United States Patent [19]

Marks

[11] **3,912,510**

[45] **Oct. 14, 1975**

[54] **ELECTROPHOTOGRAPHIC PROCESS EMPLOYING A COMPOUND DOCUMENT SCREEN**

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[52] **U.S. Cl.** ..... **96/1 R;** 96/1 PE; 96/1 M; 96/1 PS; 96/1.2

[51] **Int. Cl.²** **G03G 13/04**

[58] **Field of Search** ..... 96/1 R, 1.2, 45, 116, 1 M, 96/1 PE, 1 PS

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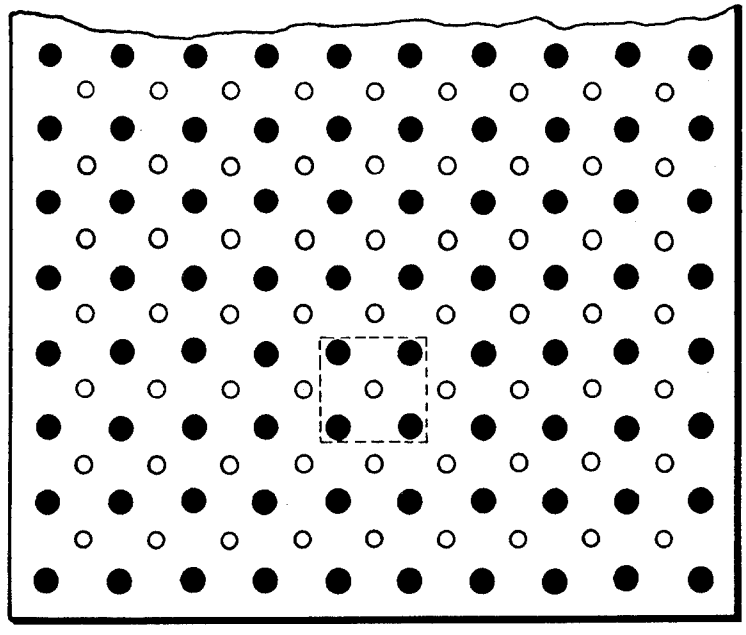
[57] **ABSTRACT**

The present invention is directed toward an electrophotographic imaging process and a method for extending the range capabilities of said process. The process includes providing a compound document screen adapted to be used at the exposure station proximate to the image face of a document to be copied, such that light reflected from the screened document is passed through a lens system and imaged onto a photosensitive member. The document screen consists of a clear transparent base member having a mixed dot pattern of substantially light absorbing dots and substantially light reflecting dots. The frequency of the like dots is such that the lens system employed in the electrophotographic process passes the fundamental spatial frequencies reflected from the screened original but attenuates the harmonic spatial frequencies. The developed image is found to consist of a plurality of halftone dots of varying sizes, the dot sizes varying in accordance with the screened output density reflected from the original document.

10 Claims, 4 Drawing Figures



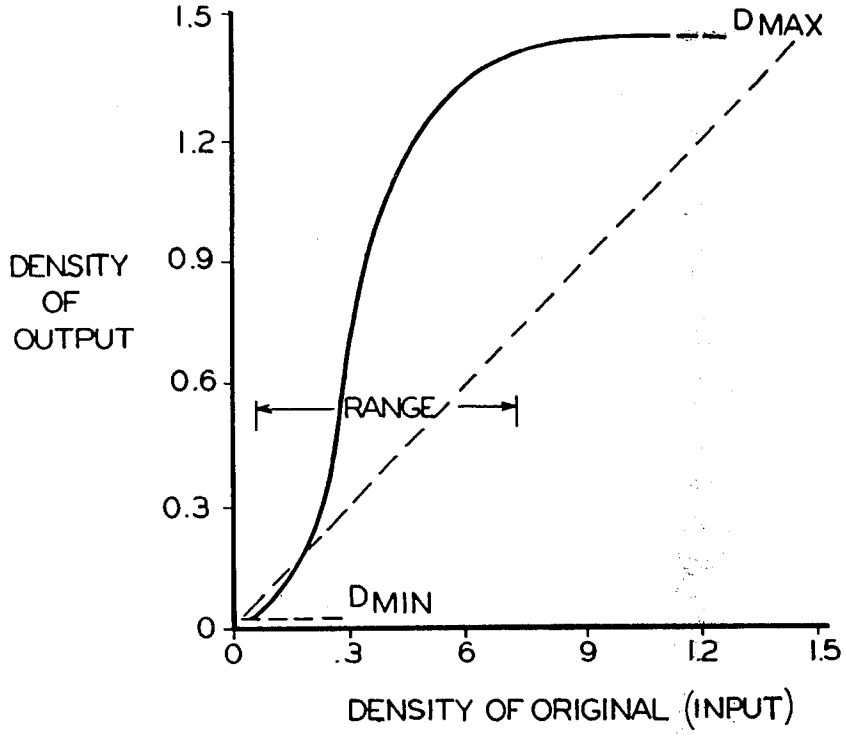

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FIG. 1

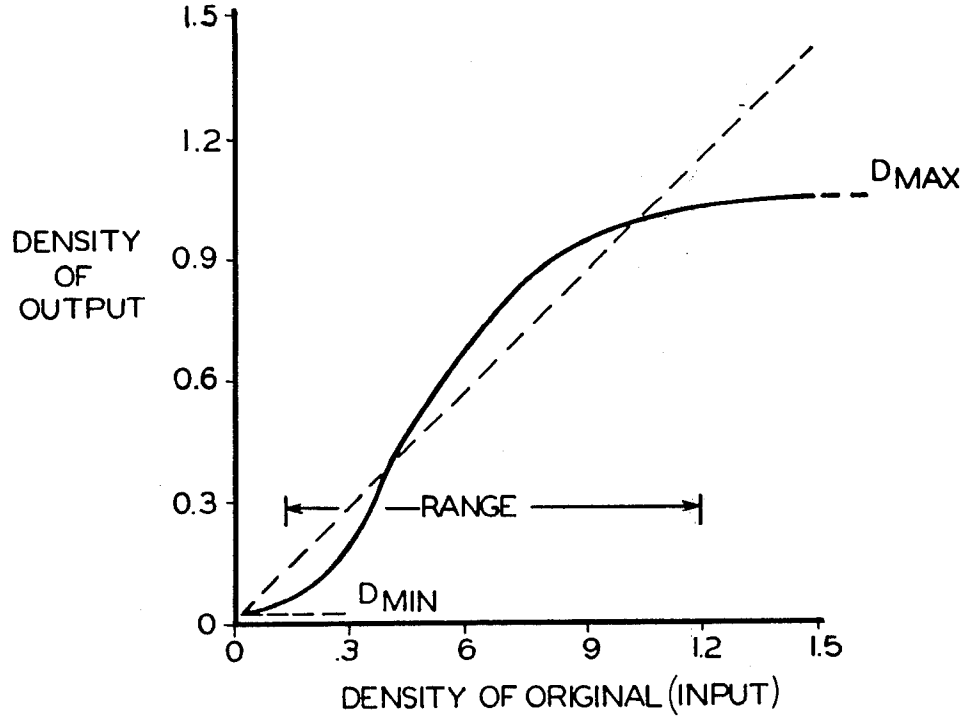
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FIG. 2

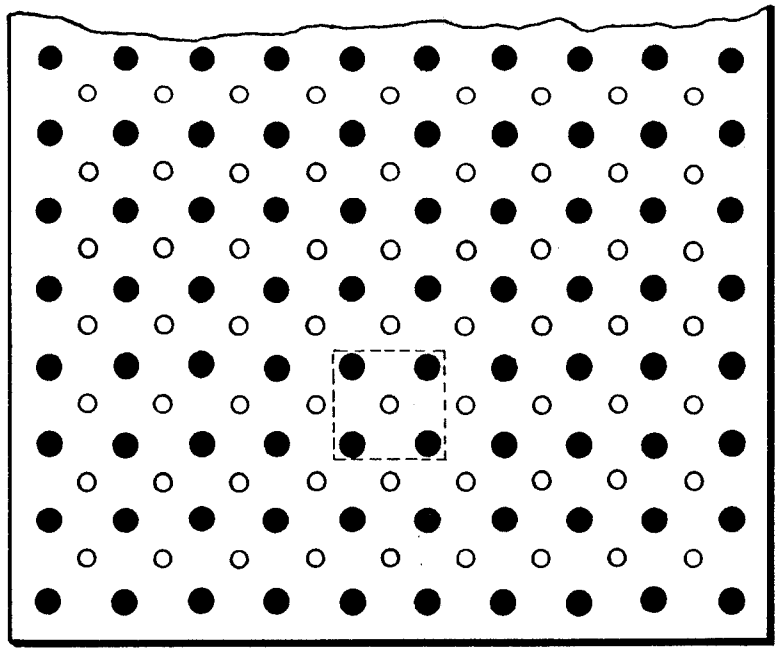

FIG. 3

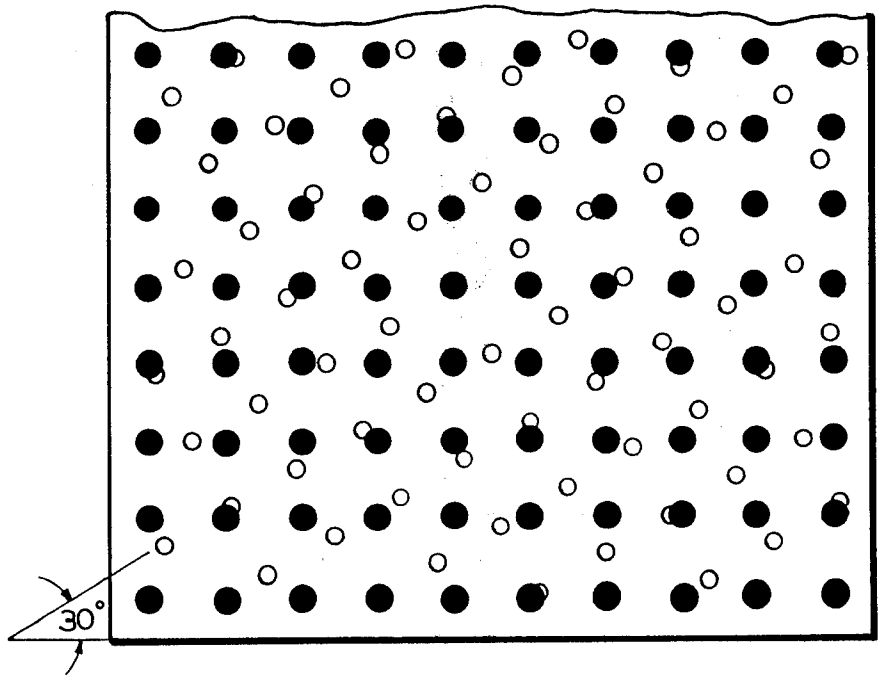

FIG. 4

ELECTROPHOTOGRAPHIC ELEMENT COMPRISING AN ORGANIC PHOTOCONDUCTIVE LAYER SENSITIZED LOCALLY AT ITS SURFACE

This is a continuation, of application Ser. No. 185,657, filed Oct. 1, 1971, now abandoned.

This invention relates to an electrophotographic element comprising organic materials, and more particularly to a novel electrophotographic element having a high sensitivity to visible light.

In electrophotography, an electrostatic latent image is formed by exposing a uniformly charged photoconductive layer to a light through or reflected from an original document. Said electrostatic latent image is developed by using a toner directly on the photoconductive layer or after being transferred to a dielectric layer, or is changed to a frost image by heating.

Selenium and zinc oxide are well known as inorganic photoconductive materials useful for electrophotography. Recently, much attention has been paid to organic photoconductive materials because of their excellent characteristics such as transparency, light weight, flexibility, and flat surface. However, the electrophotographic sensitivity of organic photoconductive materials is usually much lower than that of evaporated selenium photoconductive layer. The organic electrophotographic element having sensitizers distributed uniformly therein generally has a considerable residue potential in photo-decay process.

It is an object of this invention to provide an electrophotographic element having a high sensitivity to a visible light.

It is another object of this invention to provide a high sensitive electrophotographic element which is transparent and flexible.

It is still another object of this invention to provide an electrophotographic element which shows little residue potential in the photo-decay process.

Details of this invention becomes apparent upon consideration of the following description taken together with the accompanying drawings in which:

FIG. 1 shows a section through an electrophotographic element according to this invention.

FIG. 2 shows sensitivity curves for a conventional electrophotographic element and a novel electrophotographic element of this invention.

It has been discovered according to this invention that an electrophotographic element including a conductive support and an organic photoconductive layer comprising a polymer and an organic sensitizer, said organic sensitizer being distributed locally at the top layer of said organic photoconductive layer shows a high sensitivity to a visible light.

Referring to FIG. 1, a conductive support **1** supports an organic photoconductive layer **2** having a sensitizer distributed locally at the top layer **3** thereof. A layer **4** below said top layer **3** is named as a plain layer for convenience.

The conductive support **1** may comprise any suitable conductive support. For example, a flexible film having a cuprous iodide layer or an evaporated conductive metal layer thereon can be used when flexibility and/or transparency is required. And further, a tin oxide-coated conducting glass or metal plate can be used when flexibility and/or transparency is not required.

The organic photoconductive layer **2** comprises at least one polymer selected from poly-N-vinylcarbazole, poly-N-alkenylcarbazole, and nuclear-substituted poly-N-vinylcarbazole, in accordance with the present invention. Addition of a plasticizer and polycarbonate into the organic photoconductive layer **2** is effective to improve mechanical properties of the layer **2.** The plasticizer comprises chlorinated diphenyl, epoxy resin, chlorinated fatty acid ester, phthalic acid ester, or mixtures thereof. The amount of the plasticizer is less than 80 weight parts, preferably 20 to 40 weight parts relative to 100 weight parts of the polymer. Polycarbonate has the effect of improving the mechanical properties of the poly-N-vinylcarbazole, or nuclear-substituted poly-N-vinylcarbazole layer without reducing the transparency. The amount of polycarbonate to be added is less than 60 weight parts, preferably 10 to 40 weight parts relative to 100 weight parts of the polymer.

The organic photoconductive layer **2** has a thickness of 3 to 30 microns, preferably 5 to 20 microns. The top layer **3** having organic sensitizers distributed locally therein has a thickness of 0.1 to 1 micron, preferable 0.3 to 0.6 micron. The organic photoconductive layer **2** comprises 0.1 to 10 weight parts, preferably 0.4 to 2 weight parts of an organic sensitizer in the top layer **3** and 100 weight parts of a polymer.

The organic sensitizer comprises pyrylium salts described in U.S. Pat. No. 3,250,615, thiapyrylium salts described in U.S. Pat. No. 3,250,615, carbonium salts described in U.S. Pat. No. 3,575,698, benzopyrylium salts described in U.S. Pat. No. 3,526,502, benzopyrylium salt derivatives described in U.S. Pat. application 4200 filed Jan. 20, 1970, or mixtures thereof.

Among the many sensitizers described above, the more preferable are a reaction product of 2-(p-methoxystyryl)-3-phenylbenzopyrylium perchlorate and 2-(p-mehtoxystyryl)-3-phenyl-4-methoxypyrane, 2-[(2′-α-phenyl-p-methoxystyryl-4′-benzopyranylidene)methyl]-3-phenylbenzopyrylium perchlorate, and 2-(p-methoxystyryl)-3-phenylbenzopyrylium perchlorate. They produce a top layer **3** having spectral response more matched with a tungsten lamp and a high sensitivity. The reaction product of 2-(p-methoxystyryl)-3-phenylbenzopyrylium perchlorate and 2-(p-methoxystyryl)-3-phenyl-4-methoxypyrane is obtained from the reaction of these in hot 1,2-dichloroethane solution described in U.S. Pat. application 4200 filed Jan. 20, 1970, and the chemical structure of the reaction product has not been identified.

Any suitable method for making this organic photoconductive layer can be used. One method is as follows: A solution including aforesaid polymer in any solvent such as toluene, chlorobenzene, or dioxane is applied to any suitable conductive support by any suitable and available method such as knife, blade, or reverse-roll coating method and is dried at a temperature of 40° to 100°C for a time of more than 5 minutes to form a plain layer in a desired thickness. If necessary, the solution may further include a plasticizer and polycarbonate to improve mechanical properties of the plain layer. Another solution including aforesaid sensitizer and one monomer such as N-vinylcarbazole, N-alkenylcarbazole, or nuclear-substituted N-vinylcarbazole in a solvent inert to the plain layer is applied to the plain layer by any suitable method such as whirler, blade, or kiss coating method and is cured by heating at a temperature of 80° to 160°C for a time of more than 5 minutes to form a top layer having the sen-

sitizer destributed locally therein. It is necessary that the monomer corresponds to the material in the plain layer. In other words, when the plain layer includes poly-N-vinylcarbazole, the operable monomer is N-vinylcarbazole. After being cured, the monomer is changed to a polymer at the top layer. Thus, the top layer is well combined with the plain layer and forms a photoconductive layer according to the present invention. If necessary, said solution may further include a plasticizer and polycarbonate to improve mechanical properties of resultant photoconductive layer. A preferable solvent for use in another solution is alcohol such as methanol or ethanol, or ketone such as acetone or methylethylketone, or buthylacetate.

Another method is to deposite a sensitizer at the surface of the plain layer. A plain layer is first prepared by a method similar to that mentioned above and then is coated with aforesaid organic sensitizer by, for example, vacuum evaporation. The coating can be also achieved by applying a solution including aforesaid sensitizer in a solvent such as alcohol or ketone to the plain layer and by drying. The plain layer coated with the sensitizer is exposed to vapor such as that of toluene, chlorobenzene, or dioxane to dissolve both the sensitizer and the plain layer. The vapor controlled in density and exposure time dissolves the sensitizer and only a surface layer of the plain layer and forms a photoconductive layer having the sensitizer distributed locally at the top layer thereof in accordance with the present invention.

A further method is to use a discolored sensitizer in a solution. The discolored sensitizer can be obtained by treating aforesaid sensitizer with a reducing agent such as hydrogen or carbon monoxide and has no sensitizing action. The solution including the discolored sensitizer and aforesaid polymer such as poly-N-vinylcarbazole, poly-N-alkenylcarbazole, or nuclear-substituted poly-N-vinylcorbazole, if necessary, a plasticizer and polycarbonate in a solvent is applied to a conductive support by any suitable method and is dried. The dried material has the discolored sensitizer distributed uniformly therein and forms a photoconductive layer according to the present invention when treated, at the surface, with an oxidizing agent such as oxygen. The oxidizing agent causes the discolored sensitizer to recolor and to recover the sensitizing action. The thickness of the top layer having recovered sensitizer distributed therein is controlled by the treatment time and temperature.

In a conventional organic electrophotographic element, an organic photoconductive layer supported on a conductive support has organic sensitizers distributed uniformly therein. Even when the same polymer for example, poly-N-vinylcarbazole and the same organic sensitizer, for example, the benzopyrylium salt derivative, are used, the novel electrophotographic element has a higher sensitivity to visible light than that of the conventional organic electrophotographic element. The reason for the difference in the sensitivity between the novel electrophotographic element according to the present invention and the conventional electrophotographic element is not certain. A possible explanation is as follows: In the conventional electrophotographic element, the sensitizer distributed uniformly in the organic photoconductive layer acts as a trap to catch photocarriers. On the other hand, the sensitizer distributed locally at the top layer as shown in FIG. 1 has no bad effect on the movement of photo-carriers in the organic photoconductive layer beneath the top layer. In the element of this invention, photo-carriers generated at the top layer of the element with the help of sensitizers may drift to the conductive support without being trapped. Thus, when the element of this invention is charged to a positive potential and then is exposed to a visible light, the surface potential of the element dissipates rapidly and shows little residual potential. A conventional electrophotographic process for forming an electrostatic latent image on the element of this invention comprises a process of charging the element of this invention to a positive potential and exposing it to a light image. Said latent image is developed by using a toner directly on the surface of said element or after being transferred to a suitable dielectric layer, or is changed to a frost image by heating.

Photosensitivity of the element is defined as a half-decay exposure, said exposure is the exposure to reduce a surface potential of the element to a half of the surface potential in the dark. And further, the exposure to reduce a surface potential of the element to 20 percent of the surface potential in the dark is defined as 20 percent-decay exposure which also represents the photosensitivity. The smaller the half-decay or 20 percent-decay exposure, the more photosensitive the element.

Various embodiments of this invention will be shown in the following examples and should not be construed as limitative.

EXAMPLE 1

An electrophotographic element is first prepared. 1.0 gram of poly-N-vinylcarbazole (Luvican M-170, available from BASF Company) and 0.5 gram of chlorinated diphenyl (Kanechlor No. 400, available from Kanegafuchi Chemical Inductrial Company) are dissolved in 10 milli-liter of toluene to form a solution. The solution is applied to an aluminum plate by blade coating and dried at 60°C for 5 minutes to obtain a plain layer of about 10 microns in thickness. An acetone solution containing 1.0 gram of N-vinylcarbazole, 0.5 gram of chlorinated diphenyl and 0.1 gram of the reaction product of 2-(p-methoxystyryl)-3-phenylbenzopyrylium perchlorate and 2-(p-methoxystyryl)-3-phenyl-4-methoxypyrane is applied to the plain layer and is heated at 120°C for 30 minutes to form a top layer of about 0.5 micron in thickness. The thus obtained electrophotographic element is then charged to a positive or a negative potential of about 800 volts by corona discharge means and exposed to a tungsten lamp. The decay curve of the surface potential of the element is measured by an electrometer and is shown in FIG. 2. As shown in FIG. 2, the element of this invention has a photoresponse when charged to a positive potential (curve A) but has no photoresponse when charged to a negative potential (curve C). Half-decay exposure of the element is 5 lux seconds.

For comparison, a conventional electrophotographic element is prepared. A solution containing 1.0 gram of poly-N-vinylcarbazole, 0.5 gram of chlorinated diphenyl, and 5 milligram of the sensitizer the same as above in 10 milliliters of toluene is applied to an aluminum plate by blade coating and dried at 60°C for 5 minutes to obtain a photoconductive layer of about 10 microns in thickness. The amount of the sensitizer contained in said photoconductive layer is the same as that in the top layer of the above novel electrophotographic

cess involving projection through a lens of an image reflected from a colored or black and white original document onto a photosensitive member, such as the photoelectrophoretic process exemplified in U.S. Pat. No. 3,384,556, the manifold imaging process exemplified in U.S. Pat. No. 3,707,368 and like processes.

The halftone screen used in the present invention comprises clear transparent support material having on at least one surface thereof a mixed dot pattern of appropriate frequency comprising a plurality of substantially opaque dots of uniform density, some of which dots are substantially light-absorbing and others of which are substantially light-reflecting. The term "dots" are used herein is intended not only to emcompass dots in the classical sense such as the circular shapes depicted in FIGS. **3** and **4**, but also is intended to encompass areas of uniform density forming other geometrical shapes such as elipses, squares, triangles or polygons in general, inasmuch as any of these shapes proves operable in the present invention. The opacity of the dots should be sufficient to optically block out from the photosensitive member white or denser image information, or colored image information, contained on those areas of an original over which the dots are superimposed. The substantially light-absorbing dots, hereafter referred to as black dots, should be of such a density as to absorb more light of all wavelengths than is reflected. Conversely, the substantially light-reflecting dots, hereafter referred to as white dots, should be of such a density as to reflect more light of all wavelengths than is absorbed. Best results, in terms of range extension, are obtained where the black dots are at least 80% absorbing and the white dots at least 80% reflecting, with optimum results achieved as both values approach **100%**. The base material supporting the dot patterns may comprise any clear transparent material such as glass or plastic. Clear films made from plastics, such as polyesters, methacrylate polymers or vinyl halide polymers and having a thickness of less than about 100 mils, are especially preferred because such screens can be used with both flat and curved platen electrophotographic machinery.

The frequency of the screen dot pattern is defined for the purposes of the present invention in terms of the average period of like dots present on a given linear or area measurement of screen surface. By the term "like dots" is meant dots of similar reflectivity or absorbancy, i.e., white dots or black dots. Frequency is the reciprocal of the average period of like dots and can be defined by the equation: $f = 1/P$, where P equals the average distance between the geometrical center of one like dot and its closest like dot neighbor of the total like dot population per linear or area measurement of screen surface. Thus, a screen having a like dot inch frequency of about 100, or the equivalent like dot millimeter frequency of about 4, would be a screen where the average distance between like dots present in 1 linear inch or linear millimeter, or 1 square inch or square millimeter where the dots are not in rectilinear array, would be about .01 inch or about 0.25 millimeter respectively.

As pointed out above, the frequency and array of the dot pattern present on the screen is determined by the frequency response function, specifically, the Modulation Transfer Function (MTF), of the particular lens system employed in the electrophotographic process. The relationship between spatial frequency and optical response function is discussed, inter alia, in "Optics: A short Course for Engineers and Scientists", Charles S. Williams and Orville A. Becklund, John Wiley and Sons, N.Y., N.Y., 1972, at pages 215 through 228. For a given lens system MTF, the frequency of the dot pattern is too low if the dot pattern is accurately imaged by a properly focused lens, for in this case the aerial image of the dot pattern would be a square wave which according to conventional Fourier analysis comprises sine waves at the fundamental dot pattern frequency and many higher harmonics. Such a square wave aerial image produces only a single dot size on the photosensitive member rather than a variety of dot sizes for different input densities. Conversely, the frequency of the dot pattern is too high if the dot pattern is completely smeared by the lens, since in this case resolution of the dot pattern would be completely lost giving an unmodulated image and producing no dot pattern whatever on the photosensitive member. Lens systems commonly employed in most electrophotographic processes and in commercially available xerographic equipment begin to exhibit the desired modulation at a spatial like dot millimeter frequency of about 2, or a like dot inch frequency of about 50, and modulation may be lost completely at like dot millimeter frequencies ranging anywhere from about 6 to about 16, or like dot inch frequencies of approximately 150 to 400, depending on the quality of the lens. Thus, for the purposes of the present invention, halftone compound screens having a like dot inch frequency within the range of about 50 to 400 are generally suitable. Specifically, the MTF of lens systems commonly used in the xerographic process or in xerographic equipment is such that compound screens having a uniform like dot inch frequency within the range of about 70 to 150 are sufficient for appropriate image modulation such that the lens will pass the fundamental spatial frequencies and attenuate the harmonic spatial frequencies.

The fundamental and harmonic frequencies of the screen dot pattern mentioned above refer to the frequencies of sine waves required to synthesize the reflectivity patterns or like dots within the screen according to conventional Fourier analysis. Within the scope of this invention it should be appreciated that like dots may be positioned in any regular array or may occupy random positions with respect to other like dots. Examples of the regular array would be square, triangular, or hexagonal lattices, with the fundamental screen frequency defined by the basic periodicity of the array of like dots. The frequency is given by $f = 1/p$ where p is the average distance between like dots per rectilinear measurement of screen surface. In the random case, the fundamental frequency is substantially that defined where p is the average distance between one like dot and its closest like dot neighbor in the random array per area of screen surface. Although the like dots may occupy completely random positions in the random array, it has been found to be advantageous for like dots not to overlap. It should also be pointed out that it is not necessary that the frequency of the white dot pattern be identical to the frequency of the black dot pattern, nor is it necessary for the frequency to be uniform on all areas of screen surface, so long as the frequency of each like dot pattern is sufficient to achieve appropriate modulation within the modulation or frequency parameters specified above.

One embodiment of dot array is the body centered regular pattern shown in FIG. 3 which consists of a plurality of square arrays of like dots surrounding a centrally positioned different dot. The square array in FIG. 3 is depicted in the area encompassed by the dotted line which shows four black dots in square array with a white dot positioned at the intersection of black dot diagonals. Of course, the array may be equally described at another area as four white dots in a square array surrounding a centrally positioned black dot. Assuming the like dot inch frequency of the black and white dots of the compound screen of FIG. 3 to be 100, this means for the purposes of the present invention that there is a repetitive two dimensional pattern of 100 black dots along each of two mutually perpendicular rectilinearly directed imaginary lines 1 inch long encompassing a common end dot and 100 white dots along each of two mutually perpendicular different rectilinearly directed imaginary lines also one inch long and encompassing a common end dot. Thus, 1 square inch of compound screen surface with a body centered like dot inch frequency of 100 would contain approximately 10,000 black dots and 10,000 white dots.

Although the body centered pattern of FIG. 3 is very desirable in terms of dot pattern spatial array, it is often a tedious and relatively expensive matter to prepare screens where the body centered pattern can be accurately reproduced throughout a large screen area, particularly at higher screen frequencies. Improper registration of the body centered pattern at various areas of the screen can give rise to an undesirable moire pattern which adversely affects the modulation of the dot pattern. Accordingly, a simpler realization of the compound screen is a random mixed dot pattern which may be achieved by orientating a black dot and white dot linear array at a suitable angle to achieve randomization and minimize moire. This is best accomplished by orientating a regular linear array of white dots at a suitable angle, such as about 30° or about 60°, with respect to a regular linear array of black dots. In this type of array, the relative spacing of black and white dots is not uniform as in the body centered pattern and, in fact, at various areas of screen surface some of the black and white dots will overlap. An example of a dot pattern formed by superimposing a linear black dot screen over a linear white dot screen orientated at an angle of 30° is shown in FIG. 4. As in the case of compound screens having a body centered pattern, the inch frequency of like dots in the orientated array should be within the range of about 50 to 400 for best results.

The mixed dot pattern forming the compound screen serves to extend the range of the electrophotographic process in both the highlight and shadow areas of a continuous tone original document, with the black dots modulating in the highlight areas of the original and the white dots modulating in the shadow areas of the original. Thus, the degree of range extension achieved in the highlight or shadow areas is controlled within certain limits as a function of the relative surface area of the compound screen containing black dots and white dots respectively. For example, a half tone document screen of regular array and appropriate frequency, e.g., 100 dots per inch, consisting solely of black opaque dots covering about 30% of the screen surface was evaluated in the xerographic process using a black and white continuous tone photograph as the original document. After adjusting exposure to compensate for additional light absorption caused by the screen, it was found that range extension in the copy has been achieved only in the highlight areas of the original document, i.e., the low density end of the tone reproduction curve. Similarly, a half tone document screen consisting solely of white substantially opaque dots with a frequency of 100 dots per inch and coverage of about 30% gave range extension in the shadow areas of the original, i.e., the high density end of the TRC. It is thus evident, that with the mixed black and white dot patterns of the present invention, the dots of each gray scale color operate independently to achieve range extension at both ends of the TRC, thereby flattening the curve to more nearly approximate the ideal TRC represented by the dotted lines in FIGS. 1 and 2. FIG. 2 depicts such a flattened curve. Note that the range has been extended to about 1.1 as opposed to the range of about 0.6 shown in FIG. 1.

The relative proportion of the area of the compound screen covered by black or white dots may vary as a factor of the type of electrophotographic process in which the screen is to be used, the nature of the particular continuous tone document to be copied, and exposure limitations in the electrophotographic process. In general, it has been found that desirable results in terms of range extension in the xerographic process have been achieved using compound screens having from about 2% up to about 65% opaque area coverage, 1 to 64% of which opaque area coverage is provided by either black or white dots. As the black dot area increases above 1%, additional exposure in the form of increased document illumination or longer exposure time of the screened document is necessary to compensate for the absorbance of the screen. As the white dot area is increased above 1%, there is a corresponding lowering of the maximum output density in solid or dense areas of the copy. Thus, the composition of a screen to suit a particular process, apparatus or category of document may require some trial and error work within the parameters specified above on the part of the technician to achieve optimum results in terms of range extension.

For pictorial reproduction via the xerographic mode, screens having about 40% total opaque dot coverage, composed of about 30% black dots and 10% white dots have been found to be most satisfactory. Use of such a document screen requires approximately double the unscreened exposure to achieve accurate xerographic reproduction of the original. Where such a screen is to be used as a document screen with commercially available xerographic equipment, it may be necessary in some cases to modidfy the equipment to increase the exposure twofold either by providing additional exposure lamps, by using exposure lamps of higher lumen values, by slowing down the equipment to provide a longer exposure time of the document to the photosensitive member, or by combinations of these.

The halftone screen is designed for use proximate the original document at the exposure station in an electrophotographic process. By the term "proximate" is meant that the screen is used positioned either in direct contact with the image face of the original document or at a distance away from the image face within the focal capabilities of the lens, usually not greater than about ¼ inch.

The compound screens of the present invention may be fabricated by printing, etching, dye transfer, photo-

graphic processes or other well-known techniques which are employed to prepare analogous screens used in the graphic arts. The simplest and most effective procedure is to print directly onto the clear transparent base member by offset printing techniques using opaque black or white inks or pigments to provide the desired black and white dot patterns. The total percentage of opaque area coverage at a given frequency for a given area of screen may be established by controlling the size of the dots printed on the screens, i.e. the larger the fixed frequency dot size, the greater the area of dot coverage. The relative proportion of black and white dot area coverage can be controlled in the same manner. For example, to print a compound screen having a like dot inch frequency of about 100, or a like dot millimeter frequency of about 4, with a total opaque dot area coverage of 40% consisting of 20% black dots and 20% white dots, simple calculations indicate that each of the approximately 16 black and 16 white dots per square millimeter should be printed to occupy an area of about 0.0125 square millimeters per dot. To print a similar screen where the black dots account for about 30% screen opacity and the white dots account for about 10% screen opacity, each of the 16 black dots should be printed to occupy an area of about 0.019 square millimeters and each of the 16 white dots should be printed to occupy an area of about 0.006 square millimeters.

Compound screens having the body centered dot pattern similar to that shown in FIG. 3 may be printed on a clear transparent substrate by first applying dots of ink of one color to one side of the substrate, and subsequently of the substrate and subsequently printing dots of the color on the same ink of the other color in proper spatial array to the same or opposite side of the substrate. Alternatively, the body centered compound screen pattern may be provided by two separate sheets or layers of substrate with white dots printed on one sheet and black dots printed on the other sheet such that when the two sheets are superimposed and fixed in place, the body centered pattern of FIG. 3 is evident. The orientated compound screen pattern of FIG. 4 may be printed in a similar fashion by first printing dots of one color on one side of the substrate or opposite side of the substrate, care being taken to insure that the latter dots are printed orientated at suitable linear angles to minimize moire, e.g., angles of 30° or 60°, with respect to the former dots. With this technique, no specific care need be taken with regard to the relative spatial array between black and white dots. Alternatively, the black and white dots may be printed on separate sheets, and a compound screen formed by superimposing and orientating these sheets at appropriate linear dot angles, e.g., 30° or 60°. The laminated sheets may then be fixed in place such that relative movement of the sheets is prevented, followed by trimming to the desired screen dimensions.

As previously indicated, the compound half tone screen of the present invention is suitable for use in any electrophotographic imaging process, both color and black and white, and designed to be positioned proximate to, preferably adjacent and in substantial contact with, the image face of the original to be copied, and between the original and lens system employed in the electrophotographic process. The compound screens are particularly adapted for the xerographic process as half tone document screens used in contact with the image face of an opaque, colored or black and white original document such as a continuous tone photograph. Light illuminating the original passes through the transparent areas of the screen and is selectively reflected or absorbed by the opaque dot areas of the screen. The pattern of light reflected by the screened original is passed through a lens system and focused on a charged photoconductive plate. This spatial modulation of a continuous tone image on an original document gives rise, after xerographic development of the latent image formed on the plate, to an area modulated pattern of half tone dots in the copy, said dots varying in size as a function of the screened output density in various areas of the original. In a black and white process, these dots are black; in a color process, these dots would be of appropriate color.

The dimensions of the compound screen should be sufficient to cover either the entire image area of the document or selective pictorial areas of the document. Thus, an 8½ inch × 11 inch opaque original photograph requires an 8½ inch by 11 inch compound screen. Other originals containing both pictorial and line copy require screens of dimensions sufficient to cover the pictorial copy only. When used with commercial xerographic equipment, the compound screen is simply positioned at the platen or exposure station and the original document placed over it. If desired, the glass platen of a xerographic apparatus may itself constitute the screen, having the appropriate dot pattern directly affixed thereto.

While the invention has been described with reference to the structure disclosed herein, it is not confined to the specific embodiment set forth, and this application is intended to cover such operative modifications or changes as may come within the scope of the following claims.

What is claimed is:

1. In an electrophotographic imaging process comprising the steps wherein an original document is provided at an exposure station, illuminated, and light reflected from said illuminated original document is passed through a lens system and directed onto an electrically photosensitive member, the improvement comprising conducting said imaging process with a compound document screen positioned proximate to the image face of said original document between said document and said lens system, said compound document screen comprising:

a clear transparent substrate material having clear areas and bearing opaque areas;

said opaque areas comprising a repetitive pattern of substantially opaque mixed dots comprising substantially light absorbing like dots and substantially light reflecting like dots;

said like dots arranged with respect to other like dots at an average like dot inch frequency such that the lens system employed in the electrophotographic process passes the fundamental spatial frequencies and attenuates the harmonic spatial frequencies.

2. The process of claim **1** wherein the substrate material comprises a single sheet of clear transparent material having the substantially light absorbing like dots affixed to one side of said sheet and the substantially light reflecting like dots affixed to the same or opposite side of said sheet.

3. The process of claim **1** wherein the substrate material comprises two superimposed sheets of clear trans-

parent material having the substantially light absorbing like dots affixed to one of said superimposed sheets and the substantially light reflecting like dots affixed to the other of said sheets.

4. The process of claim **1** wherein said compound document screen is positioned in contact with the image face of said original document.

5. The process of claim **1** wherein each of said like dot patterns on said substrate material is of substantially uniform frequency, like dots being arrayed along generally rectilinearly directed lines with respect to other like dots.

6. The process of claim **5** wherein said mixed dots on said substrate material are arranged in a body centered pattern.

7. The process of claim **5** wherein the rectilinear arrays of substantially light absorbing like dots are disposed at an angle with respect to the rectilinear arrays of substantially light reflecting like dots, said angle being appropriate to minimize moire and provide optimum randomization of the mixed dot pattern.

8. The process of claim **5** wherein the uniform like dot inch frequency is within the range of about 50 to 400.

9. The process of claim **1** wherein said repetitive pattern of substantially opaque mixed dots occupies from about 2% to about 65% of the image area of the compound screen, said substantially light absorbing like dots constituting from about 1% to about 64% of said image area and said substantially light reflecting like dots correspondingly constituting from about 64% to about 1% of said image area.

10. The process of claim **9** wherein the like dot inch frequency is within the range of about 70 to about 150.

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