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(54) ELECTRORADIOGRAPHIC RECORDING DEVICE

(71) We, N.V. PHILIPS' GLOEILAMPENFABRIEKEN, a limited liability Company, organised and established under the laws of the Kingdom of the Netherlands, of Emmasingel 29, Eindhoven, the Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The invention relates to an electroradiographic recording device having a source of X-ray radiation, an electrode passing X-rays, an intermediate recording space for an object to be displayed, in which the electrode on a side remote from the recording space is provided with a layer of dielectric material, a second electrode which has a photoconductive layer, the dielectric and photo-conductive layers being separated by a gas gap, and facing each other, the gas gap being bounded by one or more side walls arranged between the electrodes, and a direct voltage source via which the electrodes are in electrical contact. Such a device will be referred to herein as a device of the kind referred to.

Electroradiographic recording is a form of electrophotographic recording. Whereas in electrophotography light rays are used for the recording, electroradiography uses X-rays or other directly ionizing rays. In both cases the photoconductive layer in the non-radiated condition has a high resistivity (approximately 10^{14} Ohm.cm) which is lower upon irradiation. This highly insulating layer is charged electrostatically before irradiation. Upon local exposure with ionizing radiation in accordance with the pattern to be reproduced, the surface charges on the exposed places are reduced by photoconduction. The resulting charge image can be developed to a visible image by means of a powdered or liquid toner on the photoconductive layer. It is also known, however, to obtain a latent electrostatic image on an insulating image recording surface by providing the image recording surface very close to a photoelectric layer, subjecting the photoelectric layer pictorially to a radiation distribution, for example by X-ray radiation, and to apply an electrical field between the insulating picture recording surface and the photoelectric layer (German Auslegeschrift 1063899).

It is disclosed in German Auslegeschrift 1610757 that in the manufacture of a charge image on a dielectric layer, in which a charge image is made on a photoconductive layer and is transmitted to a dielectric image receiving material, either a precisely adjusted air gap of 50 to 200 μm exists between the two layers, or the layers are in virtual (nominal) contact, or an intimate contact is obtained by using high mechanical pressure.

It is furthermore disclosed in German Auslegeschrift 1810757 that when a constant air gap of approximately 50 to 200 μm is maintined, the disadvantage arises that an unsharp image is obtained which is particularly evident when reproducing small details, such as small characters. Accordingly, the German Auslegeschrift 1063899 proposes that the insulating image recording surface during the image formation be maintained at a distance of at most 20 μm from the photoconductive layer, whereas German Offenlegungsschrift 1597905, 1622370, 1622371 and 1622372 propose a nominal (virtual) contact of 10 μm, or the use of mechanical pressure to reduce the airgap.

It is an object of the invention to provide an improved electroradiographic recording device.

According to the invention there is provided a device of the kind referred to, wherein the photoconductive layer is formed from a photoconductive material in powder form and a binder, the gas gap between the facing surfaces of the dielectric layer and the photoconductive layer has a minimum width of 50 to 500 μm, and the electrode passing the X-rays has a surface (sheet) resistance of 10^3 to 10^8 Ohm per square.

Various embodiments of the invention will now be described by way of example.

The photoconductive material in powder form, is preferably a tetragonal lead monoxide having a grain size of 1 to 50 μm, and preferably 5 to 20 μm. A further suitable photoconductive material is, for example, cadmium sulphide.

As binders for the photoconductive powder material may be used binders from the group of the lacquer synthetic resins such as polyvinyl carbazol. The lacquer synthetic resins are described in Saechtling-Zebrowski "Kunststoff-Taschenbuch", 19th edition (Munich-Vienna 1974), pp. 445-448). The quantity of binder is, for example, 0.5 to 5% of the overall weight.

The second electrode which serves as a support for the photoconductive layer preferably consists of aluminium. Further suitable materials for said layer are, for example, stainless steel, brass, steel or gold vapour-deposited on a glass or PLEXIGLASS (Registered Trade Mark) carrier.

The thickness of the photoconductive layer is preferably 200 to 300 μm but may be increased without difficulty to 1 mm or more depending on the requirements set by the radiation quality.

The surface of the dielectric layer on which the latent charge image is made, is preferably separated from the surface of the photoconductive layer by a gas gap having a minimum width of 80 to 120 μm, preferably 100 μm. Because in accordance with the invention the photoconductive layer used is a porous layer of binder, hollow spaces may be formed with the above-indicated grain sizes of the photoconductive material up to 50 μm, the diameter of which spaces may exceed the dimension of the grain. The depth of the rough surface of said layer will contribute additionally to the gap width to the extent of approximately 15 μm. It is the object of said numerical values to indicate that in this case there cannot be referred to a precise separation between the dielectric and the photoconductor due to the width of the gas gap.

The gas gap and hence also the pores of the layer may be filled with a gas or a gaseous mixture. Gases which are particularly favourable for the charge transfer are normal air at usual relative air humidity and preferably at a pressure of 0.8 to 1.2 atm., oxygen, or sulpurhexafluoride, the latter preferably at a pressure of 0.5 to 1.2 atmospheres. Further suitable gases are, for example, an inert gas with electronegative gaseous additions. Said gases can be used at pressures between approximately 0,5 and 5 atmospheres.

The dielectric layer may be, for example, an insulating polyterephthalate foil having a thickness of 3 to 50 μm. Further suitable foil materials are polyethylene, polycarbonate and polyester. On the basis of the electrical properties of the device in the formation of the latent charge image, thin foils are especially to be preferred.

On the side of the foils remote from the gas gap an X-ray-transparent electrode is provided the surface (sheet) resistance of which was varied from a few ohms per square to 10^8 ohms per square in the course of experiments which have led to the invention. It was found that the quality of the electrode is of importance to the image quality of a latent charge image after a radiographic exposure. It was established that a very small surface resistance, as realized, for example, by a conductive silver layer, always results in images having noticeable image defects, and similarly when a resistor is simply connected in series with the conductive electrode. With a surface (sheet) resistance lying in the range between 10^3 Ohms per square and 10^8 Ohms per square however, said image defects can be avoided and a resolving power of up to 10 line pairs per mm can be obtained. With surface (sheet) resistances of 10^5 Ohms per square, images having a high resolving power and low noise were obtained. In order to obtain said values for the surface resistance, the electrode can comprise any of the following materials: a vapour-deposited layer of metal or metal oxide, for example chromium-nickel having a surface (sheet) resistance between 10^4 and 10^6 Ohms per square, or indium oxide, respectively; liquids, for example glycerin with ionogenic additions, such as to provide a surface (sheet) resistance between 10^4 and 10^6 Ohms per square, electrically conductive liquids, for example alcohols. The vapour-deposited layers are, for example, a few hundred Å thick, the liquid electrode layers are less than 1 mm thick.

Between said electrode and the carrier of the photoconductive layer a voltage is applied of a sufficient value. For the parameter values normal air, 250 μm photoconductor thickness and 100 μm gap width the voltage is approximately 2000 volts. When using SF_6 at normal pressure the voltage may be increased to approximately 2500 volts. At lower gas pressures the voltages become correspondingly lower.

The voltage across the device is chosen to be sufficiently low so that no self-supporting discharge occurs but is chosen to be sufficiently high so that when exposed to X-rays, a non-self-supporting discharge current which is as high as possible, flows. Incident X-rays may now cause two things:

I.

A few rapid photoelectrons which may be formed in the photoconductive layer by absorption of X-ray quanta may land in the gas gap. The electrons formed by thermal energy, are accelerated in the electrical field and may cause electron multiplication. The coming together of electronegative gas constituents terminates the multiplication. The collected negative charge carriers are transported in the electrical field to the foil. So up to this point the treatment is in principle the same as in a spark chamber.

II.

Simultaneously, however, the photoconductive layer becomes conductive by absorption of X-rays. At a constant voltage across the whole device this results in an increase of the voltage across the gas gap. Increased fields in the gap, however, mean a control of the multiplication processes of charge carriers.

An embodiment of the invention is shown in the accompanying drawing and will now be described by way of example. The sole figure is a diagrammatic representation of an embodiment of a device in accordance with the invention as a side elevation. In the figure, reference numeral 1 denotes an X-ray tube in the path of rays (not shown) of which a test object 2 is placed which is to be tested by means of X-rays. In the drawing the test object is shown as a stepped wedge. An electrode 3 passing X-rays closes the device on the side of the object. On the side of the electrode 3 remote from the test object a dielectric foil 4 is provided. Adjoining the foil 4 is a gas gap 5 which is bounded by insulating side walls 6 and 7. Opposing the foil 4 on the other side of the gas gap 5 is a photoconductive layer 8 which is provided on a second electrode 9.

As shown in the figure, prior to the actual exposure to X-rays, a direct voltage U is applied to the two electrodes 3 and 9 *via* a switch S having a positive polarity on the electrode 3. (In the direct current circuit R is a resistor). The opposite polarity is in pinciple also possible but provides a lower sensitivity in the gases used in accordance with the invention. With the preferred parameter data of 250 μm photoconductor thickness, 100 μm gas gap thickness, and air at a pressure of 1 atmosphere, the voltage is 2000 volts. Immediately after supplying the direct voltage of, for example 2000 volts, a quantity of charge flows to the foil 4 *via* the gas gap 5. During development said charge becomes noticeable as a background. There exist various possibilities to avoid said background:

A) When developing in a liquid with counter electrode the background can be compensated for by a bias voltage.

B) By inverting the polarity of the applied voltage the background can be compensated for as regards charge.

C) The charge transfer to the dielectric foil 4 after applying the voltage is associated with a "forming" of the photoconductive layer 8. On the basis of this process, which is not yet clarified in detail, it is possible to replace a foil having a background charge by a new *uncharged* foil without this taking up further charges.

Succeeding the treatments B and C is the pictorial exposure to X-rays.

After the exposure, the voltage U is switched off by means of the switch S, the electrodes 3 and 9 are shortcircuited and the foil 4 and the photoconductor 8 are separated. The charge image may then be developed.

An advantage of the invention is that porous photoconductive layers, in particular lead oxide-binder layers which are very sensitive with respect to X-rays, are made sensitive to generate a visible image.

WHAT WE CLAIM IS:-

1. An electroradiographic recording device having a source of X-rays, an electrode passing X-rays, an intermediate recording space for an object to be displayed, in which the electrode on a side remote from the recording space is provided with a layer of dielectric material, a second electrode which has a photoconductive layer, the dielectric and photoconductive layers being separated from each other by a gas gap, and facing each other, the gas gap being bounded by one or more side walls arranged between the electrodes, and a direct voltage source *via* which the electrodes are in electrical contact, wherein the phodoconductive layer is formed from a photoconductive material in powder form and a binder, the gas gap between the facing surfaces of the dielectric layer and the photoconductive layer has a minimum width of 50 to 500 μm, and the electrode passing the X-rays has a surface (sheet) resistance of 10^3 to 10^8 Ohms per square.

2. A device as claimed in Claim 1, characterized in that the photoconductive layer comprises tetragonal lead monoxide in a grain size of 1 to 50 μm.

3. A device as claimed in Claim 1 or 2, characterized in that the gas gap is 80 to 120 μm wide.

4. A device as claimed in Claim 3, characterized in that the gas gap is filled with air at a pressure of 0.8 to 1.2 atmosphere.

5. A device as claimed in Claim 3, characterized in that the gas gap is filled with sulphurhexafluoride at a pressure of 0,5 to 1.2 atmospheres.

6. A device as claimed in Claims 1 or 2

to 5, characterized in that the electrode passing X-rays consists of chromium-nickel vapour-deposited layers in a surface resistance between 10^4 and 10^6 Ohms per square.

7. A device as claimed in Claim 1 or 2, to 5, characterized in that the electrode passing X-rays consists of glycerin with an ionogenic addition with a surface resistance between 10^4 and 10^6 Ohms per square.

8. An electroradiographic recording device as claimed in Claim 1 and substantially as herein described with reference to the accompanying drawing.

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1592002 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*