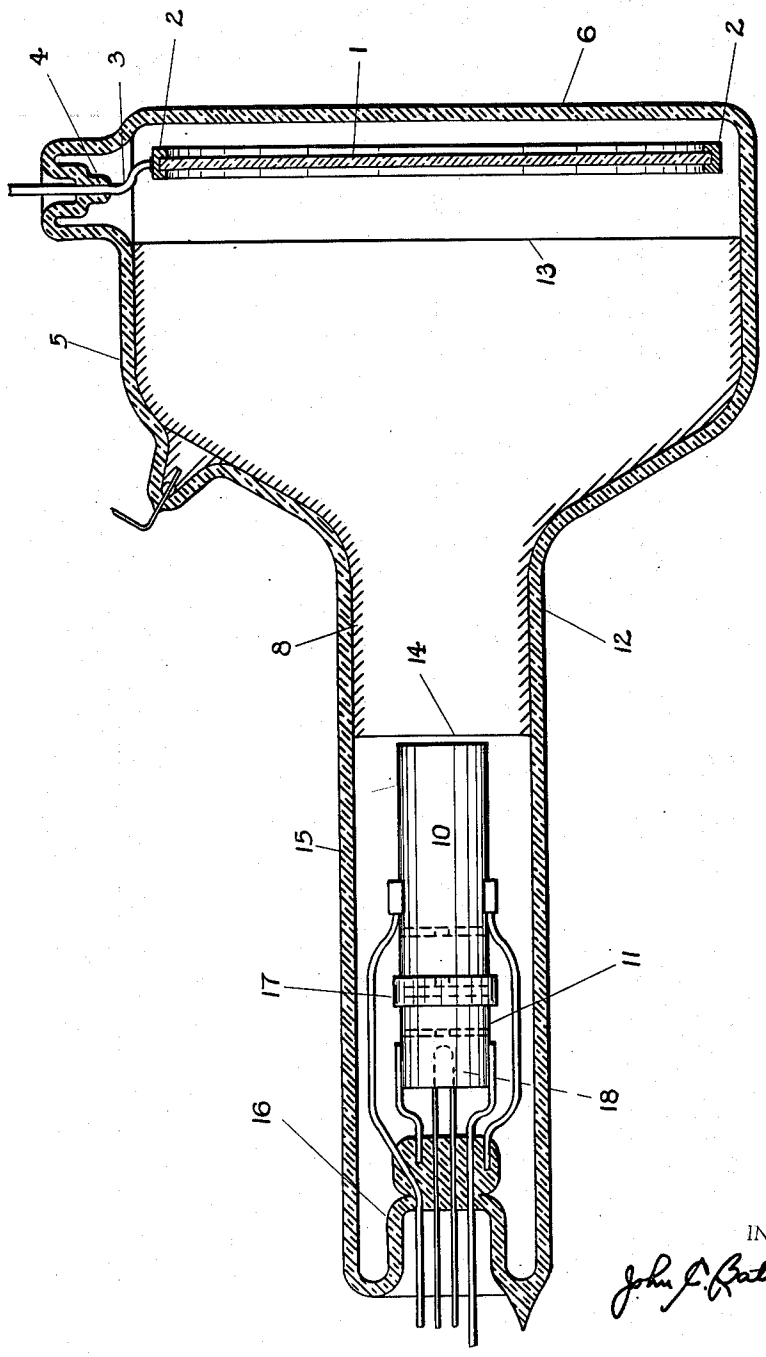
July 19, 1938. J. C. BATCHELOR 2,124,225

LUMINESCENT SCREEN

Filed Feb. 14, 1935



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Patented July 19, 1938

2,124,225

UNITED STATES PATENT OFFICE

2,124,225

LUMINESCENT SCREEN

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Application February 14, 1935, Serial No. 6,443

6 Claims. (Cl. 250—27.5)

My invention relates to luminescent screens and, more particularly, to such screens as are used in cathode ray tubes.

It is customary in the art of visual communication and other related arts to use a cathode ray tube in which a controlled beam of electrons is caused to scan a cathodo-luminescent screen rhythmically whereby the reproduction of an image of a remotely analyzed object may be accomplished. In such tubes, the luminescent screen usually comprises a layer of particles of finely divided cathodo-luminescent material, such as Willemite, deposited upon an interior wall portion of the tube or upon a suitable plate member such as mica or glass appropriately mounted within the tube. It may be recognized that such screens may in some instances be required to be made of a layer of particles of luminescent material thicker than the average diameter of a single particle of the material, and for the purpose of this discussion a screen is considered having a thickness of several times the average particle diameter. Such a screen may be considered as being made up of a number of discrete layers of luminescent material, and that number will have been determined by the density of the material and the velocity with which electrons are caused to strike the screen.

Thus, a screen of a given material one particle thick may be appropriate for bombardment by an electron beam having a velocity corresponding to 1000 volts, whereas a beam having a velocity corresponding to 5000 volts may be capable of penetrating a screen two particle diameters in thickness. In this example, departure of the depth of penetration from a quadratic function of voltage is to a large extent accounted for by the presence of a space charge between the particles within the screen. Although it is possible to produce luminescent screens of a thickness capable of absorbing almost completely the energy from an electron beam of almost any velocity, it may be seen that beyond a certain thickness, of say, three particle diameters, the effect of the light generated within the layer first struck by the electron beam is appreciably diminished by the absorption of light in transmission through the remaining layers of material to the outside of the tube. There is, therefore, a practical limit beyond which it is not feasible to increase the thickness of screens because of the failure of any substantial amount of light generated at the back of the screen to penetrate the remainder of the screen to its exterior surface.

With the foregoing in mind, it is an object of my invention to provide a luminescent screen wherein substantially no impedance is encountered by light generated at one surface of said screen in being transmitted through the screen to its other surface. This and other objects will be apparent upon examination of the following description of my invention.

The accompanying drawing represents one form of my invention applied to a cathode ray tube.

When I speak of a substance as being transparent in the following description and the appended claims, I mean that the substance admits the passage of clear views, otherwise known as specular images, of objects beyond the substance.

Referring to the drawing, a bulb 5 is prepared by introducing a metallic film 8, which may be silver deposited from a solution of silver nitrate in accordance with the known method, in a uniform film terminating in a uniform circle 13 in the enlarged portion of the bulb, and in a uniform circle 14 in the neck 15 of the bulb 5. In the neck 15, carried on the stem 16, is an electron gun 17 comprising an accelerating anode 10, a control electrode 11 and an electron emitting cathode 18 whereby an electron beam may be ejected toward the luminescent screen 1.

The luminescent screen 1, comprising a thin, transparent disc of cathodo-luminescent material, such as Willemite, is carried in the metal ring supporting member 2 which is in turn held by the lead-in wire 3 mounted in the stem 4. A clear window 6 is provided in the end of the bulb 5 adjacent the screen 1 through which images created upon the screen 1 by the impact of electrons from the electron gun 17 may be viewed.

The electron beam may be caused to scan the screen 1 by any suitable means, but in the case of the tube shown it is contemplated to provide a suitable electromagnetic field adjacent the neck of the tube at the point 12. Inasmuch as the manner of deflection comprises no part of this invention, deflecting means have not been shown.

In order to make the luminescent screen 1, I have found it convenient to use Willemite prepared in the following manner: a mixture consisting of 26 parts by weight of silicon dioxide, 71 parts by weight of zinc oxide, 1 part by weight of manganese dioxide and 2 parts by weight of boric acid is powdered and thoroughly mixed, preferably by adding distilled water and grinding in a ball mill for one hour, and removing the mixture and drying it in an oven, following which it is again crushed to a powder by means of a spatula.

The mixture is then placed in a crucible of suitable size made of a sufficiently refractory material to withstand temperatures in excess of 1600 degrees centigrade; I have found crucibles commonly referred to as Assay crucibles to be satisfactory, although I have found that carbon crucibles are sometimes desirable. The crucible containing the mixture is then placed in a furnace, such as a platinum resistance type furnace, and heated at a temperature of substantially 1500 degrees centigrade for a period of time of the order of four hours. Inasmuch as this temperature is somewhat in excess of the melting point of Willemite, at least a part of the mixture will be fused to a solid homogeneous mass of a glassy nature.

Following this period of heating, the material is removed from the oven to a region at room temperature and is allowed to cool. In some instances I have found it necessary to cool the material more slowly in order to prevent internal strains or cracks within the material. When cool, the crucible and unfused portion of the mixture if any remains, may be chipped, ground or cut away to leave a block of relatively transparent synthetically produced zinc orthosilicate, or Willemite, which is luminescent under electronic bombardment. Using this block of material as stock, a disc or discs of the material may be cut by means of a diamond saw and polished on the parallel opposite faces of the disc by using carborundum powder and rouge on a lapidary wheel. In general the minimum thickness to which the discs may be ground is determined by the maximum strength of the material rather than the depth of penetration of electronic bombardment, and I have found it possible with reasonable caution to produce plates having a thickness of less than 1 millimeter when the diameter of the plate is of the order of 6 centimeters. I have found it possible to realize still smaller thicknesses by cementing the plate being ground to a piece of hard wood or rigid metal by means of pitch or other suitable material while the exposed face is being ground and polished.

It should be understood that the temperature and duration of the heating process are subject to change within wide limits, and are determined to a large extent by the desired relation of fluorescence to phosphorescence of the screen. For example, firing for periods shorter than four hours produces a material almost exclusively fluorescent, whereas increasing the period of firing up to twenty hours produces a material preponderantly phosphorescent. In referring to fluorescence and phosphorescence I apply the definitions wherein fluorescence refers to the portion of the light emitted by a substance during the period of excitation but absent immediately upon removal of the excitation, and phosphorescence refers to the total light which is emitted by the substance subsequent to the removal of excitation. Luminescence, of course, includes the light of both fluorescence and phosphorescence.

Moreover, the rate at which the material is raised to the maximum temperature and the rate of cooling, as well as the value of the maximum temperature are important factors in determining the ratio of fluorescence to phosphorescence, and the electrooptical efficiency of the material, and the appropriate values of these factors may be determined experimentally for each set of requirements. In some instances I have found that advantage may be taken of the improved fluidity of materials at higher temperatures in preparing my screens, and temperatures of the order of 2000 degrees centigrade are sometimes advantageous.

Moreover, my invention is applicable to any fusible luminescent material, whether or not it is possible to produce that material synthetically, and to any natural material capable of cathodoluminescence and transparent to light of the color of such luminescence. Materials which are suitable for use in my invention include the silicates, tungstates and germanates of cadmium, calcium and zinc, and all of these may be produced synthetically by appropriate heat treatment of a mixture of approximately stoichiometric ratio of the oxides of the base metal and the metal of the radical, to which mixture has been added an appropriate activator and flux. Among the activators which are suitable in such materials are chromium, manganese, copper, uranium and cerium, and a small quantity of a compound of one or more activators, usually less than 1% by weight, may be added to the mixture of the constituents which produce the solvent. Among the fluxes which are suitable for use in the preparation of luminescent materials synthetically are the fluorides of sodium, zinc, cadmium, magnesium, and boric acid. In addition, I have found that very small quantities of certain metals including iron, lead, nickel and cobalt behave as poisons when present in synthetic materials and destroy the luminescence, and these materials must therefore not be present.

It should be further understood that, to have value in my invention, a luminescent screen need not be transparent to all colors of visible light, but only to such color or colors as are produced by the luminescence of the material. For example, in the case of Willemite, the preponderance of light generated is in a green band, and hence a green tint, which sometimes exists in the material, is without objection. In fact, certain advantages may be realized by applying to screens of my invention, colors which absorb substantially all colors of visible light except that generated by the luminescence of the screen itself. For example, when a cathode is employed which operates at a temperature which radiates appreciable visible radiation, certain of such radiation sometimes finds its way to the luminescent screen and causes thereon an undesired illumination. Inasmuch as the preponderance of the radiation is at the long wave end of the visible spectrum and, in general, relatively little luminescent emission lies in that region, a red elimination filter, either in the screen itself, in the window adjacent the screen, or as a separate member either inside of or external to the cathode ray tube is provided. Thus, in a preferred embodiment of my invention, I use a luminescent screen which is opaque to as large extent as possible to all colors of light different from those emitted by the luminescence of the luminescent material itself. This is to a substantial extent true of material made in accordance with the foregoing specification. If increased optical filtration is required over that available from the luminescent material itself, I have found it possible to use a filter of thin metallic gold in connection with a screen which produces green luminescence. In this case, it is convenient to apply by painting or spraying, either to the side of the luminescent screen not bombarded or to a surface of the window 6, a dilute solution known under the trade name of "Hanovia Liquid Gold" which I believe to be a solution in essential oils of a gold

salt capable of being reduced to metallic gold under the influence of heat, and heating the screen or window to a temperature of the order of 300 degrees centigrade whereupon a thin film of gold is produced which is transparent to green light. In order to produce a gold film of appropriate thickness, I have found it convenient to dilute the "Liquid Gold" solution by adding to it about three times its volume of turpentine or other suitable thinner. Clearly, other expedients will suggest themselves for use with materials having other colors of luminescence.

A still further advantage exists when a luminescent screen which is transparent only to the color of fluorescence of the screen is used in accordance with my invention. In providing a luminescent screen suitable for the reproduction of television images, it is appropriate to use a material which has, in addition to fluorescence, a limited amount of phosphorescence, and the duration of that phosphorescence upon the removal of cathodo-excitation is customarily carefully adjusted to a period of the order of the time interval between successive image repetitions. Thus, when 24 images are being reproduced in one second, it is appropriate to use a luminescent material in which substantially total extinction of phosphorescence occurs after approximately one twenty-fourth of one second; in some instances a substantially longer decay period is desirable in order to effect a degree of fusion of successively reproduced images. Although it is possible to produce luminescent materials having the required degree of persistence, it is easier to take advantage of this embodiment of my invention to accomplish appropriate reduction of the apparent persistence. It is known that in many instances the color of fluorescence of a material is appreciably different from the color of phosphorescence, and consequently a color filter as here proposed may be effective completely to eliminate light of phosphorescence. For example, luminescent material made in accordance with the preceding specification emits fluorescent light of a green color as previously discussed, but in addition, phosphorescent light in a substantial quantity is emitted having a preponderance of radiation in a red band. Thus, by providing light filtration in accordance with my invention it is possible to attenuate or eliminate that red radiation from the resultant image, and the advantages outlined accrue from that elimination.

Still further, this embodiment of my invention is particularly applicable to luminescent screens for use in cathode ray tubes in the electrical recording and indicating arts wherein it is desirable to photograph wave forms of an instantaneous character when produced on a luminescent screen in a cathode ray tube. In this case it is possible substantially completely to eliminate phosphorescence by suitable choice of luminescent materials and light filters, and consequently, only the instantaneously extinguished fluorescent light is recorded.

Furthermore, a cathode ray tube having such a luminescent material and light filter may be used to advantage in a flying-spot type of television image analyzing apparatus wherein a cathode ray tube has its luminescent screen illuminated with a uniform intensity by rhythmical scanning, and a moving spot of light is caused to explore a scene to be analyzed by projecting an image of the luminescent screen of the tube upon the scene. Photoelectric cells are provided in such a system to receive light originating at the luminescent screen and reflected from the scene, and thus television signals are provided by the photoelectric cells. In such a system it is clear that the duration of illumination from each scanned element must be substantially instantaneous and such instantaneity is provided in tubes embodying my invention.

Moreover, it may be seen that in some instances it may be unnecessary or undesirable to polish the side of the screen adjacent the electron gun; in fact, it may be desirable in some instances for changing the directional distribution of light from the screen to provide a roughly ground surface on the side of the screen adjacent the electron gun by grinding that surface with carborundum of say 150 mesh, or, alternately, by sand blasting or other means. Such a roughened surface, further, has the advantage that the efficiency of the screen is improved. The roughened surface presents small reflecting surfaces to light radiated from a point within the screen in a direction toward the roughened surface, which surfaces are in many instances at angles to the direction of travel of the light greater than the critical angle for reflection of light in passing from the material into vacuum, and consequently, an appreciable portion of the generated light is redirected toward the side of the screen to be viewed.

Although the foregoing description of my invention refers exclusively to one method of producing a satisfactory luminescent screen in accordance with my invention, it should be understood that many modifications and variations from my procedure are possible. For example, it is possible to fuse the luminescent material completely and cast it as a thin sheet upon a suitable surface, after which the sheet may be removed and polished, if desired, to give it an appropriate optical surface.

I claim:

1. A cathode ray tube comprising a luminescent screen, an electron gun whereby electrons may be caused to impinge said screen, said tube adapted to permit said screen to be viewed on the side remote from said gun, said screen characterized in that the transparency of said screen to light of the color of fluorescence of said screen is different from the transparency of said screen to light of the color of phosphorescence of said screen.

2. A cathode ray tube comprising a luminescent screen, an electron gun whereby electrons may be caused to impinge said screen, said tube adapted to permit said screen to be viewed on the side remote from said gun, said screen characterized in that it is transparent to light of the color of fluorescence of said screen and substantially opaque to light of the color of phosphorescence of said screen.

3. A cathode ray tube comprising a luminescent screen, an electron gun whereby electrons may be caused to impinge said screen, said tube adapted to permit said screen to be viewed on the side remote from said gun, said screen comprising a plate of transparent cathodo-luminescent material characterized in that the surface of said plate remote from said gun is polished to a glass-like surface.

4. A cathode ray tube comprising a luminescent screen, an electron gun whereby electrons may be caused to impinge said screen, said tube adapted to permit said screen to be viewed on the side remote from said gun, said screen comprising a plate of transparent cathodo-luminescent material and said screen characterized in that the

surface of said plate adjacent said gun is translucent to light of the color of fluorescence of said material.

5. As an article of manufacture, a screen for image reproduction comprising cast cathodo-luminescent material in the form of a relatively thin plate having a surface thereof polished.

6. A cathode ray tube including a homogeneous luminescent screen comprising a plurality of zones of thickness and an electron gun adapted to cause electrons to impinge one of said zones of thickness, another of said zones of thickness serving as a support for said first zone of thickness to render said screen self-supporting, and said second zone being adapted to permit transmission of specular images of said first zone through said second zone.

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