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Fotland

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[54] **GENERATION OF RADIOGRAPHS**

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[58] **Field of Search** ... 250/315, 275, 320, 321, 322, 250/323, 482

[56] **References Cited**

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[57] **ABSTRACT**

Radiographs are generated in an apparatus comprising a fine mesh screen coated with an X-ray sensitive photoconductor by exposing said screen to an X-ray image while said coated screen is in physical contact with an insulating charge-supporting member and while an electrical potential is applied between the screen and an electrically conducting plate located on the side of the insulating member which is opposite the side the coated screen is on, and thereafter electrostatically toning the latent image formed on the charge-supporting member as a consequence of the X-ray exposure.

6 Claims, 4 Drawing Figures

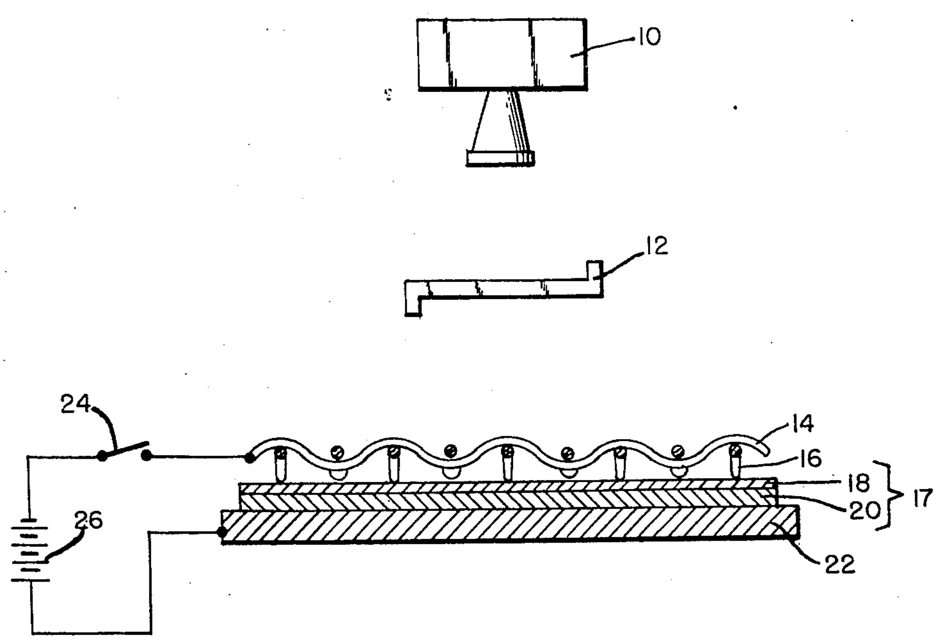


FIG. 1.

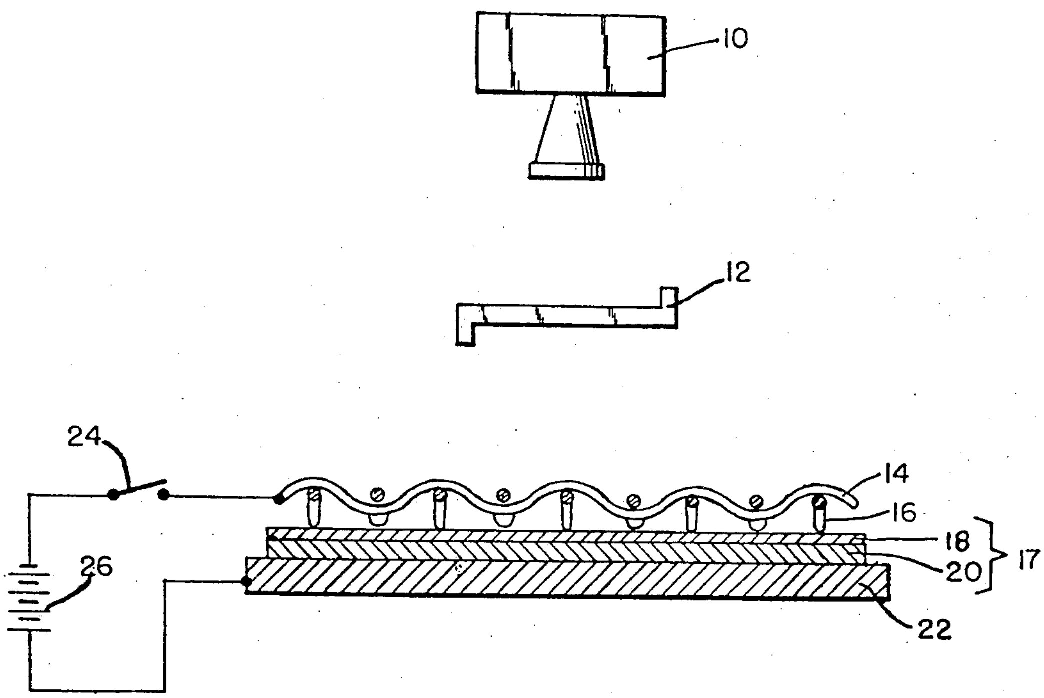


FIG. 2.

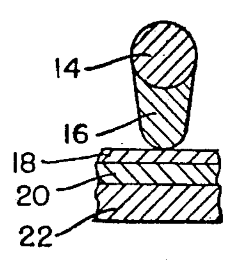


FIG. 4.

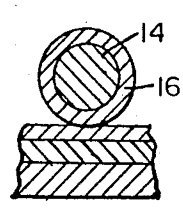
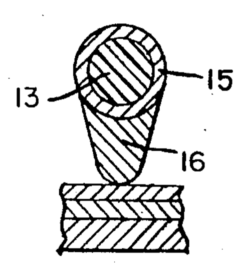


FIG. 3.



GENERATION OF RADIOGRAPHS

This invention relates to a novel electrophotographic means for obtaining radiographs.

One presently known procedure for obtaining radiographs is known as xeroradiography. In xeroradiography a selenium coated plate is electrostatically charged, exposed to an X-ray image (the charge being conducted from the surface in areas of the plate irradiated by X-rays), and then the latent electrostatic image is developed by powder cloud toning. The powder cloud image is next transferred to white paper. Then the image is fixed on the surface of the paper by fusing with heat. After each exposure, the selenium plate must be heated to slightly elevated temperatures in order to recondition the plate and eliminate the presence of fatigue or ghost images. This process is complicated and suffers from an operational life problem in that small area defects arise in the X-ray image after a number of exposures have been made on any one plate.

Furthermore, the powder cloud electrostatic toning employed in xeroradiography results in an edge enhancement of the electrostatic image and a lack of fill-in in solid irradiated areas since toners deposit in accordance with voltage gradients at the surface of the exposed plate rather than in accordance with the true potential at any point on the surface. In certain applications, this edge enhancement provides information not normally available from conventional silver halide radiographs. The image appearance is, however, different from what radiologists and nondestructive testing personnel are normally accustomed to observing.

This invention relates to a new and improved process for obtaining radiographs employing a simpler electrophotographic process than those heretofore available.

A principal object of the present invention is to provide a process for obtaining radiographs which is extremely simple and which does not require the complicated processing associated with either xeroradiography or conventional silver halide radiography.

Another object of the invention is to provide a very inexpensive means for obtaining radiographs.

A further object of the present invention is to provide a process for obtaining radiographs where the resultant toned image density is proportional to the X-ray exposure.

Other objects, features, and advantages of the present invention will become apparent in the following specification and accompanying drawings in which:

FIG. 1 is a schematic of one apparatus for practicing the present invention;

FIG. 2 is an enlarged view, in section showing a detail of the mesh of FIG. 1; and

FIGS. 3 and 4 are views similar to FIG. 2 of a modification thereof.

FIG. 1 is a schematic drawing showing an apparatus for carrying out this invention. Any conventional X-ray source **10** generates the X-rays employed in examining an object **12** to be imaged. Means (not shown) are provided to support an object between the X-ray source **10** and record sheet **17**. A fine mesh screen **14** coated with a substance **16** which is normally an insulator but which becomes partially conducting when bombarded with X-rays is placed in contact with a record sheet **17** consisting of a thin insulating charge-supporting surface layer **18** supported on a partially conducting backing layer **20**. The record sheet may be backed with a partially conducting support member **20** which is transparent. The record sheet **17** is supported upon an electrically conducting platen **22**. A source of potential **26** is connected between electrically conducting screen **16** and electrically conducting support plate **22**, through a switch **24**.

The electrically fine mesh screen **14** may be formed of a variety of metals or alloys; materials which have been found suitable include brass, stainless steel, aluminum and phosphor bronze. The mesh count, i.e. the number of wires per linear inch, may range from 100 to 1,000; the finer mesh screens providing higher resolution. Or the fine mesh may be of woven monofilament **13**, such as polypropylene, polyester or polyamide. Such woven resin screens are available in mesh sizes to over 325, are extremely strong, and somewhat less expensive than corresponding metal woven screens. When an insulating plastic monofilament screen is employed, a conducting coating **15** must be supplied to the surface of the monofilament as shown in FIG. **3**. One preferred mode of applying such a conductive coating is vacuum vapor deposition of a thin layer of a conductor such as aluminum onto the surface of the screen. Other means of providing electrically conductive coatings on the resin monofilaments, such as electroless plating, may also be employed. The screen coating **16** is formed of a substance which normally has a high resistivity, typically greater than 10^{12} ohm centimeters, and also has the property of becoming slightly conductive when irradiated with X-rays. This material may or may not also become conductive when irradiated with illumination in the visible or ultraviolet regions of the spectrum. The material may thus be categorized as an X-ray sensitive photoconductor. If the X-ray photoconductor **16** is insensitive to visible illumination, the process of this invention may be carried out in normal room lighting. If such X-ray sensitive photoconductor exhibits photosensitivity to visible illumination, the photoconductive screen must be enclosed in a light-tight cassette or otherwise shielded from room light.

Typical X-ray sensitive photoconductors which have been employed in this process include selenium, selenium alloyed with small amounts of one or more of the following elements: tellurium, sulfur, arsenic, antimony, bismuth and iodine; cadmium sulfide, cadmium selenide, and lead oxide. The thickness of coating **16** is not critical. For imaging higher energy X-radiation, it is desirable to provide sufficient thickness so that an appreciable fraction of the incident X-rays is absorbed. Typical coating thicknesses range from one-quarter mil to 5 mils. Coating **16** as shown in FIG. **1**, must be applied to the mesh screen **14** in such a manner that coating **16** is present between the conducting mesh **14** and insulator layer **18**. Coating **16** may completely surround the wires of the mesh or may be asymmetric with respect to these wires. Any of the conventional methods of coating may be employed. These include vapor vacuum deposition, settling of binder layers, spraying of a material such as selenium onto the mesh while the mesh is held at elevated temperatures, etc.

The charge receptor sheet **17** which is composed of insulating layer **18** and partially conducting layer **20**, may conveniently be a dielectric paper (also known as electrographic paper). Such papers are characterized by having a partially conducting paper base layer **20** coated with a very thin insulating polymer layer **18**. The insulating polymer layer normally includes a well dispersed white pigment to provide good feel and surface characteristics. The thickness of the insulating dielectric coating is normally in the range of one-fifth to 1 mil. Such papers are commercially available from a variety of sources.

If a transparency is desired, the dielectric paper **17** may be replaced with a thin polymer film such as acetate, polyester or polystyrene, having a transparent or semitransparent conductor **20** on the back. One consisting of copper iodide may be formed by depositing a thin layer of copper onto the film surface and subsequently treating the copper layer with iodine vapors. The thickness of the plastic insulating layer **18** is preferably not over 3 mils, and is preferably in the region of 1 mil. If it is desired to have a thicker transparency for ease of handling, such a member may consist of a 5 mil polyester base upon which is deposited a semiconducting transparent copper iodide layer, over which is next placed a one-half to 1 mil thick coating of a thermoplastic insulator such as polystyrene.

In carrying out the process of this invention, switch **24** is closed and X-ray source **10** energized. After the X-ray exposure, switch **24** is opened and the charge-supporting record sheet **18** is removed from the sandwich-like array and the latent image supported upon insulating member **18** is electrostatically toned using any conventional electrostatic toning means such as liquid toning, cascade, magnetic brush, or powder cloud. The toned image is then fused, employing any fusing means suitable for fixing the toned image.

The utility and specific means for carrying out the process of this invention are illustrated in the following examples, which are not intended to limit the invention in any way.

EXAMPLE 1

A plain square weave, 400 mesh, stainless steel, woven wire screen was stretched over a square aluminum frame whose inside dimension was 12 inches on a side and whose outside dimension was 13 inches. The stainless steel screen was fasteneed to the frame with epoxy cement. The frame-screen assembly thus prepared was mounted in a vacuum vapor coater an average distance of 24 inches from a quartz evaporation crucible mounted in a tantalum heater. A charge of 100 grams of high purity selenium was placed in the evaporation crucible. The vacuum coater was evacuated to a pressure of 10^{-5} torr and the selenium evaporated from the crucible onto the screen over a period of 1 hour. During the evaporation, the screen was maintained at an elevated temperature of 70°C. by means of an electrical heater. The resultant selenium coating thickness was found to be approximately 1 mil.

A sheet of Weyerheuser Company dielectric coated (electrographic) paper was placed, dielectric coating side up, on an 8 × 10 inch aluminum plate. The selenium coated wire mesh screen was laid (selenium coated side down) on the dielectric paper. A power supply providing 800 volts was connected in series with a switch between the conducting fine mesh screen and the aluminum platen.

A self-rectifying medical X-ray unit, employing an X-ray tube with a tungsten target, was positioned a distance 60 cm above the coated screen.

Radiographs of human extremities such as the hand were obtained using a tube operating voltage of 60 kvp and an exposure in the range of 20 to 80 mas. Radiographs of light aluminum castings were obtained at 90 kvp and 10 to 100 mas. During the X-ray exposure, the switch was closed providing a potential between the conductive screen and the paper support platen. After the exposure, the switch was opened, the dielectric paper removed and developed in an Addressograph Multigraph Corporation magnetic brush dry toner unit. The developed image was then fixed in a commercial radiant fusing unit (Sun Chemical Corporation Model 120). A negative image is obtained with this process, charge being transferred from the photoconductor to the surface of the dielectric coating on the paper in regions which are exposed to X-rays. Since the photoconductor does not uniformly contact the dielectric layer, the image is self-screened. Thus, a good solid area development is obtained and a full range of continuous-tone renditions is obtained.

With the use of the screen described in this example, the resultant sensitivity depends on the applied potential. At voltages much in excess of 900 volts, background appears as charge is transferred in areas of the screen not irradiated with the X-rays. It was also found that equivalent results were obtained independent of the polarity of the power supply. It was necessary, however, to employ toners which provided different charged pigment development particles in accordance with the sign of the charge transported onto the dielectric coated paper. For example, when the polarity of power supply was such that the screen was maintained negative with respect to the paper backing platen, then negative charge was transferred to the surface of the dielectric paper. In this case it is necessary to develop with a magnetic carrier toner system in which the toner particles acquire a positive charge with respect to the magnetic carrier.

EXAMPLE 2

An X-ray sensitive photoconductor coated screen was prepared as in the previous example with the exception that the photoconductor employed was an alloy of arsenic and selenium, the alloy consisting of 25 atomic percent arsenic and 75 atomic percent selenium. The alloy was prepared by weighing out high purity arsenic and selenium, and placing them together in a pyrex tube. The tube was evacuated and sealed off, and the materials reacted by heating the sealed tube in an electric furnace at a temperature slightly greater than the melting point of these materials for a period of several hours. Thereafter the alloy was deposited on the screen and this process was carried out in the same manner as described in Example 1. The X-ray sensitivity was improved slightly, by the use of a Se-As alloy over the use of Se alone.

EXAMPLE 3

The same procedures were employed as in Example 1, with the exception that the X-ray photosensitive coating was formed of lead oxide. In this example, lead oxide was vapor vacuum deposited onto 400 mesh stainless steel screen. Some decomposition of the lead oxide occurred during the evaporation, with the formation of a grey suboxide. The photoconductive coating, therefore, required a baking at an elevated temperature in an oxygen atmosphere in order to reoxidize the photoconductor to the point where the dark conductivity had fallen to a suitable balue. While this screen exhibited lower X-ray sensitivity at the lower X-ray tube operating voltages, i.e. in the region of 30 to 60 kvp, a higher photosensitivity was observed at tube operating potentials higher than 90 kvp.

EXAMPLE 4

The process of Example 1 was repeated with the exception that the dielectric paper was replaced with a trans-parent receptor sheet. This transparent receptor sheet was prepared by first vapor depositing a thin layer of copper onto a clean 5 mil thick polyester film base. The copper was then converted to copper iodide by holding the copper coated film in a stream of iodine vapor. Finally a thin dielectric film was provided over the now transparent semiconductive copper iodide layer by employing a draw-down coating procedure, using a Bird applicator, and a 10 percent solution of polystyrene in a 50:50 benzene-toluene solvent. The dry coating thickness of the polystyrene layer was very close to one-half mil. The same procedures were employed as in Example 1 with approximately equivalent results, except the X-ray image could now be viewed by transillumination.

EXAMPLE 5

The process of Example 2 was repeated except that the photoconductor employed was an alloy of selenium, arsenic, and antimony, consisting of 70 atomic percent selenium, 20 atomic percent arsenic and 10 atomic percent antimony. Using the conditions of X-ray exposure described in Example 1, radiographs of good quality were obtained in approximately one-half the time defined in Example 1.

EXAMPLE 6

Example 5 was repeated except that the photoconductor employed consisted of 72 atomic percent selenium, 22 atomic percent arsenic and 6 atomic percent bismuth. Again, using the conditions of X-ray exposure described in Example 1, radiographs of good quality were obtained in approximately one-third the time defined in Example 1.

What is claimed is:

1. In an apparatus for producing radiographs of an object comprising

an X-ray source positioned on one side of an object to be radiographed,

and an X-ray image generating assembly disposed on the opposite side of said object;

the improved image generating assembly comprising

an electrically conductive base layer,

a record sheet disposed on said base, consisting of an electrically conductive layer and a charge-supporting insulating layer, with the electrically conducting layer lying on said base,

and a conductive woven mesh screen lying on said charge-supporting insulating layer, at least that portion of the woven screen which is in physical contact with said charge-supporting layer being provided with a coating of photoconductive material which becomes electrically conductive when exposed to X-rays,

and means for applying a potential between conductive base layer and woven mesh screen.

2. The apparatus of claim **1** in which the photoconductive material is selected from the group consisting of selenium, cadmium sulfide, cadmium selenide, lead oxide, and selenium alloyed with at least one element selected from the group consisting of tellurium, sulfur, arsenic, antimony, bismuth, and iodine, and mixtures of said photoconductive materials.

3. The apparatus of claim **1** in which the screen consists of metal and the photoconductor is selenium.

4. The apparatus of claim **1** in which the screen consists of synthetic resin monofilament coated with a conductor.

5. The apparatus of claim **1** in which the image-receiving member is a dielectric coated paper.

6. A method of producing radiographs which comprises, assembling the apparatus of claim **1** and exposing an object to X-rays, whereby a pattern consisting of X-rays passing through said object falls on said sensitive member, said exposure taking place while a potential is impressed between said screen and said metal base, to form a latent electrostatic image on said charge-supporting insulating layer and next developing a visible manifestation of said latent charge image.

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