

May 31, 1966

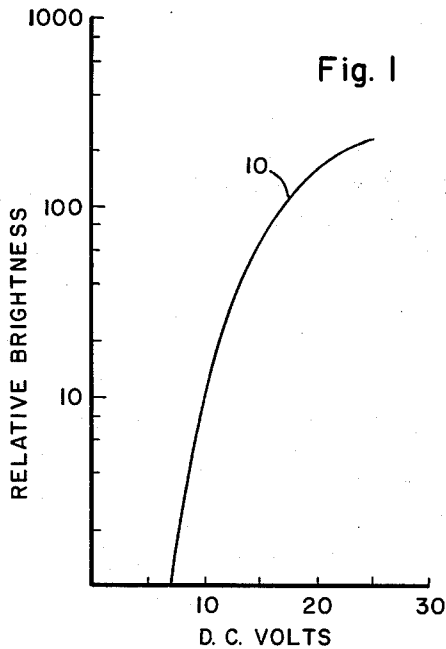
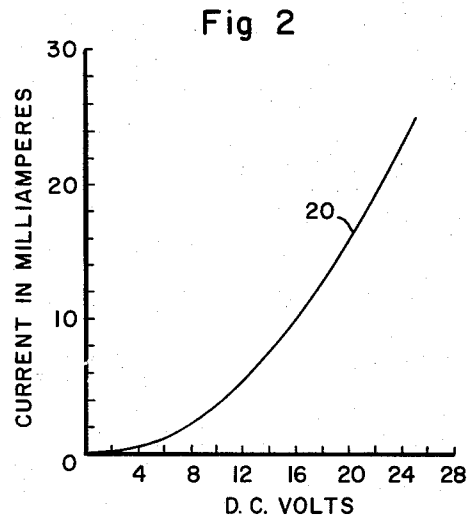
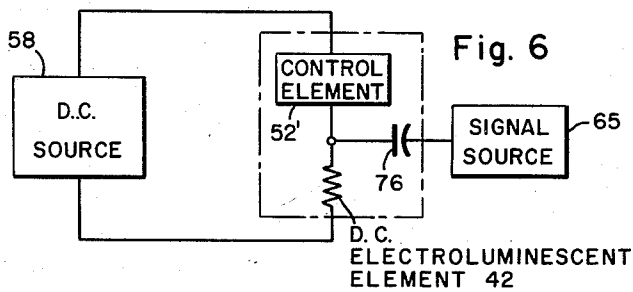
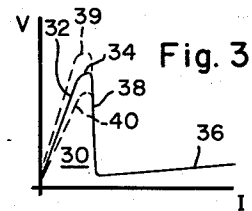
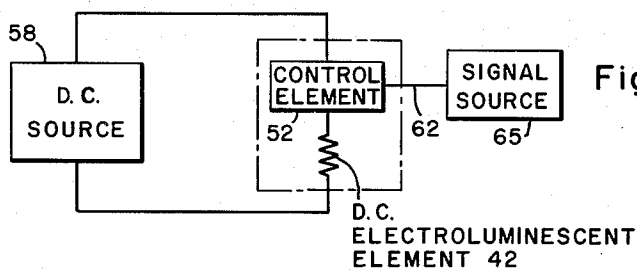
E. A. SACK, JR

3,254,267

SEMICONDUCTOR-CONTROLLED, DIRECT CURRENT RESPONSIVE
ELECTROLUMINESCENT PHOSPHORS

Filed Oct. 25, 1960

2 Sheets-Sheet 1



WITNESSES

John E. Hepsey, Jr.
Horton H. Telfer

INVENTOR

Edgar A. Sack, Jr.

BY

Charles F. Reng
ATTORNEY

May 31, 1966 **E. A. SACK, JR.** **3,254,267**
SEMICONDUCTOR-CONTROLLED, DIRECT CURRENT RESPONSIVE
ELECTROLUMINESCENT PHOSPHORS

966 E. A. SACK, JR. 3,25
SEMICONDUCTOR-CONTROLLED, DIRECT CURRENT RESPONSIVE
ELECTROLUMINESCENT PHOSPHORS

3,254,267

Filed Oct. 25, 1960

2 Sheets-Sheet 2



1

3,254,267

SEMICONDUCTOR-CONTROLLED, DIRECT CURRENT RESPONSIVE ELECTROLUMINESCENT PHOSPHORS

Edgar A. Sack, Jr., Penn Hills Township, Allegheny County, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Filed Oct. 25, 1960, Ser. No. 64,919
7 Claims. (Cl. 315-169)

This invention relates to devices for the visual display of information and, particularly, to such devices which use an electroluminescent phosphor material as the source of output light. This invention is also directed to electroluminescent devices whose light output is controlled by control elements which alter the excitation on the electroluminescent portion of the device in accordance with control signals.

Prior electroluminescent display devices generally utilize a phosphor material which exhibits appreciable electroluminescence only when subjected to a varying electric field. A typical display screen is that in which an A.C. potential is applied across an electroluminescent element and a control element whose impedance to the applied A.C. potential can be altered by the application of a D.C. signal thereto. As the impedance of the control element is reduced, more A.C. is applied across the electroluminescent element with a resulting increase in light output. Such display screens may use ferroelectric capacitors as the control elements. Display screens of this type are described in U.S. Patent 2,875,380, issued February 24, 1959, to P. M. G. Toulon, and U.S. Patent 2,917,667, issued December 15, 1959, to E. A. Sack, Jr.

The well known phosphors which require a varying field generally need an excitation potential of the order of 200 volts r.m.s. at 6000 cycles per second. Due to recent improvements in the techniques of fabricating electroluminescent phosphor layers, it has become possible to obtain electroluminescence with excitation which produces only a non-varying electric field across the phosphor. In addition, these phosphors require an applied potential of only about 5 to 30 volts D.C. As a result of the fact that the applied potential may now be from direct current sources which supply a potential which may be of about of an order of magnitude less than that previously supplied by A.C. sources, different concepts for the efficient and economical control of the electroluminescent light output are made practical.

It is, therefore, an object of the present invention to provide an improved electroluminescent display device.

Another object is to provide an electroluminescent display device which consumes less power than that required by previous devices and which may be excited solely by D.C. sources.

It is another object to provide an electroluminescent display device in which the writing and erasing of information can be performed very rapidly.

Another object is to provide an electroluminescent display device which provides for an indefinite storage of information.

Another object is to provide an electroluminescent display device in which erasing can be performed conveniently and rapidly either from a single element or from a group of elements at one time.

Another object is to provide an electroluminescent display device which has good isolation between elements and hence produces an image having good contrast.

Another object is to provide an electroluminescent display device incorporated in multi-elementary structures which may be fabricated easily and economically.

According to the present invention, electroluminescent display devices are provided wherein each electrolumines-

2

cent element is of the type which exhibits electroluminescence when subjected to a non-varying electric field and has electrically coupled thereto a semiconductor control element which responds to an applied signal to switch from a high resistance state to a state of very low resistance with a transition region of negative resistance.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with the above mentioned and further objects and advantages thereof, may best be understood by reference to the following description, taken in connection with the accompanying drawings, in which:

FIGURE 1 is a curve showing how the brightness of output light varies with the direct current voltage applied across a typical phosphor useful in the practice of the present invention;

FIG. 2 is a curve of the current-voltage characteristic of a typical phosphor useful in the practice of the present invention;

FIG. 3 is a voltage versus current curve of a typical semiconductor control element which is useful in the practice of the present invention;

FIG. 4 is a perspective view in section of part of an electroluminescent display device in accordance with the present invention with associated circuitry shown schematically;

FIG. 5 is an enlarged perspective view in section and partly broken away of the display screen shown in FIGURE 4;

FIG. 6 is a schematic circuit diagram of a single element of one embodiment of the present invention; and

FIG. 7 is a circuit equivalent of a single element of another embodiment of the present invention.

Before describing the particular embodiments of the present invention, certain of the essential components of those devices will be discussed. The electroluminescent phosphor layers which exhibit appreciable electroluminescence when subjected solely to a non-varying electric field may be referred to as D.C. electroluminescent layers, even though the A.C. characteristic of these layers may be as good or better than conventional layers which operate only on A.C. Such a D.C. electroluminescent layer exhibits a marked increase in brightness with a relatively small increase in D.C. voltage. In FIGURE 1 there is shown a typical curve 10 of relative brightness versus applied D.C. voltage for a phosphor suitable for use in devices in accordance with the present invention. Conventional electroluminescent layers produce substantially no light output with solely D.C. excitation. The curve 20 of FIGURE 2 shows the variation in current through a D.C. phosphor material for different D.C. voltage. Conventional electroluminescent layers conduct substantially no current during operation. It will be noted, therefore, that a D.C. electroluminescent layer does exhibit appreciable light output with a relatively steep slope with applied D.C. voltage when ordinary electroluminescent layers remain unresponsive. The D.C. phosphor layer appears, primarily, as a pure resistance while an ordinary A.C. phosphor layer is substantially capacitive.

The difference in the properties of A.C. and D.C. electroluminescent layers is believed to result not so much from any substantial difference in chemical composition but rather from a difference in the physical nature of the electroluminescent layer. Generally, A.C. phosphor layers are formed of granulated phosphor material which is dispersed in a dielectric medium of a glass of plastic nature. The phosphor particles are therefore insulated from each other and from the electrodes. Such electroluminescent cells are well known and examples may be found in the above referred to patents. On the other

hand, phosphor layers which exhibit good D.C. characteristics are generally formed without a dielectric binder material, or with a minimum of binder. They are generally deposited from a vapor so as to form a phosphor layer which is substantially homogeneous and crystalline in nature. The D.C. layer may be of a single crystal or polycrystalline. The D.C. electroluminescent layers may be made of the same phosphor composition as are well known for A.C. electroluminescence, particularly those of the zinc sulfide type. It has been found however that the use of manganese as an activator generally enhances the D.C. characteristics.

While the scope of the present invention extends to all electroluminescent phosphor layers which have good D.C. characteristics, the following is presented as a specific example and manner of making one D.C. electroluminescent phosphor material which is suitable for use in the practice of this invention. The electroluminescent layer is prepared on a hard glass surface. The softening point of the glass should be about 750° C. or higher to avoid deformation during subsequent processing. The coefficient of expansion of the glass should be about 5×10^{-6} per degree C. so as to roughly correspond with that of the phosphor layer formed thereon. Well known glasses which have been found suitable for these purposes are those sold under the trade designations Corning Nos. 1723 and 7280. A coating of light transmissive and electrically conducting material is formed on the glass base by well known techniques such as coating the glass surface with tin oxide applied at a temperature of about or slightly greater than the softening point of the glass which, for the above referred to glasses, is in the range from about 750 to 800° C. The tin oxide is applied by spraying a solution of tin chloride onto the hot glass. The tin oxide layer is then thoroughly cleaned to improve the adhesion of the phosphor layer to be formed thereon.

After cooling, the glass member with the tin oxide layer is then supported in an evacuated bell jar and powdered zinc sulfide is rapidly evaporated thereon to a thickness of from about 1 to 3 microns. Within the zinc sulfide evaporated there may be contained as activators manganese and copper and a co-activator such as chlorine. The activators may also be introduced after the evaporating step as will be described. The total amounts of each of the activators and co-activators should comprise, in molar percentages, about 2% Mn, 0.2% Cu and 2% Cl. The glass member with the evaporated layer is then placed in a container with the evaporated layer in contact with a layer of phosphor powder of the same type which has been evaporated. The phosphor powder contains additional amounts of activating material, namely manganese, copper and chlorine or other activators, which it is desired to incorporate into the zinc sulfide film. The container is placed into an oven with an inert atmosphere such as argon at about 770° C. for about twenty minutes. The firing treatment activates the zinc sulfide layer to a phosphor layer, that is, it is now capable of exhibiting electroluminescence. After the firing treatment, the phosphor layer is removed and cooled rapidly.

The phosphor powder is then brushed off and the glass with the phosphor film is placed in a solution of about 1 N sodium hydroxide (NaOH) plus 2 N sodium cyanide (NaCN) and is boiled for about one hour. It is then thoroughly rinsed and dried. Then a metal electrode such as aluminum is evaporated onto the exposed surface of the phosphor film in the pattern desired for any particular use. The phosphor film may then be stored or operated under any conditions in which it is kept relatively dry.

The thickness of the phosphor film determines to some extent the voltage range in which the device may be operated. Generally, thinner films may be operated at lower D.C. voltages. If found desirable a current limiting layer may be disposed in series with the phosphor layer under the back electrodes to limit the tendency for de-

structive current flow should the layer breakdown in a weak spot.

Another component essential to devices in accordance with the present invention is a semiconductor control element having certain characteristics. In FIGURE 3 there is shown the proper sort of characteristic curve 30. Since, for purposes of the present invention, the D.C. signal applied to the semiconductor control element may be of any desired polarity to achieve this characteristic and what happens when an opposite polarity signal is applied is immaterial, only one quadrant of the characteristic curve is shown and it may be considered that showing the "forward" direction of the device. The device is characterized in that as voltage or current increases from zero, there is a first region 32, or the device is in a first state, of high resistance. That is, current through the device increases slowly with increasing applied voltage. However, upon reaching a certain voltage-current point 34 a rapid switching phenomenon occurs, often referred to as breakdown, which causes the voltage across the device to drop rapidly to a very low level while the current may increase indefinitely without appreciable voltage increase. This latter region 36 is therefore one of very low resistance or it may also be termed a hyperconductive region. Between the latter region 36 of the characteristic curve and the high resistance region 32 is a transition region 38 through which the device rapidly switches and in which it has a negative resistance characteristic.

Various devices exhibit a characteristic curve of the general shape shown in FIGURE 3. The values of the curve are not critical and the particular device selected is generally a matter of choice since the breakover potential, holding potential, holding current, and the like vary somewhat from device to device. Suitable devices are described in Patent 2,953,693, issued September 20, 1960, and entitled "Semiconductor Diode" and copending application Serial No. 649,038, filed March 28, 1957, now Patent 3,141,119, issued July 14, 1964 and entitled "Hyperconductive Transistor Switches" both of which are by J. Philips and are assigned to the same assignee as the present invention. The former application describes a two terminal device which consists of three regions of alternating conductivity type semiconductor material with a fourth region of metal attached to one of the outer semiconductor regions. The latter application describes a three terminal device physically similar to that just described but having the additional terminal on the semiconductor region adjacent the metallic region for applying a signal the magnitude of which determines the break-over voltage of the device. In the latter case the characteristic curve of FIGURE 3 would be representative of such a device operated with a constant signal on the third terminal. A change in the applied signal to the third terminal raises or lowers the switching voltage as shown by the dotted curves 39 and 40. However, the general shape shown in curve 30 is substantially preserved. Such devices are sometimes referred to as hyperconductive-negative resistance devices. These and other devices having the appropriate characteristics are described in two articles by T. M. Sylvan appearing in *Electronics* on February 27, 1959 and March 6, 1959 entitled, respectively, "Two Terminal Solid State Switches" and "Solid State Thyratrons Available Today."

In FIGURE 4 there is shown an electroluminescent display device in accordance with the present invention. The device includes a multi-elementary electroluminescent cell 42 comprising a supporting member 44 of a light transmissive material such as glass having thereon a light transmissive electrically conductive coating 46 which in turn has a layer 48 of phosphor material exhibiting substantial electroluminescence when subjected to a non-varying electric field. On the back surface of the phosphor layer there is disposed a pattern of electrodes 50 each essentially defining a single electroluminescent element

whose light output may be substantially individually controlled. This portion 42 of the display screen may be made in accordance with the specific example previously given.

Each of the elemental back electrodes 50 has thereon a semiconductor control element 52 having a characteristic curve like that shown in FIG. 3 as was previously described. The back electrodes 50 are not necessary if the control elements can be adequately bonded to the electroluminescent layer 46. The element 52 is responsive to an applied signal to switch from a high resistance state to a very low resistance state with a region of negative resistance therebetween. In FIGURE 4, for purposes of example, the semiconductor control elements 52 are shown all having a common connection through a conductive layer 54 and a lead 56 connecting the negative terminal of a D.C. power source 58 represented by a battery while the front electrode 46 of the electroluminescent cell 42 is connected to the other battery terminal by lead 60. The semiconductor control elements 52 are shown as three terminal devices with the third terminal attached to one of the center regions therefore necessitating the provision of a space through which leads 62 to the third terminal can be provided. These leads 62 from the various elements are shown connected to a commutator 64 which is merely representative of many signal distribution devices by which an information signal can be sequentially or in some selected manner applied to each of the control elements 52. For clarity in the drawings, some of the leads 62 are not shown connected to the commutator 62 but, of course, in actual practice they would be. One device which is suitable for use as the signal distribution means is described in copending application Serial No. 747,799, filed July 10, 1958, now Patent 3,048,824, issued August 7, 1962 by F. T. Thompson and assigned to the same assignee as the present invention. The control structure of FIGURE 4 is encapsulated in a plastic or other suitable material 66 such as that sold under the trade name Hysol 6040, an epoxy resin made by Houghton Laboratories of Olean, New York.

Referring now to FIGURE 5, there is shown in greater detail an example of the control structure for use of the device of FIGURE 4 in which the semiconductor control elements 52 are formed in a unitary row comprising a plurality of elements. Like reference numerals indicate like features in FIGS. 4 and 5. While single elements are equally satisfactory in operation, the fabrication of a multi-elementary unit of elements may be desirable to reduce cost and make fabrication easier. Essentially the structure consists of two common layers 68 and 70 of semiconductor material which are respectively of n and p type and which have a p-n junction 69 therebetween which extends continuously through an entire row of elements 52. Another n-type layer 72 forms a p-n junction 71 with the p-type layer 70 and a second p-type layer 74 forms a third junction 73 with the layer 72. The layers 72 and 74 are separated into individual regions for each element 52 and the junctions 71 and 73 are not continuous for the entire row of elements so that the operation of each element 52 may be substantially independent. Each part of the p-type layer 70 has a contact 51 thereon to which a lead 62 is joined to provide the third terminal of the control element. Such a structure may be formed by first making a four zone structure and etching or otherwise physically removing portions to separate the necessary regions. A description of a manner of making such a device may be found in copending application Serial No. 860,174, filed December 17, 1959 by R. L. Longini and assigned to the same assignee as the present invention.

Referring now to FIGURE 6 there is shown a schematic of a display screen element which includes a two terminal semiconductor control element 52'. The other components of the circuit are a source of D.C. potential 58 and a D.C. electroluminescent element 42. Between

the semiconductor control element and the D.C. electroluminescent cell there may be provided an isolation impedance represented by the capacitor 76 connected to a suitable signal source 65. Those components which are individually used for only one display screen element are enclosed by the dotted line. The power source 58 and signal 65, may, of course, be used for many elements. The structure of a display screen incorporating the element circuit configuration shown in FIGURE 6 may be like that shown in FIGURES 4 and 5 except for the manner in which the control signal is applied.

In this case in which a two terminal control device is used, it is necessary that the D.C. source be variable or that an additional D.C. potential be applied to one of the terminals of the control element in some manner to effect switching. In the operation of the circuit shown in FIG. 6 the D.C. electroluminescent element 42 remains dark so long as the applied D.C. potential is less than the sum of the breakover voltage of the control element 52' plus a small amount equal to the voltage drop across the electroluminescent layer. If a short pulse is introduced, say for 1 microsecond or less, through the isolation impedance 76, or by varying the D.C. source 58, so that the voltage drop across the semiconductor control element 52' is momentarily increased beyond the breakover voltage, the control element switches to the low resistance and hyperconductive state and behaves like a closed switch so that substantially the total applied D.C. voltage appears across the D.C. electroluminescent element 42 which is then caused to light up. To switch back to the original condition a pulse of opposite sign may be applied to momentarily drop the voltage below the holding voltage or current below the holding current. These are, respectively, the minimum voltage and the minimum current necessary to maintain the hyperconductive state.

In FIGURE 7 a similar circuit schematic is shown but for a three terminal control element like those in the embodiment of FIGURES 4 and 5, for example. One advantage of employing the third terminal of the control component is to maintain the substantial isolation between the various elements of a multi-element display since it is convenient to give all the elements a common conductor 54 for application of the D.C. power. In the operation of the circuit of FIGURE 7 normally the D.C. voltage appears primarily across the control element 52 and the D.C. electroluminescent element 42 remains dark. With the application of a suitable pulse to the extra terminal 62 of the control element, the voltage necessary to cause breakover is reduced to less than the output of the source 58 and the element switches to the hyperconductive state. D.C. voltage across it drops to a very low level with the result that the D.C. voltage across the electroluminescent cell 42 is increased to a point at which substantial light output occurs. It has been found that with about 25 volts applied by the D.C. source 58 the current through the D.C. electroluminescent element 42 is on the order of 10 to 20 microamperes and therefore, as can be seen from FIGURES 1 and 2, there is little or no light output with a typical D.C. phosphor. The application of a pulse of about 1 milliamperes applied to the third terminal 62 causes switching with resulting light output. The element remains on until the applied voltage is interrupted or reduced or a reverse current pulse of about 10 milliamperes is applied to the third terminal.

The embodiments shown and described have an inherent high writing speed since available semiconductor control elements which are suitable achieve about .1 microsecond switching time. The power required by screens of this type is of course small because the D.C. power seldom exceeds about 30 volts or about 100 milliamperes. Storage is achieved due to the fact that the control elements 52 are bistable and, particularly with structures including three terminal devices, excellent D.C. isolation can be obtained.

It can be readily seen that a multi-elementary array as shown in FIGURE 4 can be used to present an image by modulation of the potential on the control terminals.

It should be noted and it will be obvious to those skilled in the art that the structures in accordance with the present invention need not be operated with wired control signal inputs. Substantially all of the semiconductor control elements suitable for use with the present invention have been found to be capable of operation with an input of light or cathode rays.

For example, a simple but useful device comprises a D.C. electroluminescent layer in series with a semiconductor control element, each of which may be like those previously discussed, and having a constant D.C. potential applied thereacross which is not sufficient to cause appreciable light emission from the phosphor because of the high dark impedance of the semiconductor control element. Upon exposing the control element to radiation its breakover potential is reduced so that the applied potential is sufficient to cause it to switch to the hyperconductive state. As a result substantial potential is applied across the phosphor and appreciable light is emitted. To erase, the circuit may be opened briefly.

Another possibility is a combination of electrical and electromagnetic actuation which may minimize signal distribution problems by providing a self-scanning system where the simultaneous presence of light and electrical trigger pulses are required in order to fire given elements.

While it appears particularly advantageous to operate the disclosed devices with D.C. potential sources in order to take advantage of the good D.C. characteristics of the phosphor layer, the devices are still operable when pulsating D.C. or even an A.C. potential is applied thereto.

While the present invention has been shown and described in certain forms only, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit and scope thereof.

I claim as my invention:

1. A display device comprising a body of phosphor material having the property of exhibiting electroluminescence when subjected to a non-varying electrical field, a semiconductor element electrically coupled to said body of phosphor material responsive to an applied energy signal to switch from a first stable state of low conductivity to a second stable state of hyperconductivity with a transition region of negative resistance between said first and second stable states, and means to apply an energy signal pulse to said semiconductor element to cause said element to switch to said second stable state and to remain in that state following the termination of said pulse.

2. A display device comprising a layer of phosphor material having the property of exhibiting electroluminescence when subjected to a non-varying electric field, a pair of conductive layers in contact with opposite surfaces of said phosphor layer, one of said conductive layers having a plurality of separate portions, and a semiconductor switching element comprising four regions of differing conductivity type material and first and second terminals at opposite ends disposed on each of said plurality of separate portions with one of said terminals being electrically coupled thereto to provide a plurality of individually controllable light producing elements.

3. A display device comprising a layer of phosphor material having the property of exhibiting electroluminescence when subjected to a non-varying electric field, a pair of conductive layers in contact with opposite surfaces of said phosphor layer and a semiconducting switching element comprising four regions of differing conductivity type having first and second terminals at opposite ends and a third terminal on a central region thereof, one of said first and second terminals being electrically coupled to one of said conductive layers, said semiconductor switching element operable upon the application of electrical signal to said third terminal to switch between a first state

of appreciably larger impedance compared to that of said phosphor layer to a second state of appreciably smaller impedance compared to that of said phosphor layer for the same direct current potential applied across said semiconductor switching element and said phosphor layer.

4. A display system comprising a body of phosphor material having the property of exhibiting electroluminescence when subjected to a non-varying electric field, a plurality of conductive elements on said body defining a plurality of light producing elements therein, a plurality of semiconductor elements each electrically coupled to one of said conductive elements on said body of phosphor material and responsive to an applied electrical signal to switch from a first stable state of low conductivity to a second stable state of hyperconductivity with a transition region of negative resistance between said first and second stable states, a source of direct current potential electrically coupled across said body of phosphor material and said semiconductor elements, and means to apply a first electrical signal pulse of a first polarity selectively to individual ones of said plurality of semiconductor elements to cause said elements to switch to said second stable state and to remain in that state following the termination of said pulse, until application of a second electrical signal pulse of polarity opposite to said first polarity.

5. A display system comprising a layer of phosphor material having the property of exhibiting electroluminescence when subjected to a non-varying electric field, a pair of conductive layers in contact with opposite surfaces of said phosphor layer, one of said conductive layers having a plurality of separate portions, a plurality of semiconductor switching elements each having a first terminal coupled to one of said separate portions, a source of direct current potential having a terminal coupled to the other of said pair of conductive layers and a terminal coupled to said second terminal of each of said semiconductor switching elements, said semiconductor switching elements operable upon the application of an additional electrical signal to one of said terminals to switch between a first state of appreciably larger impedance compared to that of said phosphor layer to a second state of appreciably smaller impedance compared to that of said phosphor layer for the same applied direct current potential with a transition region of negative resistance between said first and second states, said plurality of semiconductor switching elements being physically united in a unitary structure adjacent said separate portions of said conductive layer.

6. A display device comprising a layer of phosphor material having the property of exhibiting electroluminescence when subjected to a non-varying electric field, a light transmissive conductive layer in contact with a first surface of said phosphor layer, a plurality of elemental conductive layers in contact with the opposite surface of said phosphor layer, each of said elemental contacts having coupled thereto a four layer-three terminal semiconductor switching element operable upon the application of an electrical signal to one of the terminals thereof to switch between a first state of appreciably larger impedance compared to that of said elemental electroluminescent cell and a second state of appreciably smaller impedance compared to that of said elemental electroluminescent cell for a given direct current potential applied across each of said semiconductor switching elements and said elemental electroluminescent cells with a transition region of negative resistance between said first and second states and means to apply a first electrical signal pulse of a first polarity selectively to individual ones of said plurality of semiconductor elements to cause said elements to switch to said second stable state and to remain in that state following the termination of said pulse, until application of a second electrical signal pulse of polarity opposite to said first polarity.

7. A display system comprising a layer of phosphor material having the property of exhibiting electroluminescence when subjected to a non-varying electric field, a first conductive layer in contact with one surface of said phosphor layer, a plurality of elemental electrical conductive contacts in contact with the opposite surface of said phosphor layer, a plurality of semiconductor switching elements each having first, second and third terminals, one of said switching elements coupled by said first terminals to each of said elemental conductive contacts, one or more sources of direct current potential applied across said first conductive layer and said second terminal of said semiconductor switching element, signal distribution means operable to apply intelligence signals selectively to said third terminals of said semiconductor switching elements to switch said switching elements between a first state of appreciably larger impedance compared to that of said elemental electroluminescent cell and a second state of appreciably smaller impedance compared to that of said elemental electroluminescence cell for a given direct current potential applied by said potential source.

5

10

15

20

References Cited by the Examiner

UNITED STATES PATENTS

2,855,524	10/1958	Schockley	307—88.5
2,856,553	10/1958	Henisch	313—108.1
2,877,359	3/1959	Ross	307—88.5
2,877,371	3/1959	Orthuber et al.	313—108.1
2,887,601	5/1959	Bain	313—108.1
2,917,667	12/1959	Sack	313—108.1
2,938,136	5/1960	Fisher	313—108.1
2,967,265	1/1961	Diemer et al.	315—169
2,989,426	1/1961	Rutz	148—1.5
3,026,440	3/1962	Brainerd	315—169
3,083,262	3/1963	Hanlet	315—169

FOREIGN PATENTS

860,685 2/1961 Great Britain.

GEORGE N. WESTBY, *Primary Examiner.*

RALPH G. NILSON, *Examiner.*

C. R. CAMPBELL, *Assistant Examiner.*