Dec. 21, 1965 C. FELDMAN 3,225,238

CATHODE RAY TUBE WITH TRANSPARENT COLOR SCREEN

Original Filed April 19, 1957

FIG. 1

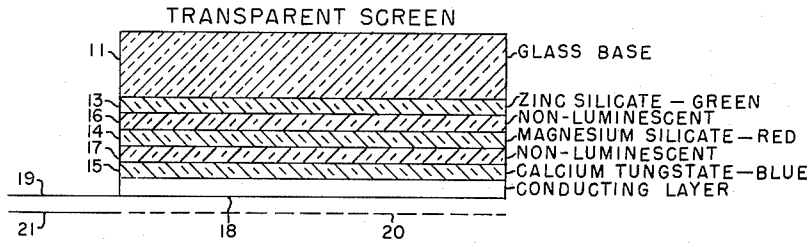


FIG. 2

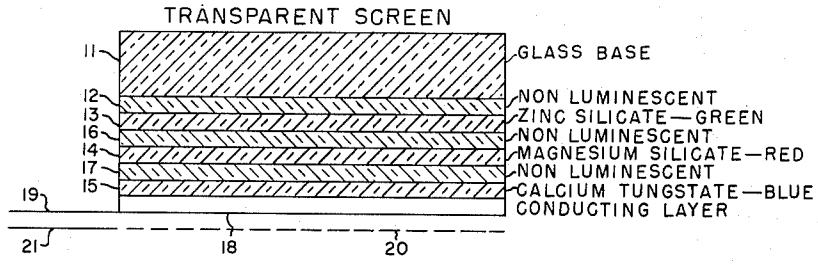
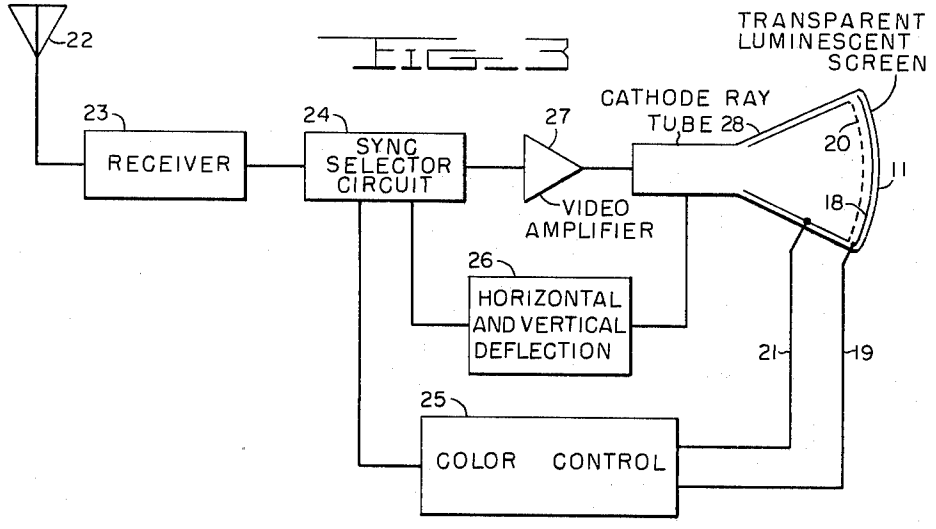


FIG. 3



INVENTOR
CHARLES FELDMAN

BY Richard C. Reed
Walter M. O'Brien

ATTORNEYS

United States Patent Office 3,225,238 Patented Dec. 21, 1965

3,225,238

CATHODE RAY TUBE WITH TRANSPARENT COLOR SCREEN

Charles Feldman, Hollin Hills, Va., assignor to Davohn Corporation, a corporation of Delaware

Original application Apr. 19, 1957, Ser. No. 653,867. Divided and this application July 20, 1962, Ser. No. 211,458

2 Claims. (Cl. 313—92)
(Granted under Title 35, U.S. Code (1952), sec. 266)

This application is a division of my copending application Serial No. 653,867, filed April 19, 1957, and which is now abandoned.

This application is related to my copending application, Serial No. 861,731, filed December 22, 1959, now Patent No. 3,046,154, granted July 24, 1962, which is a division of application Serial No. 653,867, filed April 11, 1957, now abandoned, and claims a method for making a transparent luminescent screen in one form as described herein.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to the production of color images as in television. More particularly, it relates to a transparent luminescent screen for producing color images and to a cathode ray tube containing the same.

According to the prior art, opaque powders have been used in the preparation of screens of cathode ray or television tubes to produce images. These tubes have the disadvantage of not being sharp because of the light dispersion caused by the opaque powder particles in the screen. They have the further disadvantage of reflecting incoming light, thus giving poor contrast between the background and the light producing image. The tubes therefore fail to provide good daylight viewing.

It has been heretofore proposed to obtain chromatic variations in a cathode ray tube by varying the penetration of an electron beam into a screen composed of layers of different colored light producing phosphors. In practice, however, the use of powder phosphors in forming these multilayer screens is completely out of the question. Each grain of the powder phosphor is about 1 to 3 microns in diameter and layers several grains thick must be built up to achieve efficient screens. Such magnitudes of thickness are too great for electron penetration at reasonable voltages (10–20 kv.) Furthermore, a screen sufficiently thick to be efficient is no longer transparent and several layers superimposed on one another would form a completely opaque screen preventing light from the farther layers from reaching the observer.

Transparent luminescent screens of my invention have overcome the above objections and the entire chromatic system has become more practical. A cathode ray tube has been provided with thin transparent luminescent layers, each layer being capable of emitting light of a different color upon excitation with a beam of electrons. In the transparent layers light scattering is minimized and the sharpness of the image greatly improved. The transparent films reflect no light and by making the interior of the tube light absorbing, there is no reflection and daylight viewing is greatly improved.

The general idea of a transparent multilayer chromatic screen is that electrons enter the screen and strike the first transparent phosphor layer exciting it to luminescence. This luminescence is viewed through the remaining transparent phosphor layers and the glass substrate. If the electron energy is low and the electron is stopped in this first layer, then the color viewed will be only that due to the phosphor of the first layer. As the

electron energy is increased, the electrons will begin to penetrate the second layer and excite the second phosphor which luminesces in a color different than the phosphor of the first layer. The color seen by the observer will be a combination of these two colors. This process can be extended for three or more layers.

Little information exists on electron penetration into and through solids. The existing theoretical treatments fit only the simplest systems and few meaured values for solids are available. The situation in phosphors is complicated because the exact mechanism of excitation is not certain. That is, it is difficult to determine what part of the electron energy that is lost in collision actually goes to excite the luminescent center in the solid. However, one may draw the following general conclusions from the existing published work:

The depth of electron penetration or the range (R) increases as the electron velocity or energy (E) increases, according to a relation of the following equation:

$$R=CE^n$$

where C and n are constants depending on the system involved. The constant n is between 1 and 2.

At sufficiently high electron energies, the luminescent cross section and hence the brightness starts to decrease. This decrease, of course, takes place only after the electrons have sufficient energy to penetrate the phosphor. As long as the electrons are completely stopped in the phosphor layer, they give all of their energy to the solid and the luminescent brightness is directly proportional to the energy.

It is an object of the present invention to provide an improved transparent luminescent screen for the production of color images.

It is also an object to provide a screen of this kind with which images can be obtained in purer colors.

Another object is to provide a cathode ray tube equipped with the improved transparent luminescent screen.

Other objects and advantages will become apparent and the invention better understood from the following description taken in connection with the accompanying drawing in which like numerals indicate like parts and wherein:

FIGURE 1 is a showing in cross section of one form of transparent luminescent screen embodying the improvement of the invention.

FIGURE 2 is a showing in cross section of a modified form of transparent luminescent screen embodying the improvement of the invention, and

FIGURE 3 is a schematic showing of a cathode ray containing an improved transparent luminescent screen of the invention and a circuit for operation of the tube to produce images in different colors.

In my copending application, Serial No. 650,958, filed April 5, 1957, now Patent No. 2,998,323 which is a continuation-in-part of my copending application, Serial No. 651,118, filed April 5, 1957, now Patent No. 2,996,403, I have described a method for preparing transparent luminescent screens which have a thin transparent luminescent metal silicate layer on a transparent glass base.

The method of preparing transparent luminescent screens as contained in the above noted patents involves evaporation of the metal silicate, be it zinc silicate or magnesium silicate, and a luminecent activator material and depositing a thin film of the vapors on a transparent refractory glass base, such as quartz glass and Vycor glass (96% silica, made by the Corning Glass Co.). The forming of the initial thin film by evaporation and deposition is conducted within a high vacuum, e.g., on the order of 10^{-4} to 5×10^{-5} mm. Hg. The thin film so formed on the substrate contains the solid components of the metal

silicate, but not the metal silicate itself. The oxygen necessary to the forming of the metal silicate from the solid components in the film is supplied by subjecting the thin film on the refractory glass base to baking in air at a temperature of between about 1000 and 1200° C., preferably at about 1100° C., for a period of from about 15 minutes to an hour to form a luminecent film of the metal silicate. The baking is conducted until the film is activated to luminescence in the color characteristic of the activator-silicate metal combination thereof. With manganese as activator, this color is green for zinc silicate films and red for magnesium silicate films.

Further in accordance with the method described in the above noted patents, the activator may be supplied in the films by using commercial activated zinc silicate and magnesium silicate phosphor powders for making of the films. Manganese is described as a preferred activator for production of the transparent luminescent screens.

Laminated transparent luminescent screens which comprise a plurality of superimposed, different color light producing thin transparent phosphor layers can be made by forming the layers one on top of the other using the method described in the above noted patents for a single transparent layer. Each luminescent layer is deposited and baked one at a time and one on top of the other on a substrate, which would normally be a refractory glass. In the baking process, to activate or form the luminescent layers, each succeeding layer must be of a kind which is formed or activated at a lower temperature or at the same temperature as the preceding layer. This order of application and firing is necessary to prevent deterioration of previously applied layers when subsequent layers are fired.

In place of forming the film layers directly on top of one another, it is usually desirable to separate the layers by a non-luminescent film. This causes the pure colors to be more pure for given voltages. Likewise, the layers may be separated by non-luminescent conducting layer which provide a means for controlling the luminescent color. Preferably each luminescent layer is separated from each other and from the substrate by a non-luminescent transparent layer.

In transparent luminescent screens which are formed to contain a thin transparent luminescent zinc silicate film in proximity to a thin transparent luminescent magnesium silicate film which emits light of a different color than the luminescent zinc silcate film on excitation with a beam of electrons, the separation of these two metal silicate films by means of a transparent non-luminescent layer assists in obtaining purity of the characteristic color of the light emitted by the particular luminescent metal silicate layer on bombardment with electrons. However, in order to obtain a high degree of purity of the characteristic color of the light emitted by the particular luminescent metal silicate layer, these layers, in proximity to each other, are arranged in the screen in the order, and with reference to the glass base, of first the transparent zinc silicate layer and then the transparent magnesium silicate layer, and separated by the transparent non-luminescent layer.

In illustration, a three layer screen of zinc silicate activated by manganese, magnesium silicate activated by manganese and calcium tungstate activated by tungsten is formed in the following manner. First the layer of zinc silicate with the manganese is vapor deposited on the transparent base and then baked in an oxygen atmosphere at a temperature of between about 1000° C. and 1200° C. preferably at about 1100° C. for a period sufficient to form or activate the layer in the manner described in the copending application Serial No. 650,958, now Patent No. 2,998,323. This baking step shall be called firing. The layer of manganese activated magnesium silicate is vapor deposited on top of the zinc silicate layer according to the steps outlined in the said copending application Serial No. 650,958, now Patent No. 2,998,323. It is desirable to place two layers of magnesium silicate over the zinc silicate. The first layer is fired only to a temperature sufficient to clear the film of magnesium silicate which is condensed in a black opaque state. A second layer of magnesium silicate is then condensed from the vapors in the vacuum on top of this composite screen. The entire screen is then baked in an oxygen atmosphere at 1100° C. for a time sufficient to form or activate the magnesium silicate luminescent layer. The third layer of tungsten activated calcium tungstate is vapor deposited on top of the first two layers and then baked in air at a temperature of about 550° C. for a time sufficient to form or activate the luminescent film of calcium tungstate in the manner described in the said copending application, Serial No. 650,958, now Patent No. 2,998,323. A conducting transparent layer is formed on top of the last evaporated film. This layer may be composed of tin oxide, for example, or formed of a thin metallic film in a well known manner. The non-luminescent transparent layers separating the luminescent layers from each other and from the glass substrate are formed by evaporating and depositing a layer of silicon dioxide, for example, in a well known manner between the evaporating and firing of the luminescent layers. Such a layer would be non-conducting. The screen thus formed is useful in a cathode ray tube to produce colored images as in a color television.

Referring now to FIGURE 1, there is shown a cross section of a screen which may be made by the above described process. The first deposited luminescent layer **13** of zinc silicate activated by manganese is transparent and when bombarded by an electron beam will give off green light. The second deposited luminescent layer **14** of magnesium silicate activated by manganese is also transparent and will give off red light when bombarded by an electron beam. The third deposited luminescent layer **15** of calcium tungstate activated by tungsten is transparent and will give off blue light when bombarded by an electron beam. These three colors are the primary optical colors and can be combined in permutations and combinations to produce most of the colors in the visible spectrum. The refractory substrate **11** on which the luminescent layers are deposited, is transparent and forms the face of the tube. Separating the three luminescent layers **13**, **14**, and **15** are the non-luminescent transparent layers **16** and **17**. On the luminescent layer **15** is a thin transparent conducting film or layer **18** to which a lead **19** is attached. Spaced a short distance from the conducting film **18** is a grid **20** to which the lead **21** is attached. This screen then forms the face of a color television tube or the face of a cathode ray tube.

In FIGURE 2 there is shown a cross section of another screen which may be made by the above described process. The design of this screen is like that of the screen of FIGURE 1 but with the addition of a transparent nonluminescent layer **12** which forms an elastic cushion between the luminescent layer **13** and the refractory glass substrate **11**. Without the transparent non-luminescent layer **12**, the refractory substrate **11** would have to be designed to have the same coefficient of thermal expansion as the luminescent layer **13** so that there would be no cracking of the luminescent layer **13** during the baking process.

To produce different colored images in the above screens, the depth of penetration of the electron beam is varied. If the depth of penetration is controlled to be as far as the luminescent film **13**, the color of the light emitted will be green. If the depth of penetration is only as far as the luminescent film **14**, then the color of the light emitted will be red. If the depth of penetration is only as far as the luminescent film **15**, then the color of the light emitted will be blue. The non-luminescent layers **16** and **17** help to separate the colors so that purer colors can be obtained. In respect to green light from the zinc silicate layer, a high purity green, more pure than with the non-luminescent layer **16** alone, is obtained when, in addition, the order of arrangement

of the zinc silicate layer and magnesium silicate layer in the screen is as shown in FIGURES 1 and 2. With this order in the screen of the two silicate layers and in addition the non-luminescent layer **16**, the amount of red which is developed by the electron beam passing through the magnesium silicate layer **14** will be reduced to a level where it is insignificant. By proper mixing of the colors red, blue, and green, the remaining colors in the spectrum can be obtained. The proper mixing is done by penetrating both the layers desired. For example, if yellow were desired, red and green would be combined. The electron beam would be made to penetrate both the zinc silicate layer **13** and the magnesium silicate layer **14** to cause both of these layers to emit light. Likewise, the colors from any of the other two luminescent layers can be combined in the same manner.

Connected respectively to the conducting layer **18** and the grid **20** are the leads **19** and **21**. The potential difference applied across these leads controls the depth of penetration of a scanning electron beam applied to the screen through the grid **20**. The grid **20** is maintained at a constant potential while the potential of the conducting layer **18** is varied to give different energies to the electrons impinging on the screen. The more positive the conducting layer **18** is made, the more energy an electron beam will have and the deeper the electron beam will penetrate. Therefore, by varying the potential of the conducting layer **18**, the color produced by the tube can be varied.

In addition to performing the control function, the conducting layer **18** also provides a drain for the bombarding electrons and the electrons produced by secondary emission.

The conducting layer **18** is made to be about 500 angstroms thick, the blue luminescent layer **15** is between 2000 and 5000 angstroms thick. The red luminescent layer **14** is between about 5000 angstroms and 2 microns thick and the green luminescent layer is between 1 and 3 microns thick. Each of the non-luminescent layers **12**, **16** and **17** are between 2000 and 5000 angstroms thick.

FIGURE 3 shows in block diagram a circuit for use in a television system for controlling the depth of penetration on a screen in the cathode ray tube **28** to produce colored images in accordance with a signal received on the aerial **22**. The signal received is applied first to a receiver which demodulates the signal and amplifies it and applies it to the synchronous selector circuit **24**.

The synchronizing scanning and color cycle pulses are separated from the video signals by the synchronizing selector circuit **24**. The video signals are amplified by the video amplifier **27** and impressed on the control electrode of the cathode ray tube **28** to control the intensity or number of electrons in the cathode ray beam which bombards the laminated screen. The synchronizing scanning pulses are applied to the horizontal and vertical deflection circuit which works substantially in the same way as black and white scanning in present day television sets. The color control **25** functions to produce the proper accelerating voltage between the grid **20** and the conducting layer **18**. The color control circuit thereby controls the depth of penetration of the electron beam and thereby the color produced. For a screen of the type shown in FIGURES 1 and 2, the color control circuit receives a timing signal from the synchronous circuit at the end of each field scan, that is a scan of the entire screen by the horizontal and vertical deflection circuit. Upon receipt of each timing signal, the color control switches the depth control voltages on the leads **19** and **21**, and thereby switches the color being produced by the screen. For example, when the first timing signal is received, the potential difference between the leads **19** and **21** would be controlled to be enough to cause the electron beam to penetrate only to a depth of the layer **15**, thus causing the color blue to be given off. When the next timing signal is received, this potential is increased in a step to a potential great enough to cause the electron beam to then penetrate to a depth of the layer **14**, thus causing the primary color red to be given off. When the third timing signal is received, the voltage potential between the leads **19** and **21** is further increased, thereby further accelerates the electron beam to penetrate as far as the luminescent layer **13** and causes the primary color green to be given off. Since a timing pulse is received at the end of each field scan, a different color will be produced for each field scan and the three colors are produced in rapid sequence over the entire screen.

The intensity of the colors produced depends upon the number of electrons bombarding the screen. This is controlled by the signal from the video amplifier **27** applied to the control grid of the tube. By cutting down the number of electrons at the proper times, the pure colors red, blue, and green and their combinations can be produced where desired on the laminated screen. For example, if a pure red is desired at a certain point or spot on the screen, then the intensity of the electron beam is decreased to a minimum when the beam is scanning the selected spot during the blue field scan and also during the red scan. Thus, the spot produces a pure red color. A combination of the primary colors can be obtained at a selected spot by allowing two of the colors or all three of the colors to be produced at the selected spot in varying intensities in the successive scans. For example, if a combination between the blue and red were desired, then the electron beam would be made to produce red at the selected spot when the beam is scanning the screen during the red scan and also to produce blue at the spot when the scan is scanning the blue scan. If no green were desired, then the intensity of the electron beam during the green scan of this spot is reduced to a minimum. This will cause an appearance to the eye of a combination of the colors red and blue to produce purple or violet at the selected spot. In a similar manner, the combination of any of the other two colors at any desired spot can be obtained. Thus, the video signal applied to the control grid varies the intensities of the color scans and controls the color of the picture. This system is more fully described in the Patent No. 2,580,073 to J. A. Burton issued December 25, 1951.

Beside the system outlined above, other systems for controlling the depth of penetration of the electron beam into the screen could be used such as the system shown in the patent to Sziklai, 2,704,783. Another system for controlling the depth of penetration is shown in the patent to Szegho, 2,455,710. A third system is described in the patent to Koller, 2,590,018 and a fourth in the patent to Schagen, 2,730,653. Any of these systems could be used in combination with the screens according to the present invention. The system described above is intended only as a specific example of how the present invention may be used and not as a limitation thereon.

While the above improved transparent screen of the invention has been described primarily with reference to use in a color television system, a further use of the screen is an electronic display which appears to have depth by the stereoscopic effect. Another use of the screen is for high resolution electronic display wherein the amount of information is not limited by optical scattering from particles comprising the screen.

While in the foregoing description reference has been made to certain specific embodiments of the invention, it is intended that these shall be taken by way of illustration and not in limitation except as may be defined in the appended claims.

What is claimed is:

1. In a cathode ray tube for producing colored images, an electron beam source, a transparent image screen arranged to receive a beam of electrons from said source, said transparent image screen having a plurality of super-

posed transparent layers comprising a thin transparent luminescent zinc silicate layer in proximity to a thin transparent luminescent magnesium silicate layer which emits light of a color different than that emitted by said luminescent zinc silicate layer on excitation by a beam of electrons, said luminescent silicate layers being separated from each other by a thin transparent non-luminescent layer and arranged in order in the screen such that said luminescent zinc silicate layer precedes said luminescent magnesium silicate layer relative to the face of the cathode ray tube.

2. In a cathode ray tube for producing colored images as defined in claim 1, said transparent image screen having a glass base and a thin transparent non-luminescent layer separating said luminescent zinc silicate layer from said glass base.

References Cited by the Examiner

UNITED STATES PATENTS

2,795,730 6/1957 Fromm et al. ------- 313—92 X

GEORGE N. WESTBY, *Primary Examiner.*