

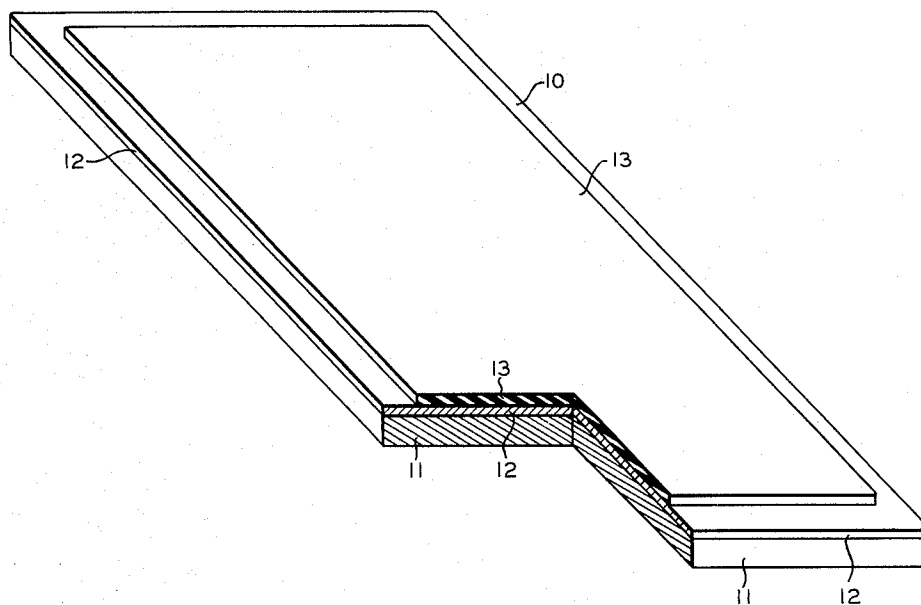
Feb. 8, 1966

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3,234,020

PLATE FOR ELECTROSTATIC ELECTROPHOTOGRAPHY

Original Filed Jan. 7, 1958



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3,234,020

PLATE FOR ELECTROSTATIC ELECTROPHOTOGRAPHY

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Continuation of application Ser. No. 707,561, Jan. 7, 1958.

This application June 21, 1961, Ser. No. 118,626

6 Claims. (Cl. 96—1)

This invention relates to xerography and in particular to an improved xerographic plate; and this application is a continuation-in-part of my application Serial No. 235,383 filed July 5, 1951 (now abandoned) and a continuation of my application Serial No. 707,561, now abandoned, filed January 7, 1958.

In the art of xerography, which was first presented in Carlson U.S. Patent No. 2,297,691, an electrophotographic reproduction is made by placing an electrostatic charge pattern or electrostatic image on an insulating surface such as a photoconductive insulating surface and thereafter developing the electrostatic image by means of an electrically-attractable material.

This invention is an improvement in the art of xerography as disclosed in the aforesaid Carlson patent of such significant character that it has now become feasible to apply the process to continuous-tone electrophotography wherein the electrostatic image runs a continuous gradation of potential corresponding to a continuous gradation in the optical density of the subject to be reproduced.

In accordance with the present invention, there is provided an improved xerographic plate which is capable of reproducing an optical image faithfully and in pleasing tone rendition. In a process for which this improved member is particularly useful, a xerographic member comprising a photoconductive insulating layer on a conductive backing is provided with a uniform electrostatic charge on its photoconductive layer and is then exposed to a light image. On exposure to the light image, the photoconductive layer becomes conductive in selective areas corresponding to the bright area of the image, and the electrostatic charge is dissipated preferentially in these areas. To meet the high requirements of continuous-tone electrophotography, it is essential that the electrophotographically-sensitive member be capable of accepting a uniform charge both in terms of uniform surface potential and in terms of total charge per unit area, and it is further essential that the photoconductivity of the sensitive member be uniform throughout the area and be generally proportional to the light intensity. Without these strictly exact characteristics, adequate continuous gradation of tone is unlikely and the sensitive member would be suitable only for line copy reproduction or for relatively crude continuous-tone work.

It is, therefore, an object of this invention to provide an improved xerographically-sensitive member suitable for fine grade continuous-tone reproduction, and to provide a process for the preparation of said improved member.

It is a further object of this invention to provide an improved electrophotographic member comprising a photoconductive layer on a conductive backing, this member being of high uniformity suitable for fine continuous-tone reproduction, and to provide a process for the preparation of such improved member.

In the production of a xerographic member suitable for electrophotography, any backing may be provided for this photoconductive insulating material which possesses greater conductivity than the dark conductivity of the photoconductive insulating layer, as stated in the aforesaid Carlson Patent No. 2,297,691, wherein reference is made to the use of metal plate backings such as zinc, aluminum,

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and brass. This patent also mentions the employment of other backings such as paper, glass, plastic or other sheets which may be impregnated or coated with a conductive material such as a conductive metal, metallic-conductive compounds, carbon and the like, both with and without some binder material. In the xerographic member, the backing serves the primary purpose of providing a conductive material in continuous, electrically coupled relation with the layer of photoconductive insulating material whereby wherever the layer of photoconductive insulating material is rendered conductive responsive to exposure of the photoconductive insulating material to light, and to the extent of such exposure, an electrostatic charge previously imposed on the layer of photoconductive insulating material may become dissipated with resultant production of an electrostatic image. Accordingly, many other backing plates may be employed in addition to those that have been exemplified. However, especially in the case of continuous tone reproduction, it is important that the electrical coupling between the backing and the layer of photoconductive insulating material be highly uniform throughout the area of the electrostatic latent image. Moreover, it is important that an original electrostatic charge be retained to the maximum extent possible and with maximum uniformity of retained charge during the interval between the charging of a xerographic member and the exposure of the member to light for the production of the desired photoelectric image.

The aforesaid Carlson Patent No. 2,297,691 gives a number of examples of photoconductive insulating materials which may be utilized in a xerographic member. Among them are sulfur, anthracene, anthraquinone, melted mixtures of sulfur and selenium with the sulfur predominating, and certain mixtures of sulfur with anthracene or linseed oil. More recently it has been proposed to employ as and for the layer of photoconductive insulating material a layer of substantially pure selenium that has been produced under such conditions that the selenium is not in the semi-conductor metallic state mentioned in the said Carlson patent but is in an amorphous, vitreous, photoconductive insulator state, such as that which results from the procedure disclosed in application Serial No. 221,042, filed April 14, 1951, entitled, "Xerographic Member, and Method and Apparatus for the Production Thereof" (now Patent No. 2,753,278, issued July 3, 1956). Such vitreous selenium photoconductive insulating material is considerably more electroconductive responsive than the materials mentioned in the Carlson patent, thus making it possible to utilize shorter periods of light exposure or less intense light exposure whereby greater all-around utility and suitability for continuous-tone are afforded. Accordingly, it is preferable to employ selenium for the photoconductive insulating material although in practicing this invention essentially the same utilization of photoconductive insulating properties is involved in the production of a photoelectric latent image, whether selenium is used or some other photoconductive insulating material. The selenium that is used is substantially pure and does not contain the small amount of halide that is essentially present to impart conductive characteristics when selenium is used for other purposes wherein substantial conductivity is a required characteristic.

Features of this invention involve the cleaning of a surface area of an electroconductive backing member which is free of substantially all foreign matter, thereby leaving the surface area substantially uniform throughout so as to be that of the substance of which the backing member is composed, and while the surface is freed of all foreign matter, as aforesaid, causing a film of insulating material to be distributed over the surface area in directly

adherent relation therewith with essential uniformity of both composition and thickness. An essentially uniform layer of photoconductive insulating material thereafter is applied to the film of insulating material. The film of insulating material is so distributed in relation to the elements on the opposite sides thereof that the xerographic plate as a whole has a substantially decreased dark decay rate as compared with a corresponding plate wherein the surface of the backing member has been similarly cleaned without, however, applying the film of insulating material. At the same time, the plate permits effective discharge of an electrostatic charge upon increase in the conductivity of the layer of photoconductive insulating material responsive to exposure to light or other radiation that is effective to impart increased conductivity to the photoconductive insulating material that is used. In preferred embodiments of this invention, the intervening barrier film does not substantially decrease the rate of light decay of the plate or otherwise affect the responsiveness of the plate to light exposure and may actually increase the rate of light decay.

By utilization of this invention, very significant improvements in xerography have been obtained, especially in the attainment of improved continuous-tone reproductions. The sensitivity of a xerographic plate to light and to the development of electrostatic image contrasts is impaired by loss of an initially imparted electrostatic charge and, inasmuch as there is always a substantial interval of time between the imparting of the charge and the light exposure whereby the latent electrostatic image is produced and between the light exposure and development of the plate, the decrease in dark decay rate that is obtained according to this invention is of major practical significance as regards its effect on the quality of the reproductions produced. Moreover, both any dark decay as may occur and the light decay response to illumination are caused to be more uniform throughout the surface area that has been treated according to this invention with the result that the electrostatic image that is produced more nearly parallels the differences in illumination and avoids inaccuracies due to the effect on the electrostatic image of factors such as non-uniform charge retention and non-uniform response to illumination.

In the drawing the figure is a diagrammatic representation partially in section of an improved xerographic member according to this invention. In the figure there is shown a new xerographic member comprising a backing plate 11 having on its surface an extremely thin interfacial layer 12 with a top layer of photoconductive vitreous-appearing selenium 13.

The general nature and scope of the invention having been set forth, the following specific examples are presented in illustration but not in limitation of the invention, and it is to be understood that the invention is limited only by the appended claims.

Example 1

A brass plate having a surface area about 4 x 5 inches and characterized by a mirror-smooth surface free from visible flaws and imperfections was selected as a base plate for a xerographic member. This brass backing plate was carefully prepared by the following cleaning steps: The surface was coated with a commercial wax base polish believed to be an aqueous emulsion of a paraffin hydrocarbon wax and the surface was polished with a soft cloth; the polished surface was washed with water containing a small amount of a Duponol (a trade name for a higher aliphatic alcohol sulfate); the surface was thoroughly rinsed with water and then with methyl alcohol; and the surface was immediately degreased by suspending it in isopropyl alcohol vapor.

The thoroughly cleaned brass base plate was then placed in a vacuum evaporation chamber with its rear surface mounted against a temperature control platen through which was circulated water at a controlled temperature

and substantially pure selenium was evaporated onto the cleaned surface of the plate according to the procedure claimed in copending application Serial No. 221,042, filed April 14, 1951, and entitled, "Xerographic Member, and Method and Apparatus for the Production Thereof." According to this procedure, the brass plate was maintained at a temperature of about 65° C. and a 50-micron layer of vitreous selenium was evaporated thereon during a period of about ten minutes. Uniformity of thickness of the selenium layer was assured by evaporating the selenium simultaneously from four evaporation boats positioned substantially directly opposite the corners of the brass plate, whereby the film was of equal thickness over the entire area within a tolerance of 2%. The resulting plate was characterized by being excellent for the reproduction of continuous-tone images by the xerographic process.

Example 2

The procedure of Example 1 was repeated employing the following cleaning steps on the brass plate: The plate was first thoroughly washed with water containing 1% Duponol and then evaporated dry. An 8% solution of paraffin wax in benzene was applied to the surface with a cotton swab and air dried. This was then rubbed briskly until polished and washed again with 1% Duponol. The surface was then rubbed with water and flushed with methanol, after which it was immediately degreased with isopropyl alcohol vapor. The plate was then placed in a vacuum chamber and coated with selenium, according to the procedure of Example 1, to yield a satisfactory continuous-tone xerographic plate.

The rigorous cleaning steps described in the examples are believed to perform two functions. In the first plate, these cleaning steps are designed to remove completely all films of dirt, grease, oxides, stains and the like from the surface of the plate, and, in the second plate, it is believed that these steps leave on the surface of the plate a very thin uniform layer of the cleaning agent, in the specific examples described, this being a wax cleaning agent, employed in the cleaning steps. Thus, it is believed that there remains a thin coating, presumably a very few molecules thick, of the cleaner component. The presence of the residual thin interfacial film or barrier layer has been established experimentally by its effectiveness in preventing amalgamation of a brass test plate of the character aforesaid with mercury placed therein. Thus three like brass test plates were cleaned by successively treating them with hydrochloric acid, isopropyl alcohol and hot isopropyl alcohol vapor. Two of the three plates had Glass Wax applied thereto which was subsequently removed with a dry cotton swab. One of the blanks that had had the Glass Wax applied thereto was degreased by treating it for five minutes in hot isopropyl alcohol vapor for five minutes. A drop of mercury was placed on each of the three plates. The mercury did not wet the surface of either of the plates that had had Glass Wax applied thereto but did amalgamate with the surface of the plate that had not had the Glass Wax applied thereto, thereby demonstrating that a barrier film is left by the Glass Wax and that the film is not removed by a degreasing treatment of the kind employed in the preparation of the plate of Example 1.

Example 3

Three brass test plates were thoroughly cleaned by treating each with successive application of 1.2 N hydrochloric acid, isopropyl alcohol, and hot isopropyl alcohol vapor. To the surface of the clean plates a film was applied consisting of polystyrene, by dipping the plate in a toluene solution of the resin. The resulting films on the three plates were, respectively, 0.5 micron, 1 micron, and 2 microns thick. These plates were then coated with a coating about 50 microns in thickness of amorphous selenium, by vacuum evaporation at about 73° C., and about 1 micron of mercury. All three plates so prepared yielded satisfactory continuous-tone xerographic plates.

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Example 4

Two brass test plates were thoroughly cleaned by treating each with successive applications of 1.2 N hydrochloric acid, isopropyl alcohol, and hot isopropyl alcohol vapor. To the surface of one of the cleaned plates a film was applied consisting of Lucite 46, which is a trade name of E. I. du Pont de Nemours & Co. for a polymeric butyl methacrylate, by dipping the plate in a toluene solution of the Lucite, the resulting film being about 3 microns in thickness. After storage of the film coated plate for 72 hours, both plates were coated with a coating about 45 microns in thickness of amorphous selenium by vacuum evaporation at about 73° C. and about 1 micron of mercury. The plate having the Lucite interfacial film exhibited much improved resistance to dark decay, without impairment of light sensitivity, as evidenced by the following data:

Interfacial layer	Initial potent. (positive), v.	Dark decay, percent	Light sensitivity (400 mμ)	Residual potent., v.
Lucite (3μ)-----	555	0.72	17.5	26
None (control)-----	500	4	17.5	25

In the foregoing table and elsewhere herein dark decay expressed in percent is computed as follows:

$$\text{Percent dark decay} = \frac{(V_o - V_t) \times 100}{V_o}$$

where V_o is the initial potential in volts and V_t is the potential after 30 minutes' storage in the dark.

In the foregoing table and elsewhere herein except as noted otherwise, the light sensitivity was measured at 400 millimicrons using light intensity of 0.03 microwatt per square centimeter, the sensitivity value S being computed as follows:

$$S = \frac{V_o^{1/3}}{2T_d I^{0.9}}$$

where T_d is the time in seconds required for the plate potential to decay under the light exposure to one-half of its initial value, V_o is the initial potential and I is the light intensity.

Example 5

Two brass plates were prepared as described in Example 4 and were placed in a common evaporator having separate shutters for screening each of the plates. While maintaining about 1 micron mercury pressure, a film of sulfur substantially 1.5 micron in thickness was applied to one of the plates while the other plate was screened by its shutter. Thereafter, without breaking the vacuum, a coating about 45 microns in thickness of amorphous selenium was applied at about 73° C. to both of the plates. The plate having the sulfur interfacial film exhibited much improved resistance to dark decay while possessing satisfactory light-sensitivity, as evidenced by the following data:

Interfacial layer	Initial potent. (positive), v.	Dark decay	Light sensitivity (400 mμ)
S (1.5μ)-----	580	520 v., 30 min. later.	Fell to 30 v. in 1 min.
None (control)-----	580	430 v., 30 min. later.	

Example 6

Two brass plates were prepared as described in Example 5 except that the sulfur interfacial film was applied so as to be substantially 3 microns in thickness. As evidenced by the following data, the increased thickness of the sulfur interfacial film resulted in an increase in the

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resistance to dark decay without adversely affecting light-sensitivity:

Interfacial layer	Initial potent. (positive), v.	Dark decay	Light sensitivity (400 mμ)
S (3μ)-----	400	440 v. 30 min. later.	Fell to 30 v. in 1 min.
None (control)---	450	350 v. 30 min. later.	

Example 7

Two brass plates were prepared as described in Example 4, and each had successively applied thereto an interfacial film of gallium triselenide followed by the deposition of a coating of amorphous selenium following in the manner described in Examples 5 and 6. On one plate the interfacial film of gallium selenide was about 1 micron in thickness and on the other plate it was between 2 and 3 microns in thickness. Each of the plates exhibited high resistance to dark decay while possessing satisfactory light-sensitivity, as evidenced by the following data:

Interfacial layer	Initial potent. (positive), v.	Dark decay	Light sensitivity (400 mμ)
Ga ₂ Se ₃ (1μ)-----	440	400 v. 30 min. later.	Fell to 14 v. in 1 min. and 0.5 v. in 25 min.
Ga ₂ Se ₃ (2-3μ)-----	560	520 v. 30 min. later.	Fell to 22 v. in 1 min. and 3 v. in 10 min.

Example 8

Two aluminum plates were thoroughly cleaned, first using isopropyl alcohol and then hot isopropyl alcohol vapor. One of the cleaned aluminum plates was coated with a Lucite film about 3 microns in thickness as described above in Example 4. The interfacial film of Lucite resulted in a very good improvement in resistance to dark decay without impairing light-sensitivity, as evidenced by the following data:

Interfacial layer	Initial potent. (positive), v.	Dark decay, percent	Light sensitivity (400 mμ)	Residual potent., v.
Lucite 46 (3μ)-----	459	3.9	19	25
None (control)-----	430	40	18.5	16

Example 9

Two brass plates which had been cleaned as described above in Example 4 were placed in a vacuum evaporator and while maintaining a pressure of about 1 micron of mercury each of the plates had applied thereto by vacuum deposition a film of aluminum of about .3 micron in thickness. Without breaking the vacuum, one of the aluminum coated plates had deposited thereon a film of sulfur about 1 micron in thickness. Thereafter each of the plates had deposited thereon a coating about 45 microns in thickness of amorphous selenium. In this instance also there was a pronounced improvement in resistance to dark decay while light-sensitivity remained high, as evidenced by the following data:

Interfacial layer	Initial potent. (positive), v.	Dark decay, percent	Light sensitivity (400 mμ)	Residual potent., v.
S (1μ)-----	567	2.6	13.2	14
None (control)-----	500	11	16	28

Example 10

A coating of chromium about 25 microns in thickness was applied electrolytically to two brass plates, which were thereafter subjected to the cleaning procedure hereinabove described in Example 4. Also as described in Example 4, a coating of Lucite about 3 microns in thickness was applied to one of the plates and thereafter each of the plates had applied thereto by vacuum deposition a coating of amorphous selenium. In this instance a very great improvement in resistance to dark decay resulted from the Lucite interfacial film, there being as well some increase in light-sensitivity. The data in connection with this example appears below:

Interfacial layer	Initial potent. (positive), v.	Dark decay, percent	Fatigue	Light sensit. (450 m μ)	Residual potent., v.
Lucite 46 (3 μ)-----	500	4	0	31	39
None (control)-----	485	45	0	9.3	25

Example 11

A film of gold about 1 micron in thickness was applied by vacuum evaporation to each of two clean brass plates. One of the plates then was provided with a Lucite film about 3 microns in thickness, as described above in Example 4. Thereafter both plates were provided with a coating of amorphous selenium. The plates thus prepared when tested exhibited much improved resistance to dark decay and the light-sensitivity was virtually unaffected by the interfacial layer. In this instance the plates were also tested for fatigue and much improved resistance to fatigue was noted in the case of the plate having the interfacial Lucite film. The data in connection with this example is as follows:

Interfacial layer	Initial potent. (positive), v.	Dark decay, percent	Fatigue, percent	Light sensitivity (450 m μ)
Lucite 46 (3 μ)-----	450	11	9.1	8.2
None (control)-----	100	32	32	8.3

Fatigue as given in the above table and elsewhere herein is obtained by dividing the difference in voltage before and after exposures to radiation (in each case taken three minutes after charging) by the voltage on the plate before exposure (three minutes after charging), the value of the ratio being expressed as a percentage.

Example 12

The procedure of Example 10 was repeated except for the vacuum deposition of a film of indium on the brass plates instead of gold, the results of this test being as follows:

Interfacial layer	Initial potent. (positive), v.	Dark decay, percent	Fatigue, percent	Light sensitivity (450 m μ)
Lucite 46-----	570	11	2.8	16
None (control)-----	477	21	1.5	14

Example 13

Example 8 was repeated except that the plates were subjected to a negative potential rather than a positive potential and the following data was obtained:

Interfacial layer	Initial potent. (neg.), v.	Dark decay, percent	Light sensitivity (400 m μ)
Lucite 46 (3 μ)-----	500	45	11
None (control)-----	30	90	1

Example 14

Example 9 was repeated except that the plates were subjected to a negative potential rather than a positive potential and the following data was obtained:

Interfacial layer	Initial potent. (neg.), v.	Dark decay, percent	Light sensitivity (400 m μ)
Lucite 46 (3 μ)-----	500	54	6.3
None (control)-----	80	70	0.3

Example 15

The plate of Example 4 having the Lucite interfacial layer and the plate of Example 6 having the sulfur interfacial layer were each subjected to a uniform electrostatic charge comparable to that imposed in ordinary commercial xerography. Both plates were then stored in the dark for three days. At the end of this period each of the plates was exposed to a light image and was developed using normal xerographic procedures. The quality of the developed image was fully equivalent to that obtained using conventional plates when such plates are exposed and developed immediately after charging. The capacity thus exhibited for resisting dark decay for three days represents a very great improvement as compared with conventional plates previously employed in xerography.

The function of the interfacial layer is not known with certainty but it is believed that in addition to protecting the surface from chemical action immediately prior to the coating operation it also acts as an insulator or at least as a barrier between the layer of photoconductive insulating material and the electroconductive substance of which the surface of the backing is composed. It is known, for example, that in vitreous selenium the mechanism of charged migration is attributable to the migration of positive holes, that is, such electrical conductivity as it possesses occurs in the form of the travel of apparent electron spaces or holes within the layer rather than by the travel of free electrons through the layer. It also is known that the preferred xerographic steps employed in connection with selenium as the photoconductive insulating material include imparting a positive polarity surface charge to the photoconductive layer, which positive charge is dissipated upon exposure to light and is believed to be conducted through the layer to the conductive base plate or backing. Basing theory upon these facts, it is believed and understood that the interfacial film or layer of insulating material that, according to this invention, is provided between the electroconductive base plate and the layer of selenium or other photoconductive insulating material serves to prevent premature transmission of the electrons to the photoconductive layer prior to its exposure to light. Whether this theory is correct or not, it has been found that in the absence of the application of the interfacial film of insulating material the resulting xerographic plate is characterized by excessive loss of charge in the absence of illumination resulting in excessive loss of charge prior to and subsequent to exposure to the light image. The direct effect of such loss of charge is a weakened electrostatic image and generally an image which is somewhat mottled and, therefore, unsuited for continuous-tone electrophotography.

The interfacial film which is employed according to this invention is composed of insulating material in contrast with the electroconductive substance presented at the surface of the base plate. The insulating material of which the interfacial film is composed also has less conductivity than the dark conductivity of the overlying layer of photoconductive insulating material in the sense that when the plate is charged and is not exposed to activating radiation an insulating barrier is provided which lessens the rate at which the potential imposed on the layer of photoconductive insulating material becomes dissipated

into the base plate. The insulating material of which the interfacial film is composed ordinarily is not a photoconductive insulating material whose conductivity is increased upon exposure to radiation. However, such increase in conductivity upon exposure of the plate to activating radiation is not inconsistent with the practice of this invention inasmuch as it is desirable rather than otherwise that an imposed charge be dissipated rapidly in those areas that are exposed to activating radiation. Thus, sulfur possesses photoconductive insulating characteristics to a certain extent but may very advantageously be used as the material of the interfacial layer in combination with an overlying layer of photoconductive insulating material such as vitreous selenium. However, the invention contemplates the employment of an interfacial film or barrier layer composed of some material which is different from the coating of photoconductive insulating material that is primarily used to receive the electrostatic charge and on which the electrostatic image is produced.

As used in the xerographic process an electrostatic field is placed across the photoconductive insulating layer. The interfacial film or barrier layer defined in the instant invention is an insulating film in the sense that it prevents the injection of carriers from the base plate into the photoconductive insulating layer under the influence of the applied field. Thus, such a layer may act to prevent the injection of both positive and negative charge carriers. However, as xerographic plates are normally used with only one polarity of charging, the barrier layer may prevent the injection of only one polarity of charge carrier. Thus, a vitreous selenium plate is normally used with a positive field applied to the surface thereof. Accordingly, the barrier layer should act to prevent the injection of negative charges from the backing member into the selenium. If the selenium contains a quantity of arsenic trisulfide, the resulting xerographic plate is normally used with negative sensitization. For such a photoconductive insulating layer the barrier layer should prevent the injection of positive charges or holes from the backing into the photoconductive layer. The minimum thickness of the barrier layer is determined by two factors: First, the difficulty of obtaining a uniform interfacial film, and, secondly, the fact that the film must not be so thin that tunneling occurs to such an extent as to obviate the effectiveness of the barrier layer. For most materials this means that the interfacial film should have a thickness of at least about 0.1 micron. For certain materials such as those applied in the Glass Wax treatment shown in Example 1, there is apparently an ability to strongly and uniformly wet the surface of the brass backing, thereby creating a highly uniform layer even under conditions wherein the layer is extremely thin. The layer in those cases is no more than about 100 or so angstroms thick. The limiting factor on the maximum thickness of the barrier layer is generally determined by the maximum residual voltage that can be tolerated under conditions of use of the plate. The formula for determining this follows from the fact that the capacity of the photoconductor is to the capacity of the barrier layer as the initial potential applied to the plate is to the residual potential. Assuming an initial potential of 500 volts applied to a selenium photoconductor, then 500 divided by the residual voltage equals the thickness in microns of the selenium times the dielectric constant of the interlayer divided by the thickness of the insulator times the dielectric constant of the selenium. For a 50-micron selenium plate, and an interlayer material with a dielectric constant of about 3, then the residual voltage is equal to 20 times the thickness in microns of the interlayer. It can be seen from this proportion that the larger the dielectric constant of the interlayer, the greater the permissible thickness of the interlayer. In general, it is desirable that the interlayer not be thicker than about 5 microns.

Apart from the presence of the thin interfacial layer

of waxy or other insulating material, it is essential that the surface area of the base plate to be used for electrophotography be scrupulously cleaned prior to the coating operation so that complete absence of any other interfacial material is assured. Dirt, moisture, spots, finger prints and other surface marks on the surface of the base plate, including even marks so slight as to be substantially invisible to the naked eye, have been found to be detectable through the coating in the form of substantial defects in xerographic prints produced from the plate. Accordingly, the surface presented by the electroconductive substance of the base plate should be cleaned so as to be essentially free of all foreign matter other than the electroconductive substance of which the surface area is composed.

In order to maintain the uniformity of results essential to fine quality continuous-tone xerography, it also is necessary that the selenium layer be of substantially uniform thickness. In the absence of such uniformity, the xerographic results are impaired in two ways. In the first place, the charge acceptance of the selenium layer is uneven so that a charge of non-uniform potential will be placed on the layer and this charge, furthermore, will be dissipated at a non-uniform rate. In addition, because of the varying distance between the surface of the base plate and the surface of the layer of photoconductive insulating material, a varying charge density, or coulombs per unit area, will be present even if the potential is made uniform, with the result that varying numbers of charged electroscopic particles will be required to neutralize the charge by deposit on the surface. It is, therefore, apparent that uniformity of structure is critically essential to the fine quality demanded for continuous-tone reproduction.

In prior research on xerographic processes and materials it had been found that gross permanent defects frequently appeared in vitreous selenium xerographic layers, these defects being apparent after the layer had been charged to a potential approximating its maximum charge acceptance or insulation breakdown potential. These defects, appearing as dots about the size of the head of a pin, were characterized by inability to accept and retain an electrostatic charge, and were of such a nature as to render the member unsuitable even for line reproduction after a relatively large number of the spots had accumulated on the surface. Later, when these gross defects had been substantially completely eliminated by improvements and methods other than those of the present invention, it was found that other fine defects were detectable, these fine defects being substantially unobjectionable in line reproduction but making the member inferior for continuous-tone reproduction. In the presently preferred xerographic procedures, a xerographic member or plate is charged to a positive polarity potential of about 100 volts and exposed to a continuous-tone light image, and under these conditions it has been found that a typical prior xerographic plate such as, for example, an aluminum plate of clean, degreased mirror finish aluminum (which inherently has a thin aluminum oxide layer thereon) with a 20-micron vitreous selenium layer does acquire such fine defects whereas the plate according to this invention does not acquire such defects.

In preferred practice of this invention, the coating of photoconductive insulating material preferably is composed of vitreous selenium. The photoconductive insulating layer should be between about 20 and about 200 microns thick, the thickness selected generally depending on the conditions of use of the plate. For line copy work the selenium usually is about 20 microns thick and for continuous-tone work preferably is about 50 microns thick, although the selenium layer may be somewhat thinner, e.g. about 40 microns, or may be up to about 80 microns in thickness. The selenium layer for the drums of automatic machines generally is about 50 microns thick. For X-ray work the selenium layer

usually is about 80 to 160 microns thick. While the nature of the selenium layer has been described as vitreous, the exact molecular structure is not known, the term being used as descriptive of its physical appearance and it is not desired to limit the use of selenium to any crystalline or allotropic form. It is believed that the selenium is present substantially in an amorphous form containing minor proportions of a crystalline form of selenium, although it is not desired to restrict this invention to the presence of such a mixture of forms. It is, therefore, to be understood that the various crystalline or amorphous structures included in the vitreous-appearing form of selenium are likewise to be included in the meaning of the term "vitreous" as used herein and in the claims. It likewise is to be understood that the term "selenium" includes not only pure selenium but also selenium that may be modified by a controlled amount of an additive that is consistent with retention of useful photo-insulating effectiveness. While the use of vitreous selenium is preferable, nevertheless xerographic plates using other types of photoconductive insulating material are improved by the employment of the interfacial film or barrier layer according to this invention. Moreover, while excellent results have been obtained wherein the base plate presents a surface composed of brass, nevertheless other electroconductive substances may be used so long as the surface thereof is free of visible imperfections and is essentially free of all foreign matter other than the electroconductive substance of which the surface area of the base plate is composed.

The presence of the barrier layer between the photoconductive insulating layer and the conductive backing not only reduces dark decay but is also believed to substantially reduce the buildup of trapped charges upon repeated use. Upon exposure to activating radiation, hole-electron pairs are created at the point of absorption of the photons. In the case of selenium this is on or close to the surface. The electrostatic field created by the sensitizing charges on the surface of the selenium cause one polarity of charge carriers to migrate through the selenium to the conductive backing. As they approach the backing charges of opposite polarity are injected from the backing to migrate toward the surface. Most photoconductive insulators, such as selenium, cadmium sulfide, cadmium selenide, etc., have a long range for only one range of charge carrier. Thus, where both polarities of charge carriers are injected into the photoconductor, the short range carriers are trapped building up a strong residual potential as the plate is reused. The presence of a barrier interlayer according to the instant invention, by preventing injection of carriers from the backing, assures that only those carriers generated by the incident radiation will be present thus reducing the possibilities for trapping.

What is claimed is:

1. A process for preparing an improved xerographic plate suitable for continuous-tone electrophotography, said process comprising thoroughly cleaning the surface of a smooth brass plate, applying a wax to the cleaned surface and polishing the wax, rinsing the waxed surface with water and then with solvent vapor and vacuum evaporating a layer of vitreous selenium on said surface while maintaining the brass plate at a temperature be-

tween about 60° and 75° C., until a uniform vitreous selenium layer, between about 40 and about 70 microns thick, is coated onto the surface.

2. The process of claim 1 wherein the vitreous selenium layer is produced at a thickness uniform within 2% of the average thickness.

3. A process for preparing an improved xerographic plate suitable for continuous-tone electrophotography, said process comprising thoroughly cleaning the surface of a smooth brass plate, applying a wax to the cleaned surface and polishing the wax, rinsing the waxed surface with water and then with solvent vapor and vacuum evaporating a layer of vitreous selenium on said surface while maintaining the brass plate a temperature between about 60° and 75° C., until a uniform vitreous selenium layer, about 50 microns thick, is coated onto the surface.

4. An improved xerographic plate suitable for the production of continuous-tone electrophotographic images, said plate comprising a brass backing member, an interfacial thin coating of a wax produced by applying a wax coating to the brass surface and thoroughly polishing to remove excess wax, and a layer thereover of vitreous selenium uniform over its entire area within a tolerance of about 5% and coated thereon by vacuum evaporation while the brass member was maintained at a temperature between about 60° and 75° C.

5. An improved xerographic plate suitable for the production of continuous-tone electrophotographic images, said plate comprising a brass backing member, an interfacial thin coating of a wax produced by applying a wax coating to the brass surface and thoroughly polishing to remove excess wax, and a 40 to 75 micron layer thereover of vitreous selenium uniform over its entire area within a tolerance of about 5% and coated thereon by vacuum evaporation while the brass member was maintained at a temperature between about 60° and 75° C.

6. An improved xerographic plate suitable for the production of continuous-tone electrophotographic images, said plate comprising a brass backing member, an interfacial thin coating of a wax produced by applying a wax coating to the brass surface and thoroughly polishing to remove excess wax, and a 50 micron layer thereover of vitreous selenium uniform over its entire area within a tolerance of about 5% and coated thereon by vacuum evaporation while the brass member was maintained at a temperature between about 60° and 75° C.

References Cited by the Examiner

UNITED STATES PATENTS

2,657,152	10/1953	Mengali et al.	
2,809,294	10/1957	Vyverberg	96-1
2,901,348	8/1959	Dessauer et al.	96-1
2,901,349	8/1959	Schaffert.	
2,970,906	2/1961	Bixby.	
3,041,166	6/1962	Bardeen.	

FOREIGN PATENTS

755,683	8/1956	Great Britain.
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