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ELECTROPHOTOGRAPHIC PROCESS EMPLOYING PHOTOCONDUCTIVE
MATERIALS OF DIFFERENT DYNAMIC RANGES
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3,756,811

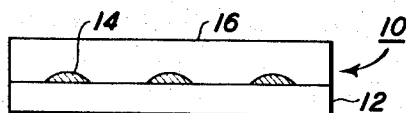


FIG. 1A

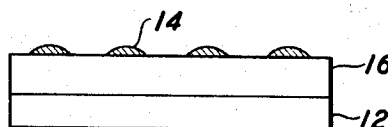


FIG. 1B

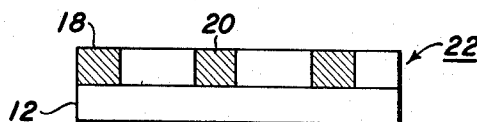


FIG. 1C

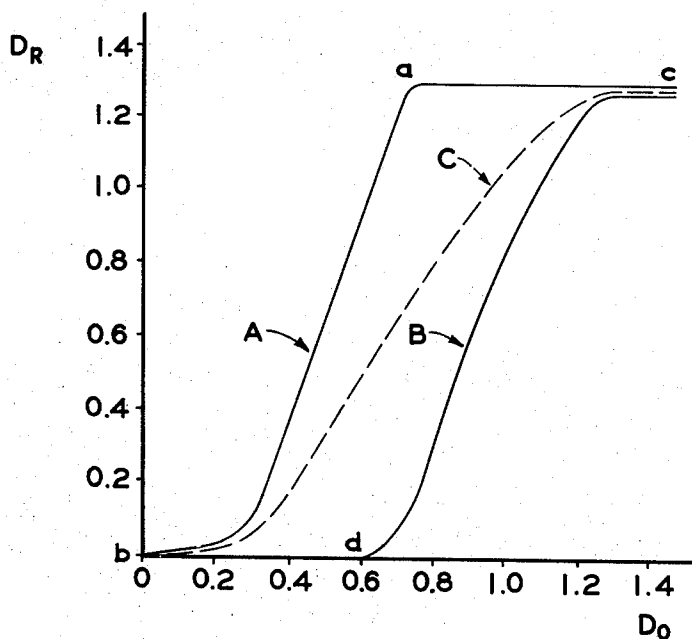


FIG. 2

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ELECTROPHOTOGRAPHIC PROCESS EMPLOYING PHOTOCONDUCTIVE MATERIALS OF DIFFERENT DYNAMIC RANGES

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1 Claim

ABSTRACT OF THE DISCLOSURE

A xerographic plate of extended dynamic range and process for using same, the plate comprising an electrically conductive backing and overlying said backing, a photoconductive insulating layer having a multiplicity of a plurality of alternating discrete small areas of photoconductive insulating material, each of said plurality of small areas having a different photosensitivity to a given exposure.

BACKGROUND OF THE INVENTION

This invention relates in general to xerography and more specifically to photoconductive insulating materials and their use in photoconductive plates for use in xerography.

In the process of xerography, for example, as disclosed in Carlson Pat. 2,297,691, a xerographic plate comprising a layer of photoconductive insulating material on a conductive backing is given a uniform electric charge over its surface and is then exposed to the subject matter to be reproduced, usually by conventional projection techniques. This exposure discharges the plate areas in accordance with the radiation intensity that reaches them and thereby creates an electrostatic latent image on or in the photoconductive layer. Development of the latent image is effected with an electrostatically charged finely divided material, such as an electroscopic powder referred to in the art as "toner," that is brought into surface contact with the photoconductive layer and is held thereon electrostatically in a pattern corresponding to the electrostatic latent image. Thereafter, the developed, "toned" xerographic powder or toner image is usually transferred to a support surface, for example paper, to which it may be affixed by any suitable means.

Amorphous selenium has been found to be a preferred photoconductive insulating material because of its extremely high quality image making capability, relatively high light response, capability to receive and retain charge areas at different potentials and of different polarity and because it may be reused over and over again in quick succession. A characteristic of an amorphous selenium xerographic plate is that it reproduces line copy and other contrasty originals in an excellent fashion because amorphous selenium in combination with conventional xerographic development processes, for example cascade, development, has a relatively short dynamic range of about 0.6. The dynamic range of a particular xerographic plate and development system as used herein is intended to mean that range of original image densities which will produce a viewable change in the density in the reproduction produced by said plate where density $= D = \log$ of $1/R$ where R equals the ratio of reflected light to incident light. For example, in a very dense area of an original where only one-tenth of the incident light is reflected back to the eye of the viewer, R would equal $1/10$ and the log of $1/R$, i.e. density, of course would be 1. A density of 1.3 is where about $1/20$ of the incident light is reflected back to the viewer. Practically, a density of anywhere from about 1.2–1.5 or above appears to the unaided human eye as a very dense black.

Because of the relationship of density to incident and reflected light, to say that an amorphous selenium plate in combination with a particular development system has a dynamic range of about 0.6 is to say that assuming sufficient exposure of the original to just substantially completely discharge areas of the plate corresponding to white background portions of the original where density is about 0, which substantially completely discharged areas of the plate after xerographic development and transfer would appear as a density of about 0, the plate is only capable of producing changes in D_r (densities of the reproduction) for D_o (densities of the original) up to about 0.6. For all D_o greater than about 0.6, no change in density will be shown on the reproduction since for these D_o , there is substantially no discharge of charge from corresponding portions of the xerographic plate, thus the marking material used in development is maximally attracted to these areas.

For conventional xerographic development systems using a dense black marking material, such fully charged areas of the plate will develop out to densities of from about 1.2–1.4. Thus in our sample, any D_o greater than about 0.6 will appear as a D_r of a single density between about 1.2–1.4. Thus, for example, a xerographic print from a selenium plate under the exposure conditions described of a black and white photograph original of a black ribbed sweater on a girl with dark hair would probably not show definition of the ribs or any hair information, but would appear as a smooth black sweater and smooth black hair because D_o in the sweater and hair region is above about 0.6 and any changes in D_o above about 0.6 reproduce as a single density in the region of from about 1.2–1.4. This same amorphous selenium plate will define the ribs in the sweater and show hair information and definition if exposure is adjusted (increased in this case) to move the dynamic range from the $D_o=0-0.6$ region to cover the desired D_o range of say from about 0.8 to 1.4 which will then reproduce the tonal differences present in this particular D_o increment of the original. But if this is done, in order to provide tonal contrast in the $D_o=0.8-1.4$ region, tonal contrast is absent in the reproduction in the region of D_o from about 0 to about 0.8. Any tones on the original in this density region will show up on the xerographic print as white or $D_r=0$.

Thus, since generally it is thought that a given imaging system must have a dynamic range of about 1.2 or 1.5 or more to produce a quality tonal reproduction with a reasonably full latitude of contrast, it is seen that conventional selenium plate xerography has serious limitations in this regard. In a conventional xerographic reproduction system, it is possible to make reproductions showing highlights or alternatively, shadows and the more dense areas of the original but to reproduce images xerographically with contrast differentiation and faithful reproduction of various tones and densities for both highlights and shadows and in between tone variations has required complex equipment and sensitive controls during processing.

The problem was approached in Gundlach et al Pat. 3,212,889 by successively exposing a xerographic plate to the same original using different magnitudes of exposure the exposure being chosen in each imaging cycle to selectively primarily reproduce after development, a marking material image of a given tone region of the original, for example a highlight or a shadow or some in between tone region and then transferring such reproduced images to a final image receiving member in superimposed register so that a composite reproduced pattern is obtained. In other words, the dynamic range is by successive selected exposures moved across the range of D_o desired to be reproduced each print produced from, for example, an amorphous selenium plate picking up tonal contrast for a

different 0.6 increment of D_o . Although this patent offers an answer to the problem, it does have certain limitations such as the necessity for successive xerographic imaging cycles to produce a single print, careful adjustment of exposure for each successive print taking operation, registering of successive image transfers and other factors which make it less than a completely satisfactory solution to the problem.

A different approach was taken in Bickmore Pat. 3,188, 208 wherein an amorphous selenium photoconductor is exposed to the pattern of light and shadow conforming to the original where the light contains at least red light and at least some blue light in a substantially lesser amount, the blue light being sufficient to permit substantially complete charge dissipation of the photosensitive member in blue light struck areas. This approach overcomes some of the limitations of the Gundlach et al. approach, but requires the careful monitoring of the relative and absolute amounts of red and blue light directed to the xerographic plate which may necessitate bulky, complex and expensive optics. Also this approach is peculiar to the amorphous selenium xerographic plate and the particular spectral response characteristics thereof.

Halftone optical screening techniques have been utilized to modulate the intensity of radiation incident to a plate thereby providing alternating discrete areas of the plate one area to produce tonal differences in a particular D_o increment and the immediately adjacent area to produce tonal differences in a different dynamic range increment of D_o . A primary disadvantage of such a system is that it is light inefficient in that light from a radiation source is first optically screened and much light is absorbed before reaching the photoconductor and thus greater exposure is required compared to an unscreened process. In a conventional xerographic setting for producing quality halftones, the optical screen absorbs so much light that the overall sensitivity of the plate is usually reduced by at least about four times. Also optical screening adds to the complexity, bulk and expense of the optical system.

Thus it is clear that there is a continuing need for a better system for providing a xerographic plate and a xerographic processing system to substantially extend the dynamic range of a xerographic plate by simple and expedient means which do not tax the simplicity and directness of the basis xerographic process and specifically the exposure system attendant thereto.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide a xerographic system having an extended or broadened dynamic range which overcomes the above-noted disadvantages and satisfies the above-noted wants.

It is a further object of this invention to provide an extended dynamic range xerographic plate and system which plate is not only not less sensitive than conventional xerographic plates but has greater sensitivity than conventional xerographic plates.

It is a further object of this invention to provide an extended dynamic range xerographic system which does not require any special optical adaptations.

It is a still further object of this invention to provide a xerographic plate and system having a dynamic range of about 1.2 or more to make it advantageous in producing quality halftone prints exhibiting a full range of tones by xerography.

It is a still further object of this invention to provide a xerographic plate and system exhibiting a variable dynamic range which can be broadened or narrowed as desired by controlling the spectral composition of the projected image.

It is a still further object of this invention to provide a xerographic plate and process especially suited for superimposing two separate images on one plate, and subsequently on one copy sheet.

The foregoing objects and others are accomplished in accordance with this invention by providing a xerographic plate and process, the plate comprising an electrically conductive backing and overlying said backing a photoconductive insulating layer having a multiplicity of a plurality of alternating discrete small areas of photoconductive insulating material, each of said pluralities of small areas having a different photosensitivity to a given exposure.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed disclosure of this invention taken in conjunction with the accompanying drawings wherein:

FIG. 1 shows a side view of three preferred xerographic plate embodiments according to the invention.

FIG. 2 is a graph of D_r , density of various image areas in the reproduction, v. D_o , density of various image areas in the original, for the two photoconductors used in a plate according to one embodiment of the invention and a graph of these two values for the resultant viewable, xerographic image produced.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1A, there is shown a preferred xerographic plate according to one embodiment 10 of this invention comprising electrically conductive substrate 12, screen 14 of a first photoconductive insulating material and an overlying layer of a second photoconductive insulating material 16. As will be described, the screen may also be laid on top of a layer of photoconductor as shown in FIG. 1B. For ease of understanding, the following description will be limited to a plate according to the invention which employs only a first and a second photoconductor, but three or more photoconductors may be used following the teachings hereof, although with more than two photoconductors, plate fabrication difficulties in order to minimize the halftone effect in the reproduction quickly become a limiting factor.

Electrically conductive substrate 12 is generally employed in the make up of xerographic plates in order to facilitate the charging or sensitization of the photoconductive insulating surface of the plate and to provide for the dissipation of electrical charge from those portions of the photoconductive surface which are rendered electrically conductive upon exposure to actinic radiation. Desirably this support member is also sufficiently strong to provide mechanical support for the remainder of the plate so as to make the plate suitable for use in xerographic copying machines. Thus, any suitable electrically conductive material may be used, which includes most metals. For example, aluminum is often used in commercially available xerographic plates. Of course, many non-metals are also electrically conductive including electrically conductive plastics, glasses such as Nesa glass available from the Pittsburgh Plate Glass Company, paper and so forth. In addition, although the xerographic imaging member is spoken of as a plate throughout this specification, the plate need not be a rigid planar member, but may consist of a web, foil or the like in the form of a cylindrical surface, endless belt, moebius strip or other shape. In addition, of course, the electrically conductive support may comprise two or more layers depending upon the desired characteristics of the total layer. For example, an electrically conductive transparent support 12 may be formulated by using a layer of Nesa glass available from the Pittsburgh Plate Glass Co. or a transparent electrically insulating film such as polyethylene terephthalate polyester film available under the trademark Mylar from the E. I. du Pont de Nemours & Co. overcoated with a transparent electrically conductive layer usually substantially thinner than the underlying Nesa or Mylar layer. For example, a thin

layer of copper iodide as more fully described in Lyon Pat. 2,756,165 may be used. Also thin, transparent and electrically conductive layers of tin oxide may be deposited on transparent substrates as more fully described in McMaster Pat. 2,429,420, Preston Pat. 2,769,778 and Haayman aPt. 2,772,190.

In FIG. 1C, there is shown another preferred embodiment of a xerographic plate 22 according to this invention comprising electrically conductive substrate 12 and alternating areas of a first photoconductor 18 and a second photoconductor 20.

A xerographic plate according to this invention comprising a photoconductive insulating portion having a multiplicity of a plurality of alternating discrete small areas of photoconductive insulating material having different sensitivities to a given common exposure may be fabricated in a number of preferred ways. One way is by depositing a screen pattern of a first photoconductive insulating material on an electrically conductive substrate and then overcoating the screen pattern and the interstices with a layer of a second photoconductive insulating material to give a free photoconductive surface of the second photoconductor. This type of plate 10 is shown in FIG. 1A. Or the screen pattern of a first photoconductor may be deposited on the free surface of a second photoconductor layer as shown in FIG. 1B. Alternatively, the second photoconductor may just fill the interstices between the screen pattern of the first photoconductor to produce a free photoconductive surface of flush, separate and distinct coplanar portions of first and second photoconductors. Generally, a smooth photoconductor surface is preferred in xerography in order to aid in the xerographic transfer and cleaning steps. This type of plate 10 is shown in FIG. 1C.

Other plate configurations and methods of fabrication are available and will occur to those skilled in the art upon a reading of this disclosure.

The screen pattern of the first photoconductive insulating material may be in the form of a dot pattern with round, elliptical, square, triangular, or any other regular or irregular dot shape or it may be in the form of a line pattern, or any other broken pattern whether regular, irregular, or random in shape and/or spacing. It should be noted that instead of making the pattern in the form of dots an outline of a dot pattern may be used. Thus, the screen may comprise an integral layer of photoconductive insulating material with a pattern of holes or voids through it. The percentage coverage of the screen pattern of the first photoconductor over the electrically conductive backing layer will vary depending upon the first and second photoconductors used, their photosensitivity difference, the amount of exposure, whether the screen pattern is sharp edged ("hard" in the language of the art) or "soft" and other factors.

The dimensions of the alternating areas of at least a first and second photoconductive insulating material can be varied over a rather wide range, although it is desirable to keep the maximum dimension of any particular discrete area not more than about 0.02 inch to insure more natural and higher quality halftone reproductions. Thus, while a coarse screen pattern of a photoconductor having 50 or 60 dots or lines or spacings of discrete areas to the lineal inch will be useful for some purposes, finer screens and spacings such as those having 100, 200, 300, or 400 or even more dots, lines or spacings to the lineal inch will give a more nearly continuous tone appearance to the finished print.

A description of how to chose materials when fabricating a plate according to the invention shall now be described in terms of a preferred embodiment wherein amorphous selenium is the less photosensitive or "slower" photoconductor used in the plate construction. This same procedure may be generally followed to choose first and second photoconductors to construct a plate according to this invention. "Sensitive," "sensitivity" and "photosensi-

tivity" as used herein, are intended to mean the rate of charge dissipation or lowering of surface potential of a xerographic plate when exposed to a given actinic radiation. As mentioned above, amorphous selenium plate xerographic systems generally have a dynamic range of about 0.6. This phenomenon may be shown graphically by reference to FIG. 2. Curve A is a graph of D_r v. D_o for a typical amorphous selenium xerographic plate in a conventional xerographic imaging system. The plate has been sufficiently exposed to just substantially completely discharge areas of the plate corresponding to $D_o=0$ areas of the original. Little or no marking material will be attracted to these areas in the xerographic development step, thus, D_r in these areas will be about 0. This amount of exposure is shown graphically by the start of curve A from point b , which is also the origin of axis D_o and D_r . It is seen that at about $D_o=0.6$ the plate will make a reproduction with corresponding areas of the reproduction at about $D_r=1.3$ and that all D_o greater than about 0.6 will show up on the reproduction as a $D_r=1.3$, which is chosen illustratively as a typical maximum density value for a fully toned xerographic image portion. To say that a particular imaging plate and system has a dynamic range of about 0.6 is also to say, as known by those skilled in the art, that system is photosensitive to an exposure difference latitude of about four (4) times, because when the dynamic range is substituted for D in the formula $D=\log 1/R$, $R=\text{about } 1/4$. In other words, if it takes 4 units of exposure, where of course exposure equals brightness times time, to substantially completely discharge the plate (represented graphically by point b on curve A) then one unit of exposure will be the threshold point of exposure (represented graphically by point a on curve A) where the amorphous selenium plate will just begin to start to lose sufficient charge upon exposure to actinic radiation, to cause a perceptible reduction in D_r . It is generally preferred in constructing plates according to this invention to provide for a second photoconductor, the D_r v. D_o curve of which (curve B in FIG. 2) relates to curve A so that point d of curve B is about on the same vertical axis as point a of curve A which simply means that where the tonal response of the amorphous selenium or other first slower photoconductor stops, the tonal response of the faster photoconductor corresponding to curve B begins, so that there is no increment of tones in the original in the region of $D=0.6$ which will not reproduce as tonal differences in the reproduction. As will be discussed, this relationship of the two photoconductors is more preferred for "hard" screen patterns than for "soft" patterns. Of course, a plate according to this invention may be suitable even if it is incapable of producing tones in a certain D_o range if originals to be reproduced are low in tones in that increment.

To provide for this registration of points a and d for a first, slower photoconductor corresponding to curve A or for any other slower photoconductor of dynamic range of about 0.6 to be used in a plate according to this invention, as the photoconductor to reproduce the lower D_o region, the second photoconductor should be about four times more sensitive than said first photoconductor. Of course, many photoconductors faster than amorphous selenium are available in the art and may be used herein and varied in their composition to provide for a photoconductor photosensitivity of about four times faster than the amorphous selenium portions of said plate. Generally, most of the photoconductors known to be faster than amorphous selenium are faster because they respond to a greater spectral range of visible light, while amorphous selenium is relatively insensitive to light of wavelength beyond about 5,500 angstrom units. As will be further explained in the examples, preferred more sensitive photoconductive materials, when used with less sensitive amorphous selenium, include selenium alloyed with tellurium, selenium alloyed with arsenic, and phthalocyanine, all of which are substantially more sensitive than amorphous

selenium to the red and near infra red region of the spectrum. A more detailed disclosure of such selenium alloys may be found in Ullrich Pat. 2,803,542; Mayer et al. Pat. 2,822,300; Mengali Pat. 2,745,327 and Paris Pat. 2,803,541. Phthalocyanine binder systems are described in more detail in copending application Ser. No. 375,191, filed June 15, 1964, now abandoned.

Of course, amorphous selenium may be used as the more sensitive photoconductor in a plate according to the invention, but then the slower or less sensitive photoconductor should preferably be about $\frac{1}{4}$ as fast which overall, produces a plate which is about $\frac{1}{4}$ as sensitive as a plate where amorphous selenium is used as the slower photoconductor. Since a variety of photoconductors faster than selenium are available, and since generally it is preferred to fabricate the more sensitive plate in order to use lower magnitude exposures, it will generally be preferred, other factors being equal, to employ amorphous selenium, if it is being used as one of the photoconductors according to this invention, as the slower or less sensitive photoconductor.

In general then, in accordance with the teaching hereof, in a plate with a first and a second photoconductor, the faster or more sensitive photoconductor preferably should be about X times faster than the slower photoconductor where X = the antilogarithm of the dynamic range of the slower photoconductor. Or the slower photoconductor should preferably be $1/X$ as fast as the faster photoconductor where X = the antilogarithm of the dynamic range of the faster photoconductor.

In connection with this description on how to choose the two photoconductors to construct a plate according to the invention, it was stated that it is preferable that point a of curve A and point d of curve B coincide on the vertical axis which is especially true for a first photoconductor layed down in a hard screen as illustrated by FIG. 1B. This characteristic of the invention is not nearly as applicable in a situation where a charge injection first photoconductor 14 is deposited in a soft dot screen pattern as illustrated in FIGS. 1A and 1B, since the rate of emission of charged particles from a portion of the screen pattern is generally dependent, at least in a certain thickness range, on the thickness of the screen or dot, and since in a soft screen pattern, the screen portions vary in thickness gradually from points of maximum thickness to points of no deposition or no thickness there is a gradual rather than an abrupt, as in a hard dot pattern, variation in the charge dissipating effect of the screen pattern, thereby providing a mechanism to produce at least some variation in D_r in any D_0 gap between points a and d on curves A and B respectively.

Another important aspect of the invention is the percentage of the whole plate to be taken up by the first and by the second photoconductor. Again referring to a preferred plate embodiment according to this invention where amorphous selenium is the "slower" photoconductor and its D_r v. D_0 curve corresponds approximately to curve A in FIG. 2 and where the faster photoconductor is about four times faster than the selenium and thus corresponds approximately to curve B of FIG. 2, and taking a period area of this plate encompassing one typical area of amorphous selenium and the typical adjacent area of the second photoconductor, it is seen that this period area must be capable, due to the contribution of the slower amorphous selenium portion, to reproduce highlights up to a D_0 of about 0.6. To substantially faithfully reproduce D_0 of 0.6, in a xerographic system illustrated by FIG. 2 wherein the maximum density of fully toned selenium areas is illustratively about 1.3, which occurs at 0.6 and greater D_0 , the question becomes what percentage of the total period area must be the maximum density of 1.3 to give a period area density of about 0.6? Theoretically, assuming that the maximum density area of about $D=1.3$ is totally light absorbing and the white area totally light reflecting, then for a density of 0.6, $R=\frac{1}{4}$ which indi-

cates that $\frac{1}{4}$ or 25% of the period area should be untoned corresponding to the faster photoconductor portion of the period area and 75% of the period area should be densely toned corresponding to the amorphous selenium photoconductor portion of the period area. This requirement is satisfied if the screen pattern of the faster photoconductor covers about 25% of the area of the conductive backing with the amorphous selenium covering about the remaining 75%.

In practice, however, since the dense fully toned areas are not totally absorbing but are of a D of about 1.3, or about 5% reflecting, slightly more than 75% of the period area, about 80%, must be taken by the slower amorphous selenium photoconductor to give a total period D_r of about 0.6. On the other hand, depending upon the paper to which the toner image is transferred, when 75% of the surface is covered by a light absorbing pigment or dye, the remaining 25% is actually less bright, because some of its brightness is due to light scattering from adjacent areas. It is found generally, that providing a screen pattern percentage coverage of the faster photoconductor anywhere from about Y to $\frac{1}{2}Y$, where $Y=1/\text{the antilogarithm of the dynamic range of the slower photoconductor} \times 100$, is preferred. For the selenium example above described, Y , of course, $=\frac{1}{4} \times 100=25\%$, and the preferred range of percentage coverage of the conductive backing by the screen pattern of the faster photoconductor is thus between about 20%–25%. Conversely, where the screen is of the slower photoconductor, a screen pattern coverage of from about $100-(Y \text{ to } \frac{1}{2}Y)$ is preferred.

Referring once again to FIG. 2 and curve C therein, curve C is the approximate graphical representation of the visual tonal effect of a reproduction from an original containing tones from $D_0=0$ to $D_0=1.3$ with a plate according to the preferred embodiment described herein with selenium as the slower photoconductor. It is seen that this plate constructed according to the invention and processed by conventional xerography has an extended dynamic range of 1.3.

One reason why the two photoconductors of the plates hereof should comprise a certain preferred percentage of the total photoconductive insulating layer is that in reference to FIG. 2 and the preferred plate represented thereby, it is seen that curve C shows that at $D_0=0.6$ there is substantially faithful reproduction in the xerographic print and again at $D_0=1.3$. If the faster photoconductor constitutes more of the plate than described to be preferred herein, then at $D_0=0.6$, D_r will be some lesser value because there would be insufficient fully toned areas of the slower photoconductor to give the $D_r=0.6$ visible effect. In addition, the maximum visible density 1.3 will be diminished by a corresponding amount. If the faster photoconductor constitutes less of the plate than the preferred percentage range, then at $D_0=0.6$, D_r will be some greater value and the maximum density will increase a corresponding amount, assuming the particular imaging system is otherwise capable of producing this increased amount. Thus, it is seen that the faithfulness of the reproduction suffers when the preferred percentage range specified herein is substantially varied from.

Referring now to the processing steps of xerography to be carried out with respect to the plates hereof, to produce prints exhibiting fine tonal response, generally the first xerographic processing step is to form a latent electrostatic image on said plate. One method of forming the latent image is to uniformly charge the plate and selectively dissipate charge in light struck areas during an image exposure. Plates may be charged in a wide variety of ways including vigorously rubbing the plate surface with a softened material such as a cotton or silk handkerchief or a soft brush or fur chosen to impart charge of the desired polarity, induction charging, for example, as described in Walkup Pat. 2,934,649, roll charging as described in Straugham, Mayer, Proc. Nat. Electronics Conf. 13, 959, 962 (1958), depositing charge from a corona dis-

charge device and other techniques. Charging by corona discharge devices, which generally can apply either positive or negative charge of varying potentials and which may be adapted for many applications, is found to be a preferred charging mechanism for use herein. For example, corona discharge devices of the general description and generally operated as disclosed in Vyverberg Pat. 2,836,725 and Walkup Pat. 2,777,957, have been found to be excellent sources of corona useful in the charging of xerographic plates.

Other methods of forming a latent image on plates according to the invention are known in the art and include first forming such a charge pattern on a separate photoconductive insulating layer according to conventional xerographic reproduction techniques and then transferring this charge pattern to the plate by bringing the two layers into very close proximating and utilizing breakdown techniques as described, for example, in U.S. Pats. 2,982,647 to Carlson and 2,825,814 and 2,937,943 to Walkup. In addition, charge patterns conforming to selected, shaped, electrodes or combinations of electrodes may be formed on the photoconductive surface of the plate by the "TEST" discharge technique as more fully described in U.S. Pats. 3,023,731 and 2,919,967 both to Schwertz, or by techniques described by U.S. Pats. 3,001,848 and 3,001,849 both to Walkup, as well as by electron beam recording techniques, as described in Glenn Pat. 3,113,179.

Preferably, a xerographic plate should be charged when it is at its highest insulating value or when there is an absence of electromagnetic radiation that would make the photoconductive insulating layer photoelectrically conductive. To allow the charge to remain on the surface of the layer once deposited there, charging must, of course, take place in the absence of that wavelength radiation or light to which the particular photoconductive material is sensitive.

After formation of the latent electrostatic image on the surface of the novel xerographic plate of this invention, the image is rendered visible by development techniques. Although a wide range of such techniques may be used, the dynamic range of the component photoconductors and of the plates of this invention may be found to vary somewhat, depending on the particular development process used.

Generally, the latent electrostatic image is rendered visible or developed by contacting the latent image areas with a finely divided marking material that is brought into surface contact with the free surface of the photoconductor or photoconductors and is held thereon electrostatically in a pattern corresponding to the electrostatic latent image. For example, the system of cascade development has found extensive commercial acceptance and is suitable herein and generally consists of gravitationally flowing developer material consisting of a two component material of the type disclosed in Walkup et al. Pat. 2,638,416 over the xerographic plate bearing the latent image. The two components consist of an electroscopic powder termed "toner" and a granular material called "carrier" and which by mixing, acquire triboelectric charges of opposite polarity. In development, the toner component, usually oppositely charged to the latent image, is deposited on the latent electrostatic image to render that image visible. Other typical developing systems include magnetic brush development, for example see Giamo Pat. 2,930,351; skid development, for example see Mayo Pat. 2,895,847; fluid development systems, for example see Carlson Pats. 2,221,776, 2,551,582, 2,690,394, 2,761,416, 2,928,575; Thompson Pat. 3,064,622; Gundlach Pats. 3,068,115 and 3,084,043 and Metcalfe Pats. 2,907,674, 3,001,888, 3,032,432 and 3,078,231 and other development processes known to those skilled in the art.

In order to enhance solid area development, development electrode techniques as described in Carlson Pats. 2,690,394 and 3,147,147 or Gundlach Pat. 2,777,418, may

be used, as well as other techniques as described in Des-sauer and Clark, "Xerography," Focal Press, page 276 (1965).

As will be apparent from the examples which follow, another important advantage of certain of the embodiments hereof is that the exposure may be accomplished from either side of certain plate embodiments hereof, depending upon which type of exposure may be more expedient in certain situations of actual machine operation.

The following examples further specifically define the present invention with respect to a xerographic plate and system according to the invention, with an extended dynamic range. The parts and percentages are by weight unless otherwise indicated. The examples below are intended to illustrate various preferred embodiments of the extended dynamic range xerographic plate configuration of this invention.

Example I

A Lektromesh grid available from C. O. Jelliff Mfg. Co. and comprising holes about 5 mils square, spaced about 10 mils between centers in a rectilinear array, so that about 25% of its area is open, is placed on an electrically conductive substrate of transparent Nesa glass.

A mixture of about 82½% amorphous selenium, about 17½% arsenic and about 0.1% iodine is then vacuum evaporated onto and through the screen to form about a 0.2 micron thick pattern of photoconductor deposit on the Nesa substrate corresponding to the interstices of the grid.

The grid is removed and about a 20 micron layer of amorphous selenium is then vacuum evaporated over the screen pattern of arsenic-selenium by the method described in Bixby et al. Pat. 2,753,278.

The xerographic plate thus formed is then xerographically processed by charging, exposing and developing. The plate is uniformly charged positively by a corona discharge device available commercially as a part of the Model D Processor available from Xerox Corporation, to a substantially uniform surface potential of about +800 volts and removed from the Processor in the absence of actinic radiation.

The sensitized plate is then put in a camera and exposed from the substrate side to a photographic original which contains highlights where D_0 approaches zero, dense image areas where D_0 is about 1.2 or more and varying in between tones.

The radiation source is an incandescent photoflood lamp, and exposure at the back surface of the plate is about 1.5 f.c.s. The latent electrostatic image is then developed by cascade development and transferred to a sheet of paper to yield a high quality halftone reproduction with excellent tonal response, i.e. a dynamic range of from about 0 to about 1.4.

This extended dynamic range results from the amorphous selenium portions providing for tonal response in the D_0 region from about 0 to 0.6 to reproduce highlights in the original, and the arsenic-selenium portions being about four times more photosensitive than the amorphous selenium portions alone providing for tonal response in the D_0 region of from about 0.6 to 1.4 to reproduce shadow tones and the denser portions of the original. Areas of the reproduction where D_r is about 0, result because the exposure being sufficient to substantially completely discharge selenium areas of the plate, is also sufficient to substantially completely discharge selenium overcoated screen portions of the more sensitive photoconductor arsenic-selenium.

Generally, where an arsenic-selenium mixture is used as the screen pattern of the more photosensitive photoconductor, as in this example, it is preferred to keep the maximum thickness of the screen portions less than about 0.2 microns, since it is found that the electron and hole range of this material is relatively short, so that charge injection into the amorphous selenium from the arsenic-

selenium screen pattern diminishes at greater thicknesses requiring increasingly greater exposures to maintain the screen's hole or electron injection capability. From this preferred maximum thickness, the hole or electron injecting capability of the screen may be thought of as roughly declining linearly with the thickness.

Where amorphous selenium is used as the overcoating photoconductor, as in this example, a layer thickness not less than about 20 microns is preferred. For thicknesses less than about 20 micron, the selenium's capacity to accept and hold a high surface charge potential preferred for quality xerographic prints, begins to drop.

Negative, instead of positive, charging of the extended dynamic range plate of this example also produces good prints, but the plate's dark discharge is found to be somewhat greater, which makes positive charging preferred.

When negative charging is used, holes migrate from the arsenic-selenium screen to discharge charge and lower surface charge potential at the surface of the amorphous selenium layer.

Similar procedures may be followed to produce a plate employing selenium alloyed with tellurium as the faster photoconductor.

Example II

Example I is followed except that

- (a) the electrically conductive substrate is about 50 mil thick aluminum,
- (b) the overcoating layer of selenium is deposited to a thickness of about 75 microns; and,
- (c) the resultant plate is exposed after charging from the top, i.e. from the amorphous selenium side, and exposure at the free surface of amorphous selenium is about 1.5 foot candle-seconds.

It is found that top exposure to the radiation source of Example I and any other source having a substantial output in the longer wavelength infrared region of the spectrum, works well for this embodiment and as will be shown, other embodiments hereof employing red and near infrared sensitive photoconductors such as arsenic-selenium and phthalocyanine binder systems.

Exposure from the top is possible in the embodiment of this example because amorphous selenium layers are substantially transparent to radiation in the red and near infrared region of the spectrum, thus transmitting this portion of the incident radiation to the red and near infrared sensitive screen of arsenic-selenium. An amorphous selenium layer thickness of not greater than about 75 microns is preferred in the embodiment of this example, since it is found that for greater thicknesses the layer begins to substantially block out some of the incident red and near infrared radiation.

The amorphous selenium layer is substantially more opaque to the blue, green and ultraviolet region of the spectrum, which renders the selenium layer more electrically conductive, thus discharging the selenium in proportion to the intensity of this radiation incident thereto.

Example III

Polyvinyl carbazole available under the trademark Luvican M170 from Winter, Wolff & Co. is mixed with 5%, dry weight, of the Lewis acid 2,4,7-trinitrofluorenone in enough solvent to give good coating viscosity. The sensitized polyvinyl carbazole is coated with a Bird applicator onto a sheet of about 50 mil thick aluminum and dried to a thickness of about 10 microns.

A 20% solution of a 1 to 1 mixture is prepared of 2,5-bis (p-aminophenyl)-1,3,4-oxadiazole available under the trademark TO 1920 from Kalle & Co., Weisbaden-Biebrich, Germany and a resinous binder material Vinylite VYNS, a copolymer of vinyl chloride and vinyl acetate available from Union Carbide Corp. in a 1 to 2 mixture of cyclohexanone and 3-pentanone. Enough X-form metal-free phthalocyanine made as described in copending application Ser. No. 505,723, filed Oct. 29, 1965, now

U.S. Pat. No. 3,357,989, is added to the mixture to give about 17% phthalocyanine when the final mixture is dried.

A grid of the type used in Example I is placed on the free surface of the polyvinyl carbazole layer.

The mixture is sprayed onto the screen to coat the polyvinyl carbazole layer in screen interstitial areas to a dried thickness of about 2 microns.

The grid is removed.

The xerographic plate thus formed is then xerographically processed by charging, exposing and developing. The plate is uniformly charged positively by a corona discharge device available commercially as a part of the Model D Processor available from Xerox Corporation, to a substantially uniform surface potential of about +600 volts and removed from the Processor in the absence of actinic radiation.

The sensitized plate is then put in a camera and exposed from the photoconductor side to a photographic original which contains highlights where D_0 approaches zero, dense image areas where D_0 is about 1.2 or more and varying inbetween tones.

The radiation source is an incandescent photoflood lamp and exposure is about 1.5 f.c.s. The latent electrostatic image is then developed by cascade development in the presence of a development electrode biased positively to about 175 volts. The toner image is transferred to a sheet of paper to yield a high quality halftone reproduction with excellent tonal response, i.e. a dynamic range of from about 0 to about 1.4.

Example IV

A Lektromesh grid of the type used in Example I is placed on about 50 mil thick brass.

A phthalocyanine pigment organic binder photoconductor about 4 times more photosensitive than selenium, for the particular light source used in this example, is prepared as in Example III.

This mixture is then deposited on the brass through the interstices of the grid by spraying, the deposits drying to a thickness of about $2\frac{1}{2}$ microns.

The grid is removed and about a 20 micron layer of amorphous selenium is then vacuum evaporated over the screen pattern of the phthalocyanine binder photoconductor.

The xerographic plate thus formed is then xerographically processed as in Example II to yield a high quality halftone reproduction with a dynamic range of from about 0 to about 1.4.

It should be appreciated that in all the foregoing examples, the exposure source was the same and that if the radiation source is changed to provide a radiation source with a different spectral curve and specifically more or less output in the infrared range, then the makeup of the two photoconductors used in plate fabrication in the examples can be changed to make the more sensitive photoconductor if that photoconductor is amorphous selenium, or to otherwise assure, for example by using a soft dot pattern, that there is no increment of D_0 , between the dynamic range curves of the two photoconductors, which is not tonally reproduced.

Alternatively, the plate may remain the same, but spectral input may be varied to obtain the preferred dynamic range, narrow, intermediate or broad, for a particular copying situation.

The system hereof may be advantageously used for superimposing two separate images on one copy sheet. For example, one might wish to copy a business form and variable information from another source, both onto a single document. If both original images exist as negatives (white characters on black background) sequential or even simultaneous exposure of the two images onto a conventional prior art xerographic photoreceptor yields a single high contrast image. However, double exposure of two positive images seriously reduces image contrast.

By using the extended range plates hereof in which a given color light can discharge (or desensitize) the plate by no more than about 50%, and a second color can discharge the next 50%, two images can be combined into a single final document with good contrast.

This is uniquely superior to charging a conventional plate to, for example 1000 volts, exposing to one image until background areas are reduced to 500 volts, then exposing to a second image for maximum contrast. Only if the discharge curve were a straight line (constant slope), would this second exposure not reduce the contrast of the first image.

Although specific components and proportions have been stated in the above description of preferred embodiments of the extended dynamic range plate of this invention, it should be appreciated that although it has been found to be preferred herein to use an infrared sensitive photoconductor as the more sensitive photoconductor when used, optimally, in combination with less sensitive amorphous selenium, which is a convenient mechanism of providing two photoconductors of different sensitivity because of the peculiar spectral response characteristics of amorphous selenium, any convenient method of appropriately varying the photosensitivities and thus providing for a photoconductor layer with a multiplicity of at least two alternating areas of different photosensitivity as described herein, may be used.

In addition, other materials may be used in plate construction to synergize, enhance or otherwise modify the plate's properties. For example, dark decay in xerographic plates may be lessened by the interposition of a thin insulating layer known in the art as a "barrier" layer, at the interface of the electrically conductive backing and the photoconductive insulating materials. The effect of such thin insulating interfaces in xerographic plates is more fully described in Dessauer et al., Pat. 2,901,348.

It will be understood that various other changes in the details, materials, steps and arrangements of components, which have been herein described and illustrated in order to explain the nature of the invention, will occur to and may be made by those skilled in the art upon a reading of this disclosure and such changes are intended to be included within the principle and scope of this invention.

What is claimed is:

1. An imaging process comprising providing a xerographic plate having an electrically

conductive backing overcoated with a multiplicity of alternating discrete areas of at least first and second photoconductive insulating material having different photosensitivities to a given exposure such that the photosensitively slower material has a dynamic range that ends at about where the dynamic range of the photosensitively faster material begins,

uniformly charging said plate,

exposing said charged plate to at least first and second image patterns of light with said first pattern of light capable of substantially completely discharging said first material without substantially discharging said second material and said second pattern of light capable of substantially completely discharging said second material without substantially discharging said first material,

said first image pattern of light being formed by steps including directing light of wavelengths from a first spectral region onto a first positive original and

said second image pattern of light being formed by steps including directing light of wavelengths from a second spectral region substantially different from said first spectral region onto a second positive original, developing the latent electrostatic image resulting from the exposure of the charged plate to the light with electroscopic marking material to form a visible marking material image.

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