosphors are not excited into luminescence, so that the panel only glows in terms of highlight areas where it is exposed to the exciting light transmitted through the document. Upon turning off or removing the light source and subsequent removal of the document, a positive image is also revealed. However, the first-named procedure for forming positive images has the important advantage in that it can be employed with an opaque document or the like whereas the latter system requires, and hence can only be used with, a transparent document which permits transmission of the exciting light in highlight or nonimage areas.

In a second aspect of the invention, it has been found quite unexpectedly that a negative image can be obtained by a simple procedure which quickly reverses the positive image formed in the previous embodiment, i.e., the embodiment wherein the panel is caused to glow uniformly, the optical excitation is removed, and the document or the like is then placed face down on the glowing panel to provide the positive image. The image reversal to provide a negative image is obtained by turning off the current for a short period of time, e.g., about a half-second, and the reapplying it. When the current is turned off for this short period of time and then turned back on, for some reason not at present understood, the relative decay between shadow and highlight areas is reversed, the decay being greater in highlight areas of the previous positive image whereas the shadow areas of the previous positive image appear appreciably brighter, thereby creating a reversed or negative image.

In a third aspect of this invention, it is contemplated to employ the imagewise glowing of the panel in either (or both) of the aforementioned aspects to expose one or more photosensitive elements to obtain one or more photographic reproductions of the original subject matter. Thus, for example, a typical photosensitive element having at least one layer of a light-sensitive material, may be placed in close optical proximity with the glowing imaging panel for a time sufficient to expose the photosensitive element to obtain a latent or developable image. Upon processing of the thus exposed element in the manner heretofore known in the art, a photographic reflection print or transparency may be obtained.

In a typical procedure of this nature for forming black and white images, the photosensitive element comprises a suitable support bearing a light-sensitive silver halide emulsion. Upon development of the thus exposed element, exposed areas of the emulsion are reduced to image silver to provide a negative or reversed image. This negative may then be used in known manner to obtain positive prints. A preferred system employs what is known as silver diffusion transfer to obtain a positive silver image in a single step. In a typical procedure of this type, the exposed element containing the developable image is developed by applying an aqueous alkaline composition including a silver halide solvent and a silver halide developing agent in a substantially uniform layer between the thus exposed light-sensitive emulsion layer and a superposed silver-receptive stratum. In exposed areas of the emulsion, the silver halide is reduced to silver while at substantially the same time an imagewise distribution of a soluble silver complex is formed in terms of unexposed areas of the emulsion. This imagewise distribution is transferred, at least in part, by imbibition, to the silver-receptive stratum where it is reduced to image silver to impart thereto a positive silver transfer image. Silver transfer processes of this nature are described, for example, in U.S. Pat. No. 2,543,181 issued to Edwin H. Land, and many other patents.

It is contemplated that color images may be obtained in the foregoing manner, and these images may be monochromatic or multicolor. One particularly useful system for preparing color images is that described and claimed in U.S. Pat. No. 2,983,606, issued to Howard G. Rogers.

It will be appreciated that the foregoing systems for obtaining photographic images from the glowing panel are illustrative only and the present invention is adaptable to any of the prior photographic systems of this nature.

An important feature of this last-mentioned embodiment of the invention is that, unlike typical prior photographic systems, no lens or optical system is needed for exposure. Thus, the present invention makes it possible to provide an office copier or document duplication system requiring no lens. Moreover, in such a system, one may obtain either a positive or a negative, or both, at the individual election of the operator, merely by electing to photograph the first-formed positive image, the later-formed negative image, or both.

A typical device for this purpose need, for example, only comprise a lighttight housing, an imaging panel, a UV light source, and means for containing a source of film within the housing. The device would include means for causing the panel to glow, means for placing a document or the like on the glowing panel, means for removing the document, means for advancing the photosensitive film into optical proximity with the panel, a developing station, exit stations for the document and the photographic reproduction, and transport means for conveying the two from the various stations. The device should further contain appropriate switches for controlling the source of current to the panel and the UV light source. Other more sophisticated refinements will be readily apparent.

The following examples show by way of illustration and not by way of limitation the preparation of images on an electrophotoluminescent panel in accordance with this invention.

EXAMPLE 1

The electrophotoluminescent panel employed was one similar to that shown in the drawing, being manufactured by Thorn Electrical Industries, Ltd., Enfield, Middlesex, England. A single UV light was positioned over the panel. The current was turned on to apply a DC electric field at about 100 volts, 70 ma. The UV light was then turned on and the panel immediately glowed yellow. While maintaining the electric field, the UV light was turned off. A typical test document consisting of an ordinary sheet of paper having indicia on one side was placed face down on the glowing panel, i.e., with the indicia-containing surface against the panel, for about 30 seconds. Upon removing the document, a positive image thereof was observed to be contained on the panel.

EXAMPLE 2

After forming a positive image in the manner described in example 1, the power supply for the current was turned off for about a half-second and then turned back on to reapply the electric field. The UV light was not turned on. In a very short period of time a negative or reversed image of the original positive image was observed on the panel.

The procedures of examples 1 and 2 were successfully repeated a number of times to establish that the phenomena observed were reproducible.

In the foregoing illustrative examples, the electric field was applied before optical excitation was effected. As was mentioned previously, electrophotoluminescence requires applying an electric field during or after optical excitation. Hence, the invention is not limited to the particular order of steps to cause initial glowing of the panel described in these examples.

The following two examples illustrate the practice of this invention wherein the panel is first subjected to optical excitation by UV light which is turned off before the electric field is applied.

EXAMPLE 3

The panel of example 1 was exposed to UV light for several seconds and the UV light source was then turned off. A DC electric field was then quickly applied in an example 1, causing the panel to glow. A document bearing indicia was then placed face down on the flowing panel as in example 1 to obtain a positive image on the panel.

EXAMPLE 4

The steps of example 2 were repeated to obtain image reversal to form a negative image on the panel.

From the foregoing description and illustrative examples it will be seen that the present invention provides novel systems utilizing electrophotoluminescent panels such as those heretofore known or available in the art to obtain positive and/or negative images of a document or the like to be copied. The panel containing the image may be used as such, e.g., for display purposes, and then erased by decay or quenching of the phosphor, or, in lieu thereof, the image-containing panel may then be employed to photoexpose one or more photosensitive elements successively to provide, by known photographic procedures, one or more permanent photographs of the original, which photographs may be positives or negatives, according to the desires of the practitioner.

The present invention therefore contemplates providing a document duplicating device requiring no lens or optical system to obtain satisfactory copies.

Since certain changes may be made in the above process without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What I claim is:

1. A process for forming images comprising the steps of exciting a layer of an electrophotoluminescent material optically and with an applied electric field to cause said material to emit visible light; eliminating said optical excitation while maintaining said electric field, whereby said material continues to emit visible light; and placing the subject matter to be reproduced in juxtaposition with said layer of material for a predetermined period of time sufficient to permit a significant imagewise differential in decay of luminescence of said material to form in said layer a positive reproduction of said subject matter.

2. A process as defined in claim **1** including the step of removing said subject matter from said layer.

3. A process as defined in claim **2** including the steps of removing said electric field for a short period of time and then reapplying it whereby to obtain an image reversal wherein said positive image on said panel is converted into a negative image.

4. A process as defined in claim **1** wherein said layer is exposed to ultraviolet light to cause said optical excitation.

5. A process as defined claim **1** including the steps of placing a photosensitive element in juxtaposition with said positive image for a time sufficient selectively to expose said photosensitive element to the imagewise emission of visible light from said material in said layer to form a developable image; and thereafter developing said exposed element to provide a photographic reproduction of said subject matter.

6. A process as defined in claim **5** wherein said photosensitive element includes a light-sensitive silver halide emulsion and said image is in silver.

7. A process as defined in claim **5** wherein said photographic image is a positive silver transfer image.

8. A process as defined in claim **3** including the steps of placing a photosensitive element in juxtaposition with said negative image for a time sufficient selectively to expose said photosensitive element to the imagewise emission of visible light from said material in said layer to form a developable image; and thereafter developing said exposed element to provide a photographic reproduction of said subject matter.

9. A process as defined in claim **8** wherein said photosensitive element includes a light-sensitive silver halide emulsion and said image is in silver.

10. A process as defined in claim **8** wherein said photographic image is a positive silver transfer image.

11. A document copying process comprising the steps of providing an electrophotoluminescent panel and a source of ultraviolet light within a lighttight enclosure; exciting said panel with said ultraviolet light and an applied electric field to cause said panel to glow; shutting off said light; placing a document to be copied in juxtaposition within said glowing panel to form a positive reproduction of said document on said panel; placing a photosensitive element comprising a layer of a light-sensitive material in juxtaposition with said glowing panel to form a developable image on said layer; advancing said exposed element to a developing station within said housing where said element is developed to provide a visible photographic image of said document; and transporting said photographic image from said housing.

12. A process as defined in claim **11** wherein said light-sensitive material is a silver halide emulsion and said photographic image is a positive silver transfer image.