

May 26, 1959

A. E. ANDERSON ET AL

2,888,593

CATHODE RAY TUBE

Filed Dec. 14, 1956

2 Sheets-Sheet 1

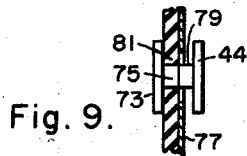


Fig. 9.

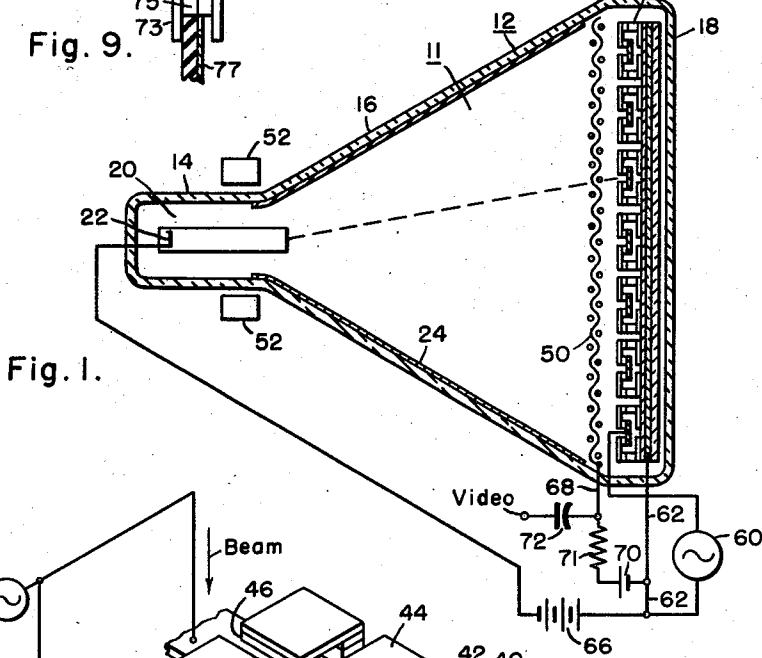


Fig. 1.

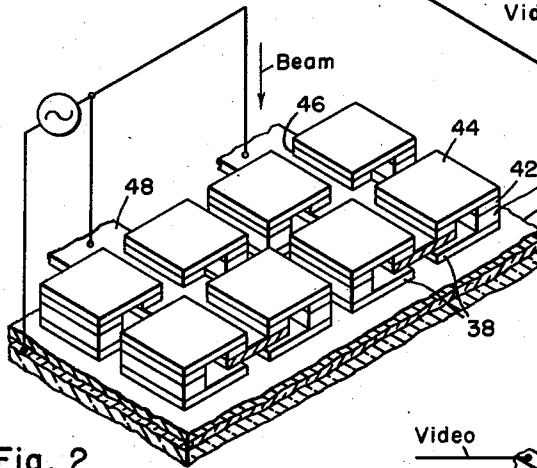


Fig. 2.

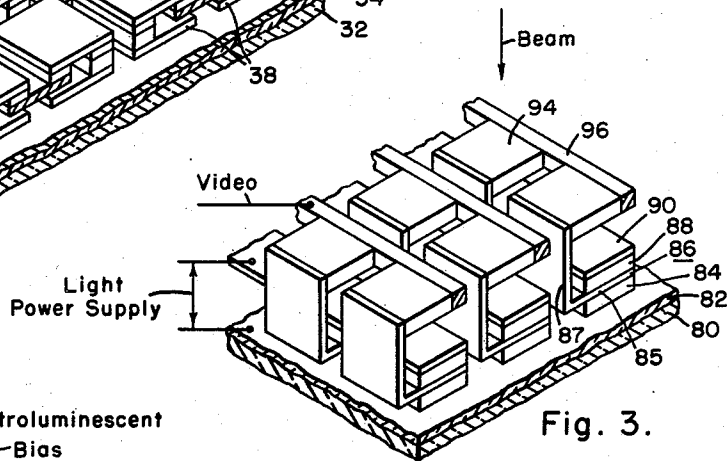
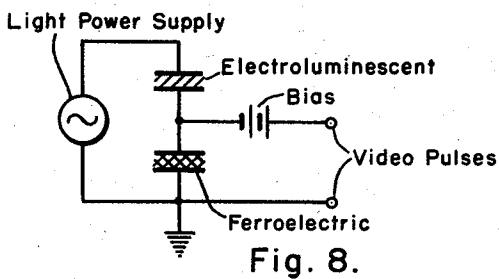


Fig. 3.



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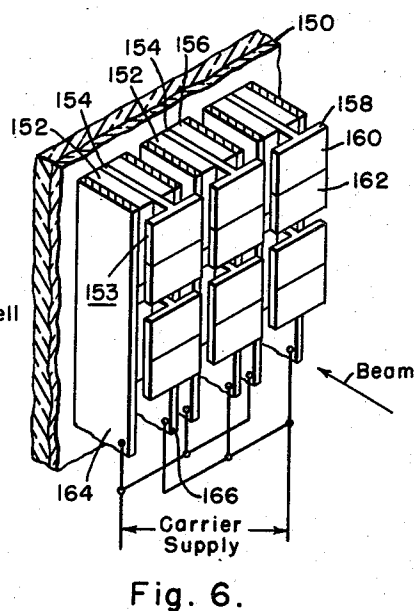
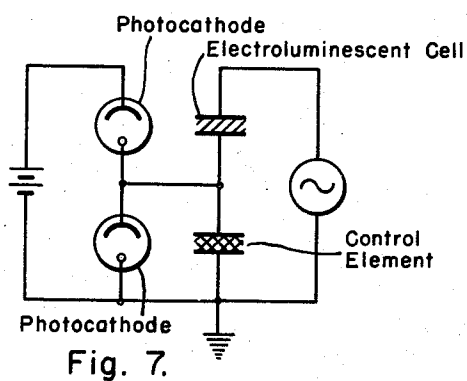
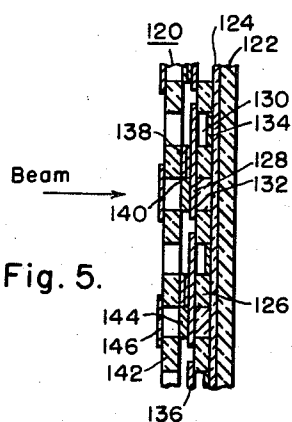
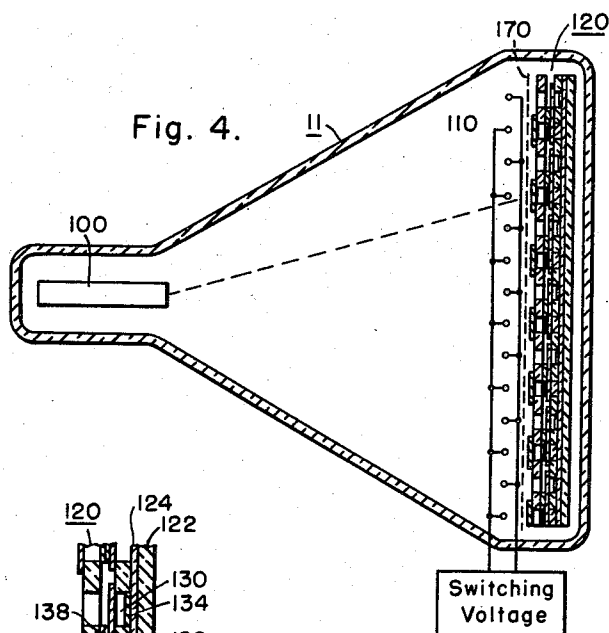
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2 Sheets-Sheet 2



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2,888,593

CATHODE RAY TUBE

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Application December 14, 1956, Serial No. 628,420

9 Claims. (Cl. 315—1)

This invention relates to cathode ray tubes and more particularly to improved means and methods of displaying information on the screen structures.

In the conventional cathode ray tube, an electron beam must supply the energy to produce the light output from the phosphor screen. In addition, the electron beam must also distribute the video intelligence over the entire screen. In the process of distributing this information, the electron beam momentarily excites each point on the phosphor screen once every frame. The decay time of the phosphor material and the persistence of the eye must combine to produce the impression of continuous light output. If a high average brightness is required in the display device, the design requirements for sufficient electron beam power becomes difficult to meet economically.

It is accordingly an object of our invention to provide an improved image display device in which the electron beam is relieved of the task of providing the energy for production of light output. Instead, the electron beam will only be utilized to distribute image data or video information to the mechanism which controls the brightness of externally powered screen elements.

It is another object to provide an improved image display device with high brightness.

It is another object to provide an image device in which flicker is reduced to a minimum.

It is another object to provide an image display system in which the voltages required for operation are of a relatively low value.

It is another object to provide an image display system which is responsive to video signals containing only picture difference information.

It is another object to provide an image device that will operate with reduced bandwidth over that of conventional type systems or will provide higher resolution with similar bandwidth.

It is another object to provide an image device in which each of the elements of the screen are isolated so that information may be written or erased on elements.

It is another object to provide an image display device in which the length of time each picture element is displayed can be varied independently of other element display times.

It is another object to provide an image display device in which the brightness of each picture element remains essentially constant during the desired display time for that element.

It is another object to provide an image display device that is adaptable to large area display systems having high output brightness.

It is another object to provide an image display device which is adaptable to both black and white and color reproduction.

These and other objects are effected by our invention as will be apparent from the following description taken

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in accordance with the accompanying drawings throughout which like reference characters indicate like parts and in which:

Fig. 1 is a sectional view of a tube in accordance with our invention;

Fig. 2 is an enlarged perspective view of the screen structure utilized in the tube shown in Fig. 1;

Fig. 3 is a perspective view of a modified type screen which may be embodied within the tube shown in Fig. 1;

Fig. 4 is a sectional view of a modified tube in accordance with our invention;

Fig. 5 is a sectional view of the screen structure shown in Fig. 4;

Fig. 6 is a perspective view of a modified screen structure which may be utilized in Fig. 4;

Fig. 7 is the circuit equivalent of the screen structure shown in Fig. 4;

Fig. 8 is the circuit equivalent of the screen structure shown in Fig. 3; and

Fig. 9 is a perspective view of a decoupling screen structure.

Referring in detail to Figs. 1 and 2, the numeral 11 indicates generally a cathode ray tube having an envelope 12. The envelope 12 consists of a neck portion 14, a flared portion 16 and a face plate member 18. The neck portion 14 contains a suitable electron gun 20 having at least a cathode 22 for generating a pencil-like stream of electrons. A conductive coating 24 is applied on the inner surface of the flared portion 16 and extending into the neck portion 14 and provides an accelerating electrode for the electron beam generated by the electron gun 20. A screen member 30 is provided within the envelope 12 and positioned adjacent to the face plate member 18. A grid member 50 of substantially the same area as the screen member 30 is positioned adjacent to the screen member 30 and between the screen member 30 and the electron gun 20. Electron deflecting means illustrated by deflecting coils 52 are provided for deflecting the electron beam within the envelope 12 so as to scan a raster of desired configuration on the screen member 30.

The screen member 30 consists of a light transparent support member 32 of a material such as glass which is positioned adjacent to the face plate member 18 and in some applications the face plate member 18 may be the support member. The surface of the support member 32 facing the electron gun 20 is coated with a layer 34 of a suitable light transmitting and electrically conductive material such as stannic oxide. The conductive layer 34 provides the front electrode of the light producing portion of the screen 30 and is connected to one terminal of an electrical energy source or light power supply. A continuous light producing layer 36 of suitable phosphor material which exhibits the property of emission of light under electric field excitation is deposited on the surface of the conductive front electrode 34. This type of phosphor material is referred to as an electroluminophor. A plurality of electrically conductive elements 38 are deposited on the phosphor layer 36. The number of elements 38 is dependent on the desired resolution. This mosaic layer of conductive elements 38 forms the back electrode and a light reflecting surface of the light producing portion of screen 30. By breaking the back electrode into a plurality of elements, the screen 30 provides a similar number of isolated individually controllable display areas or elements. The above-described structure which includes the transparent conductive front electrode 34, the phosphor layer 36 and the mosaic layer of conductive elements 38 may be referred to as the light producing means or portion of the screen member 30. The electric field that pro-

vides the stimulation to the phosphor layer 36 is impressed across the phosphor layer 36 by the front electrode 34 and the conductive elements 38 by means of an external power source. An article entitled "Electroluminescence and Related Topics" by G. Destriau and H. F. Ivey in the December 1955 issue of the Proceedings of the I.R.E. gives a complete explanation of this type of light cell.

By way of explanation, electroluminescence was first completely disclosed by G. Destriau in London, Edinburgh and Dublin Philosophical Magazine, series 7, volume 38, No. 285, pages 700-737 (October 1947), article entitled "The New Phenomenon of Electrophotoluminescence." In the phenomenon of electroluminescence, selected phosphor materials are placed within the influence of an electric field, such as by sandwiching the phosphor material between two spaced electrodes and applying an alternating potential between these electrodes. The resulting electric field which is created across the electrodes excites the phosphor material to luminescence, and the phosphor materials which display this electroluminescence are thus termed "field responsive." Such phosphor materials are normally admixed with a dielectric material or a separate layer of dielectric material is included between the electrodes in order to prevent any arcing thereacross which would short out the electroluminescence cell, but a separate dielectric material is only desirable and not mandatory for the cells may be operated under some conditions without any dielectric where the applied electric field is as high as 100 kv. per centimeter. Normally the spaced electrodes are parallel, but they need not be, as where graded field intensities are desired.

In order to provide isolated control of the intensity of light output from each of the screen display elements, it is necessary to provide a control means operatively associated with each of the conductive elements 38. The control means is a variable impedance responsive to the electron beam and adapted to control the intensity of the light output from the light producing portion of the screen. In the specific embodiment, a voltage or charge sensitive capacitor type control element is operatively interposed between the light producing area and the light power source.

On each of the conductive elements 38 of the mosaic layer a control assembly is positioned. The control assembly includes an electrical conductive contact 40, which serves as one plate of the control capacitor, deposited on the conductive element 38 and in electrical contact therewith. In the specific embodiment shown, the control contact element 40 covers only a portion of the back surface of the conductive element 38. It is desirable to have the capacitances of the light producing element and the control element approximately of the same value. A layer 42 of a suitable material whose differential permittivity is a function of applied bias voltage or charge is deposited onto the control contact element 40. An electron sensitive element 44 of electrical conductive material and of substantially the same area as the conductive element 38 is positioned between the electron gun 20 and the conductive element 38 with one portion supported on and in contact with the dielectric layer 42 and serving as the other plate of the capacitor control element. Positioned on the surface of the electron beam sensitive element 44 facing the conductivity element 38 is another dielectric layer element 46. Attached to the dielectric element 46 is a conductive bus bar 48 which extends across the entire screen 30. The electron sensitive element 44 and bus bar 48 serve as plates for the element 46 to form a second capacitor element.

In the specific example shown in Figs. 1 and 2, the display elements are in parallel rows. By proper construction of control assembly, each bus bar 48 is

connected to two control elements in each row across the entire screen 30.

The bus bars 48 are connected to a common bus bar and a lead is brought to the exterior of the envelope 12. This lead is connected to one terminal of the light power supply 60 capable of providing the necessary power to the light producing layer 36 of the screen 30. The other terminal of the light power supply 60 is connected to the front electrode 34 by means of the lead 62. The lead 62 is also connected to the positive terminal of a potential source illustrated as a battery 66. The negative terminal of the battery 66 is connected to the cathode 22 of the electron gun 20. The battery 66 provides the acceleration potential for the electron beam.

The conductive grid member 50 is provided between the electron gun 20 and the screen 30 and positioned adjacent to the screen 30. The grid 50 is provided with a lead 68 to the exterior of the envelope 12 which is connected to the positive terminal of a battery 70 through resistor 71. The negative terminal of the battery 70 is connected to the screen 30 by means of the lead 62. The grid 50 is connected through a condenser 72 to the video signal source.

The preparation of the screen structure is given in more detail in the copending application, Serial No. 628,421 entitled "Display System" by E. A. Sack, Jr., filed December 14, 1956, and assigned to the same assignee.

In general, the support member 32 is of a suitable light transmitting support member such as glass having a light transmitting and electrically conductive coating 34 of a resistance of about 100 ohms per square or less. A suitable material is stannic oxide which may be evaporated onto the glass layer 32.

The next step in the preparation of the screen is the deposition of the field-responsive phosphor onto the one surface of the exposed sandwich. There are many well-known methods of accomplishing this, and as a specific example, the finely-divided phosphor material, for example zinc sulfide activated by copper, may be admixed with a solvent such as butyl acetate and with a polyvinyl chloride lacquer. The proportions of the constituents are not critical and may be varied within wide limits, but as a specific example, three parts by weight of phosphor may be mixed with 50 parts by weight of thinner and 35 parts by weight of polyvinyl chloride lacquer. The foregoing admixture may be sprayed in a plurality of coatings, for example, four, according to the desired thickness, drying between each coating. Other dielectrics and solvents may be substituted for the foregoing specific examples, as is well known.

Suitable phosphors which are referred to as electroluminophors for this application are zinc sulfide copper and manganese activated, and zinc sulfide-copper activated, to mention a few of these phosphors.

Although we have only described the utilization of a spraying technique for embedding the phosphor in a suitable plastic, there are other techniques that are suitable. The phosphor may be deposited by the use of a glass frit or enamel as the binding agent for the electroluminescent phosphor to provide what is referred to in the literature as an enamel-type cell. Another possible technique of depositing a suitable phosphor layer is evaporation. It is also possible to prepare the phosphor layer by a sintering technique.

With the phosphor layer 36 deposited on the conductive layer 34, it is necessary to deposit the conductive elements 38 in the desired arrangement. This may be accomplished by evaporating a suitable conductive material such as silver or aluminum through a mask member to form the desired array of back electrodes 38 as is illustrated in Fig. 2. The mask should have open areas corresponding to the desired element areas and spacing and should be positioned adjacent to the phosphor layer for evaporation.

layer and is a constant potential or charge which is impressed continuously. The bias voltage is to assure that the control element operates over the optimum portion of its characteristic. By placing the plate of the capacitor control element in such a position as to allow electron bombarding as previously described, it is possible to control the impedance of the capacitor. In the voltage divider arrangement, a small control signal of a voltage or charge applied across the capacitor control element causes enough of the light power source voltage to appear across the electroluminescent layer to establish its emittance at picture high light level. As the control signal increases, a large decrease in capacitance is obtained across the control layers resulting in the light power source potential appearing primarily across the control element instead of across the electroluminescent layer and lower brightness levels result.

By the utilization of a control element capacitive in nature, it is possible to obtain a high leakage resistance and, therefore, each control element is capable of storing charge for a comparatively long period of time. Capacitance control lends itself to electron beam type excitation in that charge deposited by the beam causes the element to respond substantially instantaneously to the control excitation. The modification of the control bias or potential across the capacitive control element is brought about by modulating the intensity of the electron beam and/or by fixing the potential to which each element charges.

It is assumed in this and other embodiments herein that the peak to peak amplitude of the light power supply voltage is small compared to the control signals. In this case the charge deposited on a control element or elements by the electron beam during its dwell time which is short compared to the time of one cycle of power wave will be essentially independent of the instantaneous alternating potential on the control element. Although this condition is desirable, it is not essential for successful operation of the device. In cases where it is not practical to secure this condition the light power source may be disconnected in a predetermined order from each line of elements while the beam is on that line without greatly affecting the performance of the device.

Alternatively it is possible to effectively decouple the charge storage function from light power source by incorporation of a structure such as illustrated in Fig. 9. The decoupling structure is positioned on the surface of the screen 30 facing the electron gun 20. The structure may consist of a dielectric sheet 81 having a plurality of apertures provided in the sheet 81 with an aperture aligned with each element 44. A resistive plug 75 would be provided in each aperture and a conductive electrode 73 would be provided over each aperture of the sheet on the scanned side of the dielectric sheet 81. The opposite surface of the dielectric sheet 81 would be coated with a conductive material 77. The elements 73, 77 and 81 make up a plurality of isolated storage capacitors. The resistive plug 75 is in contact with electrode 73 and is connected to the element 44. A conductive block 79 may be utilized to position the decoupling structure from the screen 30.

In operation, the electron beam strikes the conductive element 73 to charge the decoupling capacitor. The exposed surface 73 of the capacitor is connected to the previously exposed surface 44 of the variable control capacitor or capacitors through a high resistance 75 and a conductive block 79, the opposite face or plate 77 of this storage capacitor being preferably connected to a common junction between the power supply source and the direct current reference potential of the phosphor screen.

In such a configuration it is desirable that the first storage or decoupling capacitor be as large, and preferably larger than the maximum value of the variable control capacitance to which it is connected. It is also

desirable that the series resistance be as large and preferably larger than the impedance of the first storage capacitor at the light power supply frequency. The product of this resistance times the effective capacity to which it is tied should, however, be small compared to the desired display time for an element in order to achieve maximum benefit from the storage capabilities of the screen.

In operation the voltage or charge on the first storage decoupling capacitor is used to control in the manner previously described for the case where the beam strikes the exposed surface of the variable control capacitor. Because of the alternating current voltage divider action between the isolating resistor and the first storage capacitor, only a small fraction of the light power supply voltage appears across the first storage capacitor and thus the charge or voltage on this storage capacitor can be controlled essentially independently of the instantaneous value of the light power supply voltage.

Once a specific charge or voltage has been determined on the first storage capacitor, a part of this charge or voltage is transferred during several cycles of the driving voltage of light power supply to the variable capacitance control capacitor on capacitors. Since the average alternating current voltage on the variable control capacitor is zero, the charge transferred to the variable control capacitor from the first storage capacitor will be essentially independent of the light power supply voltage as long as this transfer is allowed to proceed during the time of several cycles of the light power supply voltage. It is obvious to those skilled in the art that the decoupling system described requires only that the driving frequency be higher than the field frequency of the display. In fact, a driving frequency having a period much shorter than the beam dwell time on a single picture element would eliminate the need for a first storage capacitor and decoupling resistor altogether. It is also obvious that an inductance could be used in place of the resistor in another embodiment.

It is also possible to exploit another advantage of the use of the decoupling capacitance and resistance or inductance previously described. It is possible to remove the display screen (variable control capacitors and associated electroluminescent cells) from the vacuum envelope. In this embodiment the electron beam would strike conducting elements displayed on a screen within the envelope which are connected by separate leads through the envelope to the decoupling resistance which is in turn connected to the variable control capacitors. For remote operation of the screen, the capacitance of these leads to ground can serve as the first storage capacitance. With this configuration the size of the display screen is not limited by the vacuum envelope.

Referring in detail to Fig. 3, there is shown a modification of the screen structure shown in Fig. 2. The structure is modified so as to eliminate the requirement for the grid 50 shown in Fig. 1. Rather than applying the video information to the grid 50 to modulate the electron beam, as in Fig. 2, the electron beam simply opens the circuit and the video is applied to the individual elements by video bus bars. The screen structure consists of a support member 80 having a light transparent electrical conductive coating 82 deposited thereon in a similar manner as that described with respect to that of Fig. 2. The conductive layer 82 serves as the front electrode of the electroluminescent light panel and is connected to one terminal of a suitable light power supply. In the specific embodiment shown, a plurality of electroluminescent phosphor areas 84 are deposited on the conductive coating 82 in parallel rows.

The phosphor layer structure may be a mosaic or continuous layer as shown in Fig. 2. A control element is positioned on the surface of each of the phosphor elements 84. In the specific embodiment shown, this control electrode 86 is in the form of an L with one leg 85 of the L forming the back electrode of the electrolumi-

The control elements which are charge or voltage sensitive capacitors may be formed as a separate structure and connected to the back electrodes 38. One particular class of materials that are particularly useful in this application are ferroelectric dielectric materials. There are several suitable materials such as barium titanate, barium-strontium titanate, barium stannate, sodium-columbate, sodium-tantalate, potassium-columbate and potassium-tantalate. The preparation of barium titanate ceramics is fully discussed in an article entitled "Preparation of Reproducible Barium Titanate" by R. M. Callahan and J. F. Murray in the May 1954 issue of the Bulletin of the American Ceramic Society. The preparation of dielectric sheets is also discussed in U.S. Patent 2,539,446 entitled "Process for Producing Dielectric Sheets" by W. J. Lies and issued January 30, 1951. Various ceramic mixtures that may be utilized are also found in U.S. Patents 2,402,515, 2,402,516, 2,402,517, 2,436,839 and 2,452,532.

The dielectric sheet may be prepared by any suitable process. The dielectric sheet of a material such as barium titanate is lapped by the use of a suitable lapping compound to a thickness of approximately 10 mils. The dielectric is then sprayed with a suitable silver paint such as Du Pont 6303 thinned with toluol until the layer is completely covered. The dielectric sheet is then baked in an oven at about 700° C. for 15 to 30 minutes. After removal from the oven, both sides of the dielectric sheet are tinned with a suitable solder such as 36% lead, 62% tin and 2% silver solder. Two brass blocks or sheets of desired thickness are then prepared by tinning one side of each of the blocks with a similar solder as utilized on the dielectric and the tinned blocks of brass are placed on either side of the dielectric sheet with the tinned surfaces of the blocks adjacent the tinned surface of dielectric sheet. The sandwich is then heated to about 300° C. and then cooled. The edges of the sandwich are ground off to remove any silver or solder which might short out the dielectric sheet. Once the brass dielectric sandwich has been fabricated, it may be used in the construction of any number of screen control configurations. The sandwich may be cut out into elements by any appropriate machining process. This is described in detail in the previously cited copending application. By proper machining, the structure shown and illustrated in Fig. 2 may be obtained. It is seen by this manner of preparation of the control structure that even though a large number of control elements are necessary, the device can still be constructed economically.

The control element array may be attached to the light producing portion of the screen 30 by the application of conducting glue, paint or varnish to each of the back electrodes 38 on the electroluminescent phosphor layer 36. Before this conducting glue dries, the control element array is positioned on the light producing portion and the legs of the control matrix are held to the back electrode elements 38 until the paint has dried. This drying process may be accelerated by placing the screen in an oven at a temperature of about 50° C.

In the operation of the device shown in Figs. 1 and 2, the light power supply 60 supplies a suitable voltage, for example 400 volts and at a suitable frequency of about 2000 cycles per second. One terminal of the source 60 is connected to the front electrode 34 and the other terminal is connected to the common bus bar 48 of the screen member. A suitable video signal that may be derived from any suitable receiving circuit is applied to the grid member 50. It is also necessary in this application that the exposed surface of the conductive element or electron sensitive element 44 in contact with the charge sensitive element 46 be of a secondary emission ratio greater than one. In the structure shown, the surface of the conductive element 44 is of brass and it may be necessary to treat the surface or place a material such as magnesium oxide thereon to increase the secondary emission

ratio of the exposed surface. As the electron beam from the gun 20 scans across an element 44, the charge retained by the element 44 will be adjusted by the beam so as to minimize the potential difference between the element 44 and the grid 50 to which both video signal and bias voltage are applied. Since as previously indicated the secondary emission ratio of element 44 is greater than unity and preferably equal to two, the electron beam in striking the element 44 will, through the process of secondary emission, effectively remove electrons from the element 44 and thus charge it positively in absence of a video signal. In this manner, the potential of the bias battery 70 is applied across the control capacitors consisting of the layers 42 and 46 one or both of which may be nonlinear. Scanning a raster with no video applied to grid 50 will therefore establish an initial operating point about which a large change in average capacitance will be obtained with a relatively small change of charge or voltage on the capacitor control elements. By proper choice of capacitance ratios between the electroluminescent capacitor and control capacitor at this operative point the alternating or time varying voltage from supply 60 is made to divide so as to cause the light producing or display area to emit sufficient light to set it about in the middle of its most useful brightness range. If any display element is to be darker on a succeeding scan, the video voltage is polarized so as to add bias voltage on the element 44 as the beam crosses the element. In this manner the element 44 is charged to the new or more positive level. If, instead, the display element is to be brighter, the screen voltage is made less than the voltage applied by the previous scan as the beam crosses the element. In this case, electrons from the beam are deposited on the element and it is made more negative. In this embodiment, the electron beam remains at a given level at all times except during the retrace scanning movement.

In a second form of operation the intensity of the beam may be modulated by the video signal and the grid 50 may be kept a constant potential during one complete raster scan. If, as before, the elements 44 have a secondary emission ratio greater than unity, the beam will effectively remove electrons from the elements so long as grid 50 is more positive than these elements. On the other hand, electrons will be deposited on the same elements whenever the elements are more positive than grid 50. It is, therefore, apparent that a sequential form of operation can be used in which elements are first charged with large beam current to dark level (maximum positive potential) or high light level (minimum positive potential) and secondly charged toward the opposite state to a limit proportional to the beam intensity during the time the beam is on any element. With constant velocity scan, the beam dwell time on all elements is the same and the deposited or removed charge from each element is directly proportional to the beam current. The operation of the screen structure impressed thereon by the electron beam in response to the control signal is given in more detail in the previously mentioned copending application.

In general, the light power supply or carrier power supply is provided in the form of a time varying potential. The light power voltage is applied over all to the screen structure across each of the elemental display areas. The circuit illustrated in Fig. 8 aids in the operating description of the screen. Each display area consists of a light producing member such as an electroluminescent layer and a control layer connected in voltage divider network. The light power supply supplies the energy required to excite the electroluminescent layer. It may also be desirable to utilize a light power current supply rather than light power voltage supply in which case the elements would be connected in current divider arrangement.

The bias voltage or charge is applied to the control

nescent light cell. The other leg 87 of the L-shaped control electrode 86 is substantially perpendicular to the transparent support member 80 and directed away from the screen structure. Deposited on the exposed surface of the leg member 85 of the control electrode 86 adjacent the phosphor element 84 is a layer of dielectric material 88. A conductive bus bar 90 is connected to the exposed surface of the dielectric layer 88, and extends across the entire screen and is connected to a dielectric layer 88 within each row of elements. The leg portion 87 of the control electrode 86 supports and is electrically connected to an electron sensitive element or area 94. The element 94 is parallel to the electroluminescent light layer and positioned between the electron gun 20 and the light display element. The electron sensitive element 94 is connected to a video bus bar 96 which runs parallel to the conductive bus bar 90. The electron sensitive area 94 which connects the control electrode 86 to the video bus bar 96 is of a material which exhibits electron bombardment induced conductivity. It may be desirable to utilize an insulating support portion with the electron bombardment induced conductivity material deposited in the surface facing the electron beam source. A suitable electron bombardment induced conductivity material would be cadmium sulphide powder. The conductive bus bars 90 are connected to the other terminal of the light power supply while the video bars are connected to the video source.

In the operation of the device shown in Fig. 3, a constant current electron beam is utilized to scan the screen structure. In the scanning movement the electron beam will strike the electron sensitive area 94 and cause the material normally resistive to become conductive and thereby apply the video intelligence to the selected control electrode from the video bus bar 96. During the time that this control electrode 86 is connected to the video bus bar, the control electrode 86 is charged to a potential indicative of elemental brightness desired. This charge remains on the control electrode 86 until it is adjusted to a new value on the following scan. In the device shown in Fig. 3, there is shown only the utilization of an electron bombardment induced conductivity material. It is obvious the other beam sensitive switches could be utilized to control the video application to the selected control elements. A decoupling structure similar to that shown in Fig. 9 may be provided between the beam sensitive switch and the control capacitor in this configuration.

In the embodiments shown in Figs. 1, 2 and 3, it is only necessary to readjust the brightness level of each elemental area without first erasing the information that was stored on the element in the preceding scan. In Figs. 4, 5 and 6 there are structures illustrated in which the design is such that it is necessary to store the information and then to erase the information before proceeding with additional display information.

Referring in detail to Figs. 4 and 5, there is shown a cathode ray tube 11 having an electron gun 100, display screen 120, and deflection grid 110. The deflection type grid tube is well known in color television and an example of such a device is given in an article entitled, "The PDF Chromatron—A Single or Multi-Gun Tri-Color Cathode-Ray Tube," by R. Dressler in the July 1953 issue, volume 41, page 851, of the "Proceedings of the I.R.E." The screen structure 120 shown in Figs. 4 and 5 consists of a light transparent support member 122 having a layer 124 of a suitable light transparent electrical conducting material on the electron gun side of the support 122. The grid structure 126 of an insulating material is positioned on the surface of the transparent conductive coating 122. The grid 126 may be of glass and prepared by photoetch process to provide a plurality of horizontal rows of apertures 128 and 130. If a deflection grid, such as shown in the specific embodiment is utilized to provide a vertical deflection of the electron beam, the even horizontal rows of apertures 128 will be filled with

a dielectric material 132 in contact with the transparent conductive coating 124. The odd horizontal rows will be partially filled with a suitable ultraviolet light emitting phosphor material 134, such as rhombohedral aluminum oxide activated by aluminum. A plurality of horizontal strips 136 of a thin conductive coating of a material such as gold having a high secondary emission ratio are deposited on the grid 126. Each of the strips 136 extends across the screen and covers a pair of rows including an odd and even row of apertures 128 and 130. A strip 138 of electroluminescent phosphor is positioned on each gold strip 136 between the odd and even rows of apertures associated with each strip 136. An electrically conductive strip 140 is deposited on the phosphor strip 138 and serves as the back electrode. A second grid 142 of insulating material and of similar configuration as the first insulating grid member 126 is positioned on the screen structure. The grid 142 has its openings aligned with the first insulating grid member 126. An ultraviolet phosphor material 144 of similar material as 134 is deposited in the even rows of apertures 128 in the grid 142 into contact with the gold foil strips 136 and then a gold foil strip 146 is deposited over each of the even rows of apertures 128 across the entire screen.

The light power supply for the phosphor layer 138 is applied across the conducting strips 140 and the transparent conductive coating 124. The electron beam from the electron gun 100 in scanning across the target may act to charge or discharge the dielectric capacitor 132 situated in the even rows of apertures 128 of the grid 126 depending on whether the beam position is on the even or odd rows of apertures. The position is determined by a control signal applied to the deflection grid 110. If the electron beam is directed on the even rows of apertures 128, the electron beam bombards the gold foil strip 146 causing the generation of secondary electrons from the opposite surface thereof, which in turn strike the ultraviolet phosphor material 144. The photons emitted from the ultraviolet phosphor excite the negative ultraviolet sensitive photocathode, the gold layer 146, which emits electrons. These electrons are collected by the phosphor supporting electrode 136 which also forms an inner face between the electroluminescent material and the ceramic material. With the electron beam in this position, accumulation of a negative charge on the inner face layer 136 acts to charge the dielectric layer 132 since its other face is returned to ground. When the electron beam is on the odd row of apertures 130, the beam strikes a positively polarized phosphor 134, which in turn excites a photocathode, the layers 136, that is electrically a part of the inner face layer. In this case, the electrons are removed from the inner face 136 and the dielectric is charged positively. It may be necessary to reset each element before applying new charge information. This can be accomplished by using a full-on beam to completely charge or discharge an element. The scan structure shown in Figs. 4 and 5 has the advantage that the electron beam current is multiplied in the charge and discharge phototubes, thus decreasing the time required to write or erase with a given beam current. The equivalent circuit of the screen structure shown in Fig. 5 is illustrated in Fig. 7. The video signal may be applied to the electron gun.

In Fig. 6, another modified type of screen structure is illustrated, which may be embodied in the tube shown in Fig. 4. The screen consists of a support structure with the light producing and control structure layers deposited on edge with respect to the viewer.

The screen structure is again comprised of a plurality of elemental screen display areas positioned on a support structure 150 of a suitable light transparent material, such as glass.

Each display area of the screen consists of a sandwich made up of a layer 152 of dielectric material, a layer 156 of an electroluminescent material and a layer 154

of an electrically conductive material between the layers 152 and 156. The layers 152, 154 and 156 are perpendicular to the support member 150 and may be fastened by suitable cement with a vertical orientation. The conductive layer 154 extends beyond the layers 152 and 156 and is provided with an electron sensitive electrode 158. The electrode 158 is perpendicular to the layer 154 and of similar area as the display area. The exposed face of the electrode 158 is provided with an upper area 160 and a lower area 162. The upper portion 160 has a secondary emission ratio greater than unity while the lower area 162 has a secondary emission less than unity. The areas 160 and 162 may be treated in a well known manner or suitable materials deposited to give the desired secondary emission.

The light power potential is again applied across the sandwich structure of the layers 152, 154 and 156 by vertical conductor bars 164 and 166. A pair of bars 164 and 166 is provided for each vertical row of display elements or areas. The light power supply is applied across the bars 164 and 166. A direct current bias voltage is applied between the screen and the electron gun.

It is also necessary to insert a grid member 170 in the tube shown in Fig. 4 between the deflection grid 110 and the screen structure. The grid is biased positive with respect to the acceleration voltage applied to the screen.

In the operation of the device, if we assume that all the areas 160 and 162 are at the direct potential of the grid 170 and that this voltage is sufficiently greater about 600 volts than the accelerating voltage supplied to the conductors 164 and 166, then the electroluminescent cells are biased "off." If the switching potential is applied to the deflection grid 110 such that the electron beam modulated by the video signals applied to the grid 170 impinges on the lower area 162 of each display element during the scan, then each electrically conductive layer 154 will be charged negatively with respect to voltage on grid 170 depending on the current in the electron beam as it traverses the elements. This would be the write or storage condition within the tube. The brightness of each element is determined by the amount by which the electrode 154 remains positive with respect to the accelerating voltage. The elements will remain in this storage state emitting light in accordance with the storage pattern until the control charge is removed from the electrode 154. This may be accomplished on the erase scan when the switching voltage on the deflection grid 110 is such that the electron beam will impinge on the upper area 162 of the electron sensitive elements. During the erase scan, the electron beam will be turned on full so that each element electrode 154 returns to the potential of grid 170 as the beam passes over the element and the brightness is diminished.

From the foregoing, it will be seen that we have provided several tube display devices incorporating screen structures which are sensitive to electron bombardment. The display devices provide increased brightness over the conventional cathode ray tube and also provide display storage.

While we have shown our invention in several forms, it will be obvious to those skilled in the art that it is not so limited, but it is subject to various other changes and modifications without departing from the spirit and scope thereof.

We claim as our invention:

1. An image display device comprising an evacuated envelope and having therein a light producing means responsive to the variations of a time varying electric field, a first means operatively associated with said light producing means for providing an electric field therefor and a second means operatively associated with said light producing means and said first means for controlling the magnitude of the time varying electric field across said

light producing means in response to electron bombardment.

2. An image display device comprising, an envelope and having therein an electron source for producing and generating an electron beam, a screen member, said screen member comprising a plurality of light producing means responsive to variations of an electric field impressed thereacross, means for providing an electric field across said light producing means, and storage control means interposed between said light producing means and said means for providing an electric field for controlling said electric field impressed across said light producing means, said control means responsive to electron bombardment by said electron beam.

3. An image display device comprising, an envelope and having therein an electron source for producing and generating an electron beam, a screen member, said screen member comprising a plurality of light producing means responsive to variations of an electric field impressed thereacross, a light power source for providing an electric field across said light producing means, control means interposed between said light power source and said light producing means for controlling said electric field impressed across said light producing means, said control means comprising a capacitor whose reactance varies with applied bias and electron sensitive means associated with said capacitor for modifying the reactance of said capacitor in response to electron bombardment.

4. An image display device comprising, an envelope and having therein an electron source for producing and generating an electron beam, a screen member, said screen member comprising a plurality of light producing means responsive to variations of an alternating electric field impressed thereacross, means for providing an alternating electric field across said light producing means, and control means operatively interposed between light producing means and said means for providing an alternating field for controlling said electric field impressed across said light producing means in response to electron bombardment by said electron beam, said control means comprised of at least one body of a material exhibiting the property of variable differential permittivity in response to an applied bias or voltage.

5. An image display device comprising, an envelope and having therein an electron source for producing and generating an electron beam, a screen member, said screen member comprising a plurality of light producing means responsive to variations of an electric field impressed thereacross, means for providing an electric field across said light producing means, and control means for controlling said electric field impressed across said light producing means in response to electron bombardment by said electron beam, said control means comprising a body of ferroelectric material whose permittivity is a function of applied voltage or charge.

6. An image display device comprising, an envelope having therein an electron source for producing and generating an electron beam, a screen member, said screen member comprising a layer of phosphor material exhibiting the property of light emission in response to electric field excitation, electrode means positioned on opposite sides of said phosphor layer for impressing an electric field across said layer, a light power source for impressing a voltage across said electrodes, and control means operatively interposed between said phosphor layer and said light power source responsive to bombardment by said electron beam for controlling the voltage impressed across said phosphor layer.

7. An image display device comprising an evacuating envelope and having therein a light producing screen member and an electron beam for scanning a raster on said screen member, said screen comprised of a plurality of isolated light producing elements, each of said light producing elements comprising a light producing layer

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of an electroluminophor material, a capacitor type control element exhibiting the property of variable permittivity in response to a potential variation applied thereacross, means for providing a time varying electric field across said control element and said electroluminophor layer, and means for modifying the potential across said control element in response to bombardment by said electron beam to vary the voltage division between said control element and said electroluminophor layer.

8. An image display device comprising an envelope and having therein an electron source for generating electrons, a screen member for intercepting the electrons from said electron source, said screen member comprising a plurality of light producing means responsive to variations of a time varying electric field impressed thereacross, control means connected to said light producing means, means for providing a time varying electric field across said light producing means and said control means, said control means comprising a capacitor whose reactance varies with applied bias, means for applying the bias to said control means to modify the reactance of said control means and thereby modify the voltage distribution across said control means and light producing means from said time varying electric field, said biasing

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means comprising a photosensitive device responsive to radiations generated by the electrons from said electron source.

9. An image display device comprising an envelope and having therein a display screen, said screen member comprising a plurality of light producing means responsive to variations of a time varying electric field impressed thereacross, control means connected to said light producing means, means for providing a time varying electric field across said light producing means and said control means, said control means comprising a capacitor whose reactance varies with applied bias, means for applying the bias to said control means to modify the reactance of said control means and thereby modify the voltage distribution across said control means and light producing means from said time varying electric field, said biasing means comprising a photosensitive device.

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