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(54) METHOD OF ELECTROPHOTOGRAPHICALLY MANUFACTURING A DISPLAY SCREEN OF A COLOUR TELEVISION DISPLAY TUBE

- (71) We, PHILIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED, of Abacus House, 33, Gutter Lane, London, E.C.2, a British Company, 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:—
- 10 The invention relates to a method of electrophotographically manufacturing a display screen of a colour television display tube, a colour television display tube display screen made by such a method, and to a
- 15 colour television display tube having such a display screen.
- United States Patent Specification 3,475,169 describes a method of electrophotographically manufacturing a display
- 20 screen of a colour television display tube, which method comprises the steps of applying a volatilizable conductive layer to a face-plate of the tube, applying a volatilizable photoconductive layer over the conductive
- 25 layer, providing a first pattern of phosphor regions by uniformly electrically charging the photoconductive layer, forming a latent charge image which comprises charge in the regions corresponding to the said first pattern by
- 30 exposing the photoconductive layer to light through a mask, and depositing phosphor particles charged with opposite polarity from an insulating developing liquid on the said charge image, providing in an analogous manner at least one subsequent pattern of phosphor regions, providing a light absorbing
- 35 layer between the phosphor regions by uniformly electrically charging the photoconductive layer with the phosphor regions, uniformly exposing to light the photoconductive layer with the phosphor regions, and depositing light-absorbing particles charged with the same polarity from an insulating developing liquid between the charged phosphor regions,
- 40 and baking the face-plate so as to remove the conductive layer and the photoconductive layer. This United States Specification also described a few variations of the above-mentioned electrophotographic method. In a first variation which is termed direct imaging, the charged particles are deposited on the charged regions of the charge image because the charged particles have the opposite polarity to that of the charge image. In a second variation which is termed reverse imaging, the charged particles are deposited between the charged regions of the charge image because the charged particles have the same polarity as that of the charge image. Moreover, two exposure methods are possible. In the first method, a positive light pattern is formed of the apertures in a colour selection electrode. In the second method a negative light pattern is formed of the apertures in a colour selection electrode, that is to say that each aperture in the colour selection electrode is reproduced by a shadow region on the photoconductive layer.
- 70 In a given type of colour television display tube the phosphor regions on the display screen are smaller or narrower than the electron spots. This is of great importance since then a much smaller part of the surface of the display screen is occupied by phosphor regions and the intermediate space can be filled with a light-absorbing material, so that the colour television display tube can provide a much greater contrast, because ambient light reflected by the screen is minimized. The tolerance which is necessary between the dimensions of the phosphor regions and the dimensions of the electron spots in produced in that the electron spots overlap the phosphor regions.
- 85 A colour television display tube of the shadow mask type in which the phosphor regions are smaller than the electron spots and are separated by regions having a light-absorbing material and a few methods of making such a tube are described in United States Patent Specification 3,146,368. These

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methods depend on the fact that by carefully dosing the exposure to light, phosphor regions are manufactured on the screen which are smaller than the apertures in the colour selection electrode. This method is very difficult to perform, while the achieved reduction of the areas of the phosphor regions is not sufficient. Another known method starts from a colour selection electrode having small provisional apertures. After using the colour selection electrode for the exposure, said apertures are made larger by after-etching or by removing a layer which was provided thereon temporarily. Of course this method is very cumbersome, which is a decisive drawback in practice.

United States Patent Specification 3,615,459 describes a method whereby phosphor regions which are smaller than the apertures in the colour selection electrode can be manufactured on the display screen in a simple and non-critical manner. In this method, each aperture in the colour selection electrode is represented during the exposure by a shadow region on the photoconductive layer. This exposure method is very suitable for use in combination with the electrophotographic provision of the phosphor regions and the light-absorbing layer. This is actually due to the free choice between the direct and reverse imaging which one has in a electrophotographic method. The exposure method described in United States Patent Specification 3,615,459 combined with the electrophotographic method described in United States Patent Specification 3,475,169, however, shows the drawback that previously provided patterns of phosphor regions are slightly contaminated by the phosphor of subsequently provided patterns.

The present invention provides a method of electrophotographically manufacturing a display screen of a colour television display tube, the method comprising the steps of applying a volatilizable conductive layer to a face-plate of the tube, applying a volatilizable photoconductive layer over the conductive layer, providing a first pattern of phosphor regions by uniformly electrically charging the photoconductive layer, forming a latent charge image which comprises charge in the regions corresponding to the said first pattern by exposing the photoconductive layer through a mask, and depositing phosphor particles charged with opposite polarity from an insulating developing liquid onto the said charge image, providing in an analogous manner at least one subsequent pattern of phosphor regions, providing a light-absorbing layer between the phosphor regions by uniformly electrically charging the photoconductive-layer with the phosphor regions, uniformly exposing the photoconductive layer with the phosphor regions, and depositing light-absorbing particles charged

with the same polarity from an insulating developing liquid between the charged phosphor regions and baking the face-plate so as to remove the conductive layer and the photoconductive layer, wherein prior to mixing the phosphor particles of at least one of the patterns with the respective developing liquid the phosphor particles for this pattern are provided with a layer of a hygroscopic material which is electrically conductive in a moist condition, wherein between the provision of two patterns of phosphor regions the hygroscopic material on the phosphor on the face-plate is brought into a moist condition and wherein between the provision of the final pattern of phosphor regions and the provision of the light-absorbing layer the hygroscopic material on the phosphor(s) on the face-plate is brought into a dry condition in which it is non-conductive.

The investigations which led to the present invention showed that the phosphor regions of already provided patterns have insufficient electrical conductivity to be discharged during the subsequent exposure which is necessary to provide a subsequent pattern. For that purpose it would be necessary for the phosphor particles to be made slightly conductive. The provision of a conductive layer on the phosphor particles as such, however, serves no purpose, for in that case the phosphor regions would also lose their charge during the last uniform exposure for providing the light-absorbing layer. So it must be possible for the conductive phosphor particles to be made non-conductive again. According to the invention, a hygroscopic material is used for that purpose which in itself is non-conductive but which is made conductive by the absorption of moisture and is afterwards made non-conductive by drying.

It is to be noted that the influence of possible conductivity of the phosphor regions is stated in column 12 of the already mentioned United States Patent Specification 3,475,169. Here, however, it is described that the patterns of phosphor regions are made conductive afterwards by means of an agent which also serves as a fixative. According to said Patent Specification this would have for its result that during the electric charging of the photoconductive layer, the charge of the phosphor regions would leak away, as a result of which the light-absorbing layer could be provided by a method of direct imaging and without exposure. Apart from the fact that said method has not been found to be satisfactory in practice, no solution is given in said passage for the problem of the contamination of the phosphor patterns.

An embodiment of the invention will be described with reference to the following Example and to the single Figure of the accompanying drawing which shows part of a

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display screen of a colour television display tube during the performance of the method according to the invention.

EXAMPLE

5 An organic conductive layer 2 consisting of polyvinyl piperidinium chloride is provided on a face-plate 1 of a colour television display tube of the shadow mask type. An organic photoconductive layer 3 consisting of
10 polyvinyl carbazole is provided on the conductive layer 2. A colour selection electrode 4 having apertures 5 is arranged inside the face-plate 1 in exactly the same position as it will afterwards occupy in the finished tube made using this face-plate 1. A light source
15 6 of comparatively large dimensions throws light through the apertures 5 on to the photoconductive layer 3. A correction lens (not shown) for accurate matching of the place of the light source to the deflection point of the electron beam in the operating tube is arranged between the light source 6 and the shadow mask 4. A light spot 7 on the conductive layer 3 is surrounded by a half-shadow 8. As a result of this, the effective
20 areas of the light spots on the conductive layer 3 are considerably larger than the areas of the apertures 5. Prior to the exposure to light, the photoconductive layer 3 is provided with a negative surface charge by exposing the layer 3 to a corona discharge of an electrode which is at a high potential relative to the conductive layer 2. This is a known method which is described in United
25 States Patent Specification 3,475,169. The photoconductive layer 3 becomes conductive in the places illuminated by the light source as a result of which the negative surface charge leaks away to the conductive layer 2. The light source 6 is first arranged in the deflection point of the electron beam which in the operating tube is to impinge upon the discrete regions with green phosphor. The light source is then arranged in the deflection
30 point for blue. After this, only parts of the photoconductive layer which have not been exposed to light still contain negative electric charge. After removing the shadow mask 4, a suspension which comprises positively charged red luminescing phosphor particles (europium-activated yttrium oxysulphide) in an insulating liquid is sprayed against the photoconductive layer 3. The said layer consists of branched chain alkanes, for example, Shellsol TD (Trade Mark) which is
35 a mixture of branched chain alkanes having from 9 to 11 carbon atoms. Before the phosphor particles were suspended in the insulating liquid, they were covered with a thin layer of a hygroscopic material by immersing
40 the particles in a solution of 2 gs. of polyvinyl alcohol [Denlea Poval B24 (Trade Mark)] and 0.5 gs. of choline chloride together with 0.1 g. of glycerine made up to

100 mls. with water. The red phosphor
65 adheres to the oppositely charged unexposed places which form a pattern of dots having diameters smaller than the diameters of the apertures 5.

It is to be noted that in direct imaging,
70 one single exposure from the deflection point for the colour to be provided will also be sufficient when a special form of light source is used, for example, an annular light source which is described in the United States
75 Patent Specification 3,152,900. When such an annular light source is used, it is possible to perform the exposure in such manner that the unexposed parts form a pattern of dots having diameters smaller than the diameters of the apertures 5.
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After drying the provided layer of red phosphor dots, the display screen is exposed to moist air (at least 65% R.H.) for at least 10 minutes. As a result of this the
85 hygroscopic material with which the phosphor grains are covered absorbs some water and the phosphor dots become conductive.

The photoconductive layer 3 with the conductive phosphor dots is then again provided with a negative surface charge and exposed to light for providing the next pattern of phosphor dots. Since the red-luminescing phosphor dots are conductive, the surface charge thereof can leak away via the exposed parts of the photoconductive layer 3. The subsequent patterns of phosphor dots are provided in an entirely analogous manner to that used to deposit the red-luminescing phosphor dot pattern.
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The display screen provided with all the patterns of phosphor dots, usually red, blue and green, is then heated in dry air as a result of which the water is expelled from the hygroscopic material around the phosphor grains. The photoconductive layer 3 is then provided with a positive surface charge. After uniform exposure of the photoconductive layer 3, said charge leaks away everywhere with the exception of the phosphor dots which are now non-conductive. The space between the phosphor dots is then filled with a light-absorbing material. For this purpose, a suspension is sprayed against the photoconductive layer 3 which consists of positively charged particles of a black pigmentation agent, for example graphite or a black metal oxide, in an insulating liquid. A light-absorbing material suspension was used which consisted of 3 gms. of black Fe_2O_3 per litre of Shellsol T.D. The light-absorbing material is repelled by the charges of the same sign on the phosphor dots and adheres to the remaining surface between the phosphor patterns. The blue phosphor used was silver-activated zinc sulphide and the green phosphor was copper-aluminium activated zinc cadmium sulphide.
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The volatilizable organic layers 2 and 3

are then removed by baking so that the phosphors and the light-absorbing substance directly adhere to the glass of the display screen 1.

- 5 It will be obvious that the invention is not only suitable for manufacturing a colour television display tube of the shadow mask type but that it may also be used in manufacturing other types of display tubes. The
10 problem of contaminating previously provided patterns with the phosphor of subsequently provided patterns always occurs in those cases where the direct imaging as stated in the United States Patent Specification
15 3,475,169 is used for providing the phosphor patterns and/or subsequently a light-absorbing layer between the phosphor patterns is provided with the reverse imaging.

WHAT WE CLAIM IS:—

- 20 1. A method of electrophotographically manufacturing a display screen of a colour television display tube, the method comprising the steps of applying a volatilizable conductive layer to a face-plate of the tube,
25 applying a volatilizable photoconductive layer over the conductive layer, providing a first pattern of phosphor regions by uniformly electrically charging the photoconductive layer, forming a latent charge image
30 which comprises charge in the regions corresponding to the said first pattern by exposing the photoconductive layer through a mask, and depositing phosphor particles charged with opposite polarity from an insulating
35 developing liquid onto the said charge image, providing in an analogous manner at least one subsequent pattern of phosphor regions, providing a light-absorbing layer between the phosphor regions by uniformly electrically
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phosphor regions, uniformly exposing the photoconductive layer with the phosphor regions, and depositing light-absorbing particles charged with the same polarity from an insulating developing liquid between the
45 charged phosphor regions and baking the face-plate so as to remove the conductive layer and the photoconductive layer, wherein prior to mixing the phosphor particles of at least one of the patterns with the respective
50 developing liquid the phosphor particles for this pattern are provided with a layer of hygroscopic material which is electrically conductive in a moist condition, wherein between the provision of two patterns of phosphor regions the hygroscopic material on the
55 phosphor on the face-plate is brought into a moist condition and wherein between the provision of the final pattern of phosphor regions and the provision of the light-absorbing layer
60 the hygroscopic material on the phosphor(s) on the face-plate is brought into a dry condition in which it is non-conductive.

2. A method of electrophotographically manufacturing a display screen of a colour
65 television display tube, substantially as herein described with reference to the accompanying drawing.

3. A colour television display tube display screen manufactured by the method as claimed
70 in Claim 1 or Claim 2.

4. A colour television display tube having the display screen as claimed in Claim 3.

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