

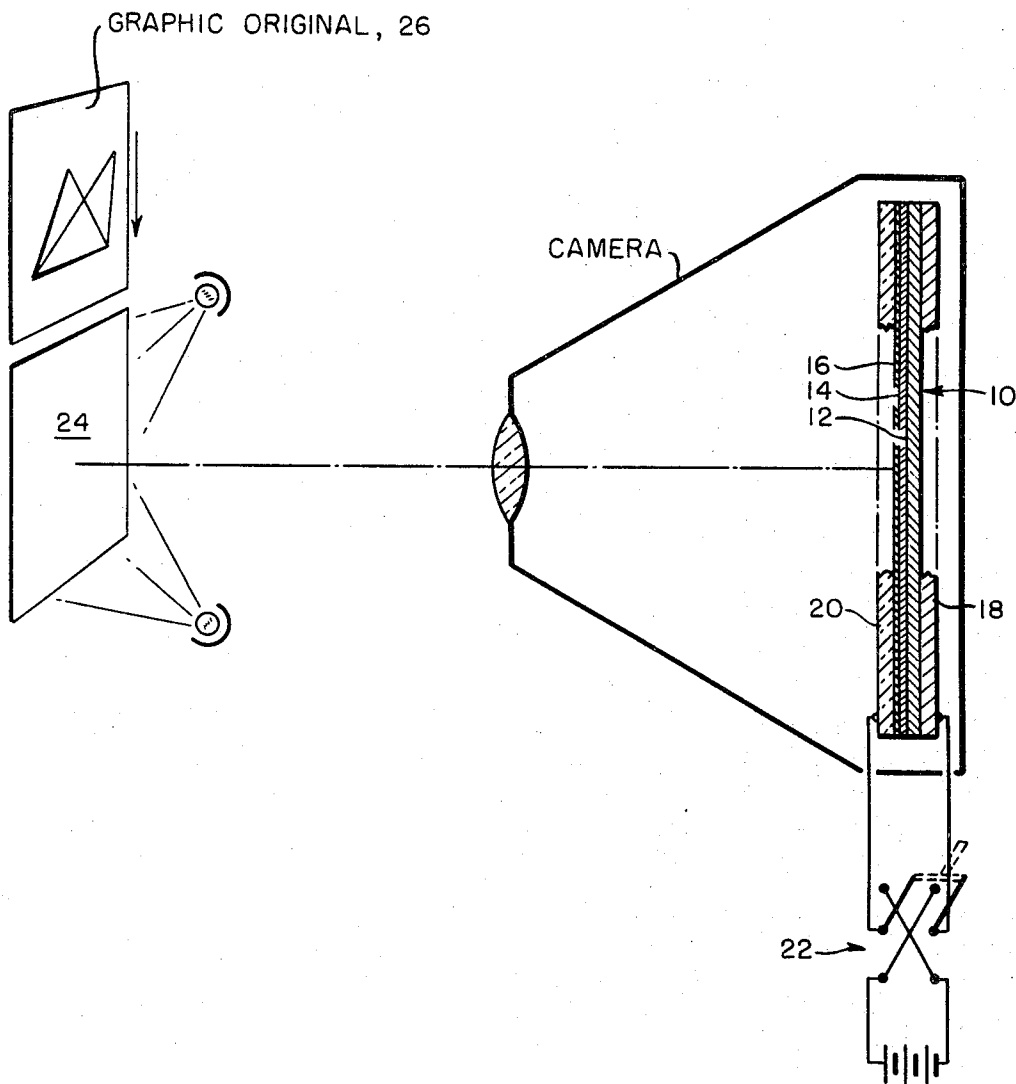
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ELECTROPHOTOGRAPHIC PROCESS

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ELECTROPHOTOGRAPHIC PROCESS

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ABSTRACT OF THE DISCLOSURE

Improved reproductions in photographic processes utilizing light-sensitive plates having persistent internal polarization properties are realized when the plate is provided with a continuous layer of an insulating material which is retained in contiguous relation to the plate throughout exposure, the application of the polarizing potential, the removal of an electrode and development.

This invention relates to copying processes, and in particular to electrophotographic processes that make use of the phenomenon of persistent internal polarization, referred to herein as PIP. These processes are described in Kallmann et al. Patent No. 3,005,707.

The art is currently familiar with several electrophotographic copying processes in which a latent image defined by an electrical charge pattern on a photosensitive plate is developed by applying a finely divided toner that adheres by electrostatic attraction to the charged areas. Examples are the now commercial xerographic processes, both direct and indirect, and the PIP processes to which this invention relates.

Both the xerographic and PIP processes make use of light sensitive materials to which an electrical charge pattern may be induced, but are otherwise essentially different.

In PIP processes, a separation of charges within the material is brought about by means of an electrical field in which the material is placed while it is exposed to light or after it has been exposed. Light exposure excites the material to a state whereby the field causes negative charges (electrons) in the material to move toward one surface while positive charges (holes) moved toward the other. There may or may not be an overall D.C. electrical current associated with the excited state or during the period that the material is exposed to light. Xerography, on the other hand, depends on the passage of a D.C. current through the light sensitive material to cause an electric charge which has been applied to the surface of the material to drain away in the areas exposed to light. In xerography a positive or negative charge is first applied to the surface of the material in the dark (when its ohmic resistance is high), and an exposure to a light pattern then causes the charge to drain away where the light strikes the material, leaving the dark areas charged in conformity with the pattern.

Xerographic processes may accordingly be characterized by the requirement that the photosensitive material conduct a relatively large D.C. current in the areas exposed to light, whereas PIP processes do not require that any D.C. current ever flows in the light sensitive material, but do require that the photosensitive material be polarizable in the light exposed areas so that it may be selectively polarized or depolarized.

In one form of PIP process, a latent image is formed by initially exposing the material to the light pattern (image) to be reproduced to produce initially polarization only in the light exposed areas. In another procedure, the entire area of the PIP material is first exposed, so that

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the entire area becomes polarized, following which an exposure to a light pattern (image) in the absence of the field, or preferably with the field reversed, causes depolarization or reverse polarization of the light exposed portions.

In the preferred methods of using PIP processes, exposure to an image takes place while the sensitive layer is in contact with an electrode which is removed after the electrical field has been applied. Typically, the sensitive element will consist of a layer of a PIP phosphor on a conductive backing, which is retained between a transparent glass electrode in contact with the phosphor layer and a backing electrode. After applying an electrical field between the electrodes sufficient to produce polarization, the glass electrode is removed from the phosphor and toner is then applied to develop the image. A troublesome problem arises from these operations because removal of the glass electrode tends to distort the polarization pattern, and as a result the developed image deviates from the original.

The cause of this distortion is not fully understood, but we assume that it results from the electrostatic attraction between the electrode and the phosphor layer which causes some kind of migration or alteration of the charge pattern when the electrode is removed. Aside from distortion of the latent image, the electrostatic attraction of the electrode can also lead to damage to the phosphor layer.

In the process described in U.S. Patent No. 3,005,707, distortion effects are minimized by providing a pattern of conductive islands on the surface of the photosensitive material, on which isolated charges are induced. That, however, provides a "half tone" effect and limits the resolution obtainable in the copy.

We have now found that distortion of the polarization pattern and damage to the phosphor layer can be avoided without sacrificing the quality of the reproduction by providing an insulating layer over the phosphor layer.

These advantages accrue if the photosensitive layer of material exhibiting the PIP effect is covered with a layer or film of an insulating material sufficiently thick to provide an overall high resistance of at least 10^9 ohms per sq. cm. Phosphors known to the art as exhibiting a PIP effect are frequently materials that are also more or less photoconductive, and some may in fact be employed in xerographic processes. Accordingly, when layers of these phosphors are placed in contact with two electrodes, and a field is applied, a D.C. current will flow at the same time polarization of the material takes place. When the electrodes are disconnected from the external polarization circuit, there will remain on them a charge induced by the polarization potential of the PIP material, and upon removal of one of the electrodes this charge apparently alters the polarization pattern. If, however, an insulating layer overlays the PIP phosphor and separates it from the removed electrode the alteration of the polarization pattern within the phosphor does not occur. Moreover, the presence of an insulating layer also increases the duration of persistence of the image, particularly with the more conductive phosphors.

Improved PIP elements may be made in accordance with this invention simply by applying a layer of an insulating material, preferably one having a specific volume resistivity in excess of 10^{12} ohms-cm. to a thickness sufficient to provide an area resistance of at least 10^9 ohms per sq. cm., as a continuous unbroken film of at least 0.5 mil thickness adjacent one or both surfaces of the phosphor layer.

The PIP element itself may be any of those with which the art is familiar such as those described in the above identified Kallmann et al. patent or in Kallmann, Rennert and Sidran "A Photographic Process Using Persistent

Internal Polarization in Phosphors," Photographic Science and Engineering, vol. 4, No. 6, pp. 345-353, November-December 1960.

A typical PIP element, in the form of a plate useful in transfer processes, may be prepared as follows: To a conductive backing layer of aluminum foil, one mil in thickness, is applied the following composition:

	Parts by weight
Zinc cadmium sulfide phosphor	92
Binder—a copolymer of polyvinylidene chloride and acrylonitrile contain about 80% by weight of polyvinylidene chloride (Saran F220)	8
Solvent—methyl ethyl ketone	100

The phosphor composition is applied to a thickness, dry, of about two mils, corresponding to about 9 pounds per 3000 sq. feet and is then dried.

The foregoing example is presented as a typical PIP element known to the art and useful in this invention. The preferred zinc cadmium sulfide phosphor is described in detail in the Kallmann et al. article referred to above as K powder. Other phosphors referred to in that article or known to the art, having PIP properties, are also useful and may also be employed in the practice of this invention. Suitable phosphors may be readily selected by measuring their PIP effect, for instance by the electrometer method described by Freeman, Kallmann and Silver "Persistent Internal Polarization" Rev. Mod. Phys. Vol. 33, No. 4, 553-573, October 1961. Other binders may also be used, such as Cycloac I (terpolymer of butadiene, styrene and acrylonitrile known to the trade as ABS), polystyrene, nitro cellulose lacquers and similar liquid resin compositions useful as vehicles.

After the phosphor layer has been applied to the aluminum backing, and while it is dry, or slightly moist, a solution of cellulose triacetate in amyl acetate, formulated to a coatable viscosity (e.g. 1000 cp. and containing about 5-8 weight percent resin) is applied over the phosphor layer to a thickness providing a film of preferably one mil or more. Upon drying, the plate is ready for use in the conventional manner.

The invention is not limited to the use of cellulose triacetate as the insulating material, but may make use of any of numerous well known insulating materials having the requisite specific volume resistivity and capable of forming a continuous film of at least 0.5 mil and preferably 1 mil or more. Suitable materials are polyethylene, polypropylene, polyethylene glycol terephthalate (Mylar), polytetrafluoroethylene (Teflon), and polyvinylidene-acrylonitrile copolymers (Saran) and inorganic films such as glass and mica. Inasmuch as the insulating layer should itself serve no other function than to insulate the electrode from the phosphor, it is preferred that the material itself be essentially non-polarizable, that is, a material having a low tendency to form an electret as described by Fridkin and Zheludev—Photoelectrets and the Electrophotographic Process, 1961, Consultants Bureau Enterprises, New York. Thus, while significant improvements in the PIP plate may be made by applying such materials as polystyrene or the acrylic resins they are not preferred, because they themselves have a tendency to become polarized, particularly in strong electric fields.

In the foregoing example, the phosphor was coated on the conductive backing, and a coating of an insulating resin composition applied to it. Alternatively, a film of the insulating transparent resin may be coated with the phosphor, and a conductive backing member laminated, or otherwise applied to it, or the phosphor composition may be applied to the backing and a film of transparent insulating resin laminated to its surface. Casting or coating techniques for applying the transparent insulating resin are preferred, however, because they provide a smoother surface.

When applying a coating of a resin solution or lacquer over the phosphor layer, it is preferable that the solvent in the solution of lacquer is not a solvent for the binder of

the phosphor. Hence in the foregoing example, amyl acetate was selected in preference to ketones as the latter would also tend to dissolve the Saran binder.

The improved PIP plates produced as described above, may be used in the process described in the Kallmann patent referred to above. A preferred manner of using it is shown in the accompanying drawing which illustrates schematically apparatus useful in PIP technology.

The plate 10 consisting of the conductive backing 12, the phosphor layer 14 and the insulating film 16, is positioned between a backing electrode 18 and a transparent electrode 20 (e.g. NESA glass), the latter being in generally close contact with the insulating layer 16. A reversible potential source 22 is connected between the electrodes 18 and 20, the glass electrode 20 being positive and a voltage, typically 600 volts is applied. At the same time, the plate is illuminated with white light from a lighted white panel 24 for a brief periods—20 secs. After the light has been extinguished, the potential is reversed and the white panel 24 is replaced by the graphic original 26 which is to be copied. The plate is then exposed to the graphic original at the same light intensity and duration, and the polarization of the light exposed areas is thereby reversed, while the dark areas retain their original positive charge. After the light has been extinguished, and in the dark, the glass electrode 20 is removed, and a negative toner powder applied to the plate to develop the dark positive areas. The toner image may be fused directly to the plate, or transferred to a paper sheet and fused to it. In either case a clear and faithful copy of the original is produced without significant distortion.

From the foregoing description, it will be appreciated that the essential characteristic of the invention is the provision of an insulating layer over the PIP phosphor sufficient to bring above an overall substantially non-conductive condition. In embodiments designed for photographic purposes, the transparent electrode will ordinarily be removed from the plate, in which case the insulating layer on the adjacent surface of the plate should be transparent. However, the phosphor layer may also be applied directly to the transparent electrode, with provisions for removing the backing electrode in which case the insulating layer need not be transparent. Thus the insulated layer may be applied to either or to both sides of the phosphor and may itself serve as the support or backing sheet, as long as electrode means are available for applying the field.

We are aware that the provision of an insulating layer over a xerographic plate has been suggested as a means of providing mechanical protection and humidity insensitivity. See Deubner, U.S. Patent No. 2,860,048, and Owens U.S. Patent No. 2,886,434. In those cases, however, the layer must be sufficiently thin and of a sufficiently conductive material that overall conductivity is retained for the requisite DC current to flow in the light exposed areas. This invention differs in that the insulating layer must be sufficiently thick to prevent the flow of any DC currents, a suitable criterion being that the overall resistance must be excess of 10^9 ohms per sq. cm.

Having thus disclosed our invention and described in detail the preferred embodiment thereof, we claim and desire to secure by Letters Patent:

1. In an electrophotographic method in which a charge separation pattern is produced in a photosensitive film comprising a phosphor that exhibits the property of persistent internal polarization, by exposing said phosphor film to a light image while said phosphor film is retained between a backing electrode and a transparent electrode, and a polarizing potential is applied, thereby to produce in said phosphor film a charge separation pattern corresponding to said light image, then removing one of said electrodes and developing the said charge separation pattern: the improvement which comprises interposing between said phosphor film and said one electrode a layer of an insulating material contiguous to said phosphor film

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sufficient to provide an area resistance across said phosphor film of at least 10^9 ohms per square centimeter, said insulating layer being retained in contiguous relation to said phosphor film throughout said exposure, the application of the polarizing potential, the removal of said one electrode and development.

2. The method defined by claim 1 wherein said phosphor film is first illuminated with uniform light while a first polarizing potential is applied between said electrodes and thereafter said phosphor film is illuminated with a light image while an opposite polarizing potential is applied between said electrodes.

3. The method defined by claim 2 wherein said insulating layer and said one electrode are transparent and said light image is projected through them upon said phosphor film.

4. The method defined by claim 3 wherein said transparent electrode is removed from said phosphor film in the dark after said application of said second polarizing potential and said exposure to said light image, en elec-

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trically charged toner powder is applied to said insulating layer to develop said charge separation pattern.

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