OR 3,820,875

United States

Bohmer

1] 3,820,875

5] June 28, 1974

[54] **SCANNER DEVICES UTILIZING FIELD EFFECT LIGHT SCATTERING DIELECTRICS**

[76] Inventor: **William Bohmer,** 763 Van Nest Ave., Bronx, N.Y. 61646

[22] Filed: **Apr. 14, 1972**

[21] Appl. No.: **243,996**

[52] **U.S. Cl.** .... **350/160 LC,** 350/160 R
[51] **Int. Cl.** **G02f 1/28**
[58] **Field of Search** .... 350/160 LC, 150, 160 R

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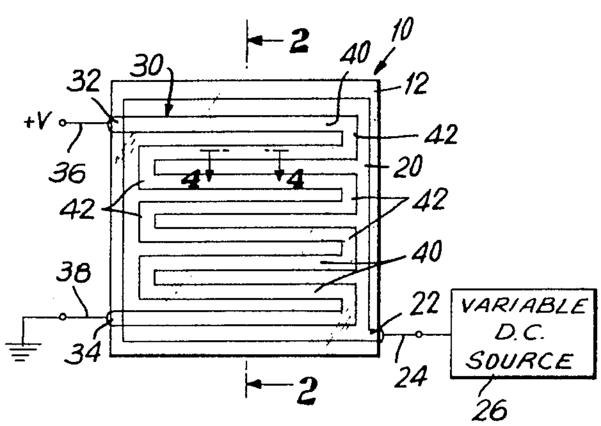
Primary Examiner—Ronald L. Wibert
Assistant Examiner—Paul K. Godwin
Attorney, Agent, or Firm—Blum, Moscovitz, Friedman & Kaplan

[57] **ABSTRACT**

A region of a field effect light scattering dielectric is selectively actuated in a device including a pair of spaced plates having said field effect light scattering dielectric therebetween and having a resistor defining a resistive electrical path of predetermined length and configuration mounted on the inner surface of one of said plates and a substantially nonresistive conductor mounted on the inner surface of the other of said plates in facing relation to said resistor. At least one of said plates and the resistor or conductor mounted thereon are transparent. A first voltage is applied between the ends of the electrical path of said resistor and a second variable voltage is applied to said conductor. Selective adjustment of said second voltage displaces the point on said resistor at which the voltage equals said second voltage to render the region of said dielectric adjacent said point visually distinguishable from other regions thereof.

39 Claims, 14 Drawing Figures



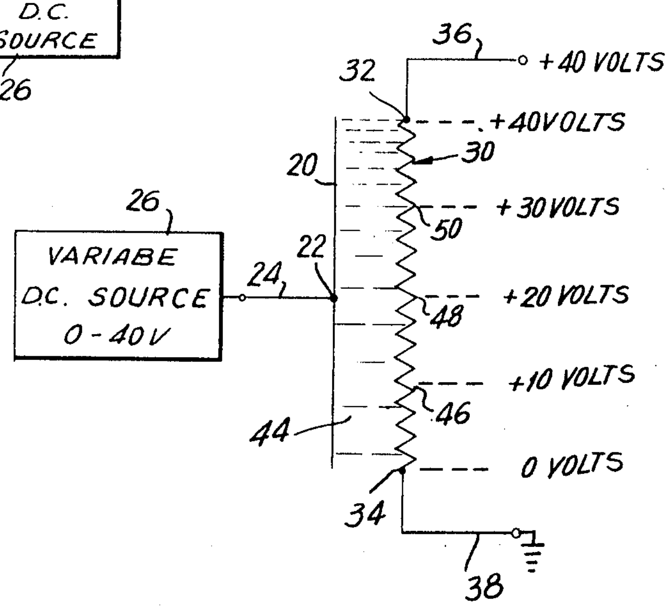


FIG. 1

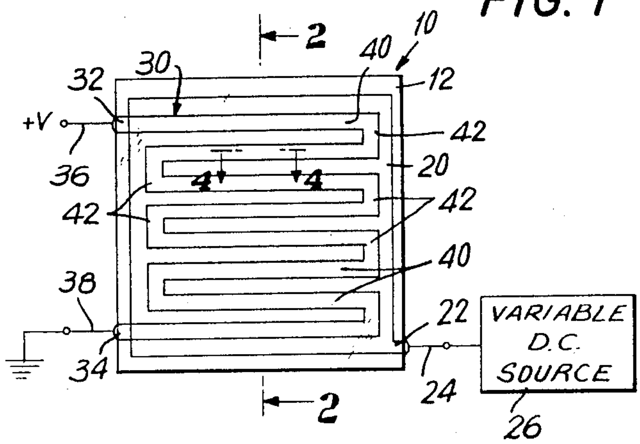


FIG. 2

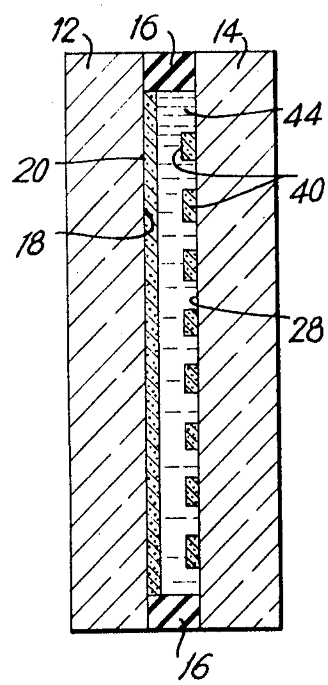


FIG. 3

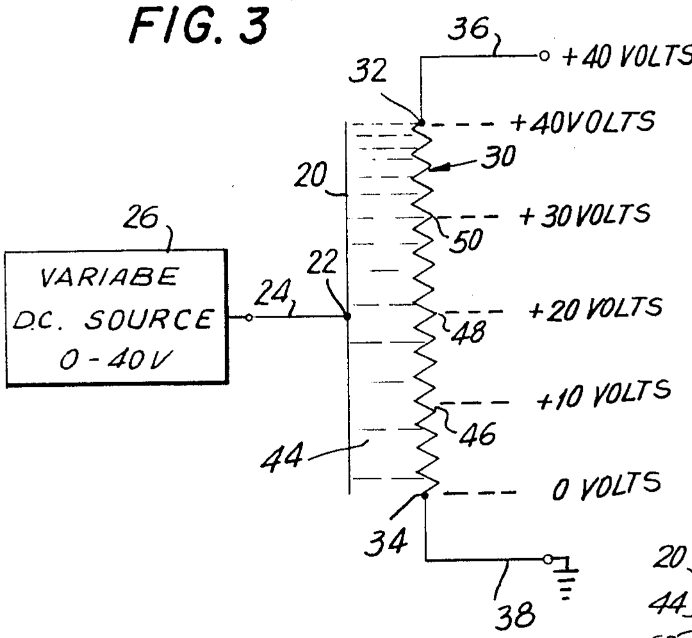


FIG. 4

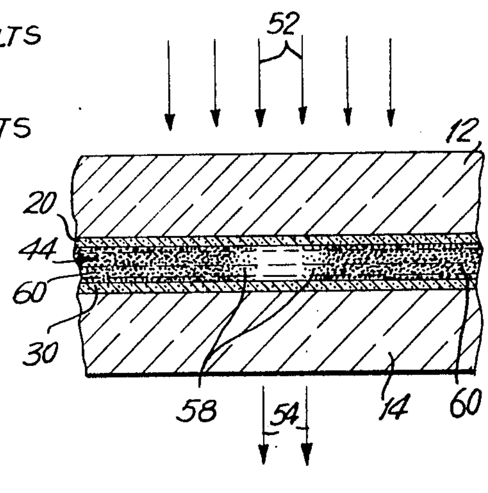


FIG. 5

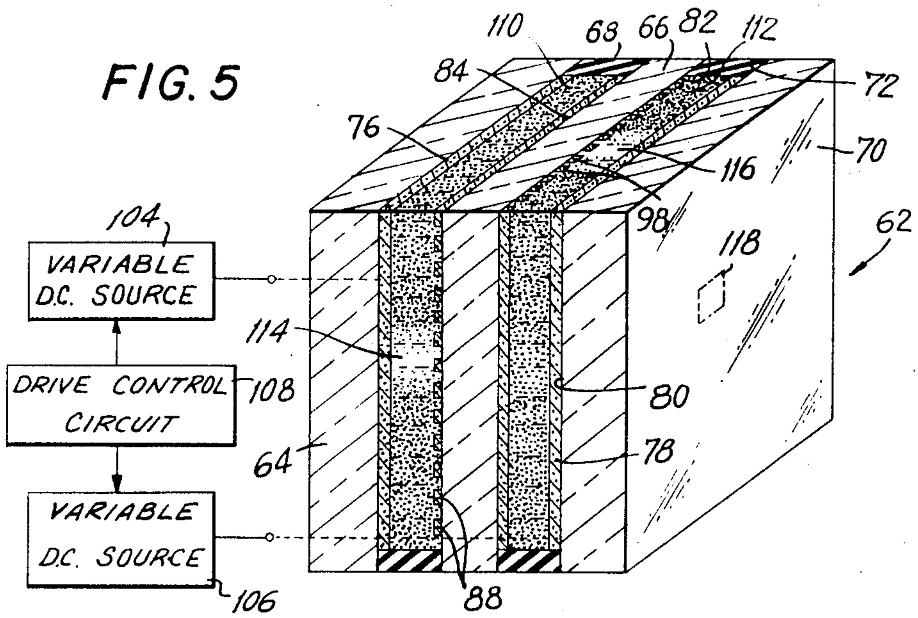


FIG. 6

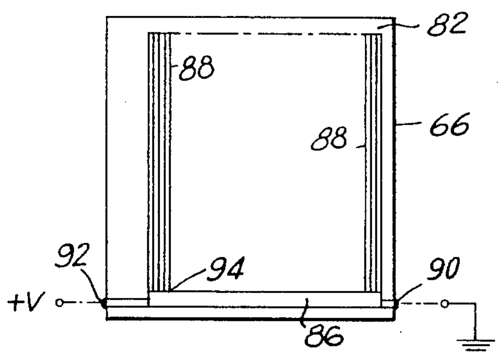
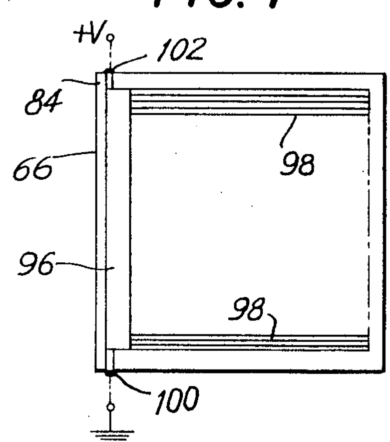


FIG. 7



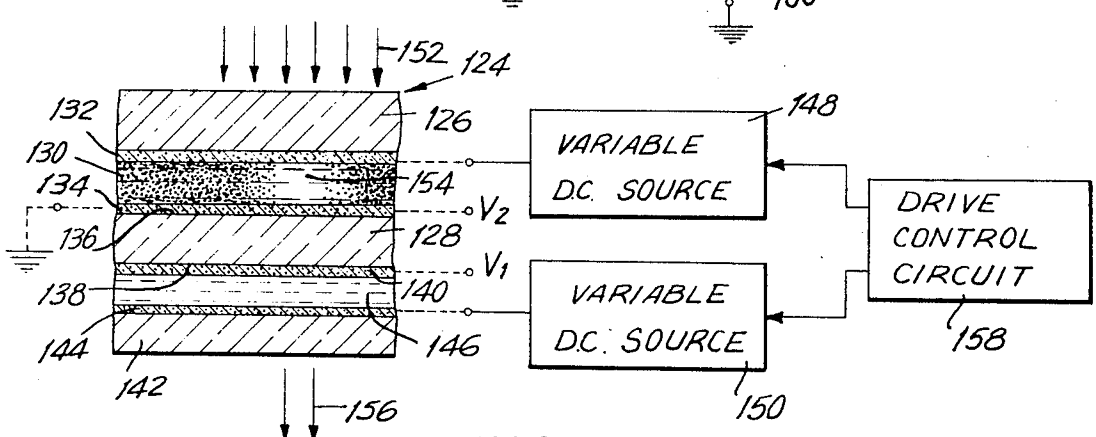


FIG. 8

FIG. 9C

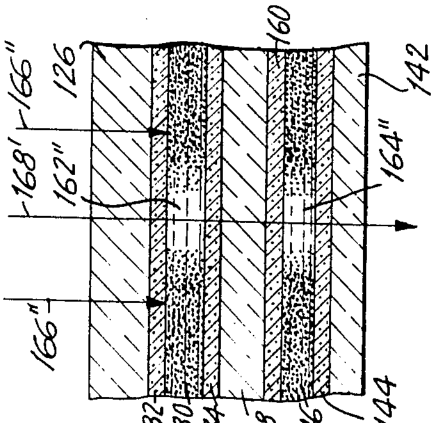


FIG. 9B

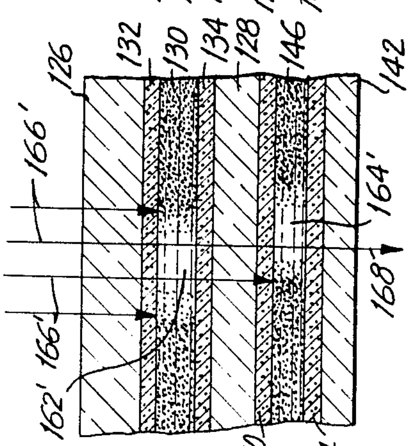


FIG. 9A

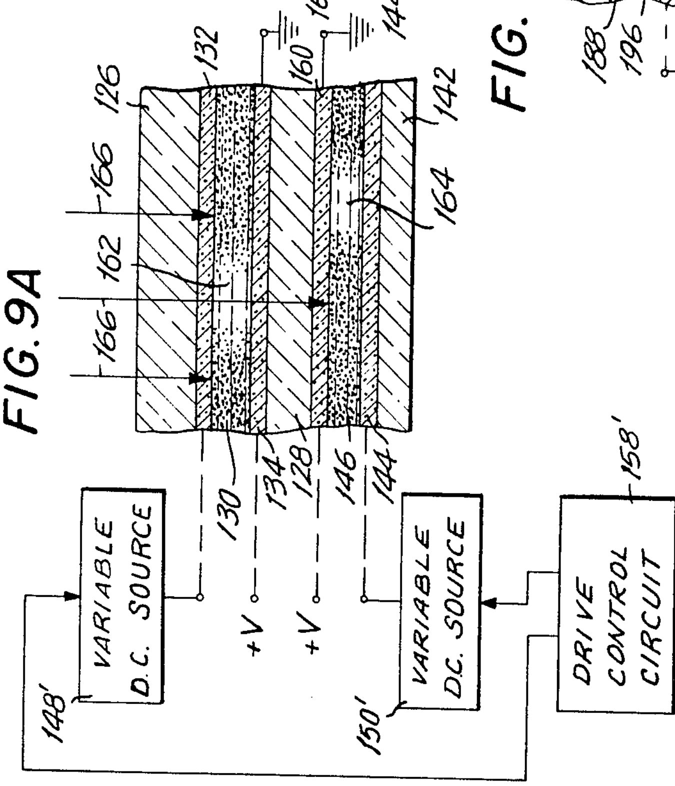


FIG. 11

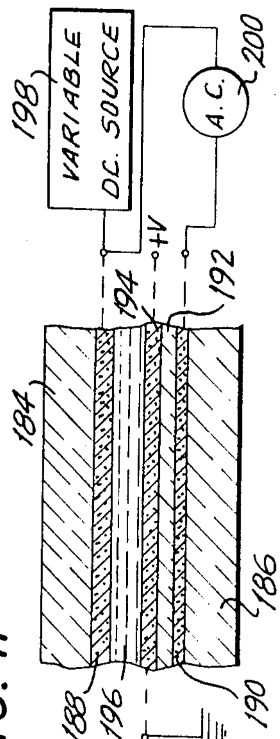


FIG. 12

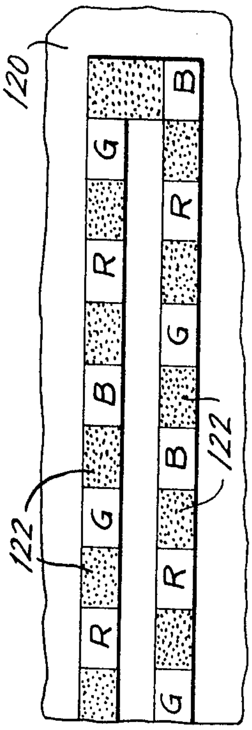
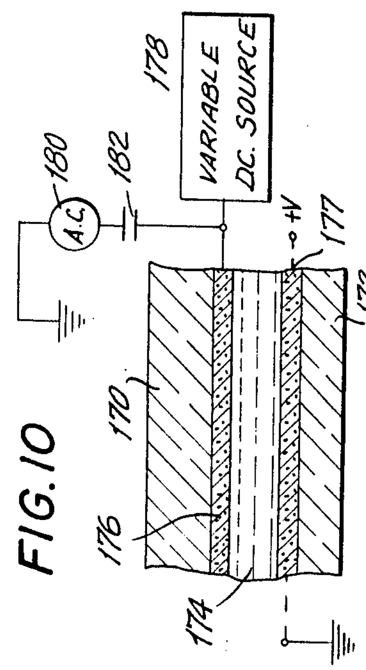


FIG. 10



SCANNER DEVICES UTILIZING FIELD EFFECT LIGHT SCATTERING DIELECTRICS

BACKGROUND OF THE INVENTION

This invention relates to devices utilizing field effect light scattering dielectrics, and in particular, to scanning and display devices incorporating such dielectrics.

The dielectrics in question have at least some characteristics of and are characterized by the phenomenon of voltage controlled light scattering. Examples of such dielectrics are nematic liquid crystal materials, mixtures of nematic and cholesteric liquid crystal materials, and ferroelectric ceramic crystal materials. Examples of such materials are available which will transmit light in the absence of the application of an electric field thereto, but will scatter light when an electric field is applied thereto. Thus, in the case of nematic liquid crystal materials, such materials are transparent in the absence of an electric field, and become cloudy or opaque to a degree proportional to the strength of the electric field applied thereto, until such field is of a value where no light may pass therethrough.

Electric fields are applied to such dielectrics by mounting the dielectric between a pair of conductive electrodes and applying a voltage between said electrodes. The dielectrics in question are further characterized by an ultra-high resistance so that either no current or a negligible current flows between the electrodes.

In the art, liquid crystal materials have been utilized in display devices, with selective regions of a thin layer of the liquid crystal material being rendered visible in response to selectively applied electric fields. However, such prior art devices have required the provision of at least one separate conductive electrode associated with each of the regions to be selectively rendered visible, and a lead connected to each such separate electrode. Where patterns are to be displayed by means of the liquid crystal display, a suitable matrix of separate conductive electrodes must be provided, each element in the matrix being separately energized through a separate lead. The large number of leads required for complex displays has rendered this device impractical.

It has also been proposed to activate field effect light scattering dielectrics by means of a CRT election beam scan. However, this approach still requires the bulky filament, deflection coils, etc. so as to be both expensive and of large size.

By providing a scanner device wherein scanning is achieved on a flat screen display without mechanical moving parts and through the use of a minimum number of lead connections, the foregoing disadvantages in the prior art are overcome.

SUMMARY OF THE INVENTION

Generally speaking, in accordance with the invention, a device for rendering selected regions of field effect light scattering dielectrics visually distinguishable from othe regions thereof is provided, including a pair of spaced plates having a field effect light scattering dielectric retained therebetween. A resistor defining a resistive electrical path of predetermined length and configuration and a substantially non-resistive conductor are respectively mounted on opposed facing surfaces of said plates with said selected regions of said electric therebetween. At least one of the plates and one of the resistor or conductor mounted thereon are transparent. Means are provided for applying a first voltage between the ends of the electrical path of said resistor and a second variable voltage to said conductor, said means permitting selective setting of said second voltage to displace the point on said linearly extending resistor at which the voltage equals said second voltage to render the region of said dielectric adjacent said point visually distinguishable.

A scanning device may be provided by forming said resistor so that the electrical path thereof follows the path to be scanned, and varying said second voltage substantially over the voltage drop range defined by the application of said first voltage to said resistor. An alternate embodiment of the scanning device in accordance with the invention may be produced by providing two of said devices in side-by-side relation, the first of said devices having a resistor in the form of a strip longitudinally extending along a first axis on the surface of the associated plate and having a plurality of discrete substantially non-resistive conductor strips extending substantially laterally from spaced positions along the length of said resistor strip and in electrical connection therewith. The second of said devices has its respective linearly extending resistor in the form of a resistor strip extending longitudinally along the surface of the associated plate on an axis extending substantially parallel to said first-mentioned discrete non-resistive conductor strips, and having second discrete substantially non-resistive conductor strips extending laterally along said associated surface from spaced locations along the length of said second resistor strip, said second discrete conductor strips extending substantially parallel to said first-mentioned resistor strip of said first device. Means is provided for varying the second voltage applied to each conductor of each of the two devices substantially over the voltage range drop defined by the application of said first voltage to each of said resistors, so that the region of the field effect light scattering dielectric of each device adjacent the discrete non-resistive conductor strip engaging each resistor at the point on said resistor at which the voltage equals said second voltage would be rendered visible but for the existence of the two devices side-by-side. In fact, only the point representing the intersection of said two discrete non-resistive conductors is rendered visible, which point can be selectively positioned for scanning by adjustment of the second voltage of each device.

Means may be provided for selectively adjusting the degree of visibility of the selected visible region. Said means may include a further device positioned in side-by-side relation with the device for rendering visible selected regions of field effect light scattering dielectrics in accordance with the invention. Said further device may include a pair of spaced plates having a field effect light scattering dielectric retained therebetween, a substantially non-resistive conductor being respectively mounted on opposed facing surfaces of said plates. Means is provided for applying second and third voltages respectively to said further non-resistive conductors and for selectively varying the relative values of said third and fourth voltages for selective control of the degree of light transmission of the further field effect light scattering dielectric, and therefore the degree of visibility of said selected region of said first-mentioned field effect light scattering dielectric.

In another embodiment, two of said scanning devices are provided in side-by-side relation, the resistors of each of said two devices being substantially aligned. Means is provided for selectively varying the respective second voltages of each of said devices for the selective relative positioning of the points on the electrical path of said resistors at which the voltage equals the respective second voltage, the degree of visibility depending on the degree of alignment of said points.

Visual resolution at selected points along the electrical path of the resistor of the scanning device in accordance with the invention may be controlled by regulating the speed at which said second voltage is varied, selected points along said path not being rendered visible since the voltage at that point equals said second voltage for too short a time to render visible the region of said dielectric adjacent said point. A suitable mask may be mounted on one of said plates either covering points along the electrical path of said resistor or including colored elements to provide a color display.

Where said dielectric is a storage mode nematic-cholesteric liquid crystal material, means may be provided for applying an alternating signal between said resistor and said conductor to render visible the points on the electrical path of said resistor at which the voltage equals said second voltage. Said means may include a capacitor isolated A.C. source coupled to said conductor. In another embodiment, said resistor is mounted on a thin layer of insulation, which in turn is mounted on a substantially non-resistive conductor, which in turn is mounted on the surface of one of the plates, an A.C. source being connected between said first-mentioned and further conductors.

Accordingly, it is an object of this invention to provide a device for rendering selected regions of field effect light scattering dielectrics visually distinguishable from other regions thereof through the use of a minium number of leads.

A further object of the invention is to provide a scanner device having no mechanical moving parts, and which will selectively scan a predetermined pattern.

Another object of the invention is to provide a scanner device formed from a substantially flat plate, which permits sequential scanning of points along a predetermined scan pattern, and the modulation of said points in order to form images.

Still another object of the invention is to provide a scanner device which permits the control of the hue or color at selected points along a scan pattern to permit the production of full color images.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification and drawings.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the apparatus embodying features of construction, combinations of elements and arrangement of parts which are adapted to effect such steps, all as exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a top plan view of one embodiment of the scanner device in accordance with the invention;

FIGS. 2 and 4 are sectional views taken along lines 2—2 and 4—4 respectively of FIG. 1;

FIG. 3 is a schematic representation of the operating principle of the scanner device of FIG. 1;

FIG. 8 is a fragmentary sectional view of a second embodiment of the scanner device in accordance with the invention;

FIG. 5 is a sectional perspective view of a third embodiment of the scanner device in accordance with the invention;

FIGS. 6 and 7 are, respectively, plan views of each surface of the central plate of the embodiment of FIG. 5, depicting the configuration of the resistor and discrete non-resistive conductor thereon;

FIGS. 9A, 9B and 9C are fragmentary sectional views of a fourth embodiment of the scanner device in accordance with the invention under three different operating conditions;

FIGS. 10 and 11 are fragmentary sectional views of fifth and sixth embodiments respectively of the scanner device in accordance with the invention; and

FIG. 12 is a fragmentary top plan view of a tri-color mask in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, a first embodiment 10 of the scanner device in accordance with the invention is depicted. Device 10 consists of a first transparent plate 12 maintained in closely spaced relation to a second transparent plate 14 by means of a peripheral sealing member 16. Deposited on the inner surface 18 of plate 12 is a layer of a substantially non-resistive conductor 20. Conductor 20 is provided with an external terminal 22. A lead 24 connects external terminal 22 to a variable D.C. source 26, the function of which will be more particularly discussed below. One characteristic of conductor 20 is that, since it is substantially non-resistive, a voltage applied to external terminal 22 would be present along the entire area of conductor 20. In the embodiment of FIGS. 1 and 2, this area is represented by the area of the surface 18 of plate 12 encompassed by peripheral sealing member 16. Deposited on surface 28 of plate 14 is a narrow resistor 30 extending between end terminals 32 and 34, which provide means for the external connection of a voltage said resistor defining a resistive electrical path of predetermined length and configuration between said terminals. Thus, a positive voltage +V is applied to terminal 32 through lead 36, while terminal 34 is connected through lead 38 to ground. Resistor 30 defines a series of closely spaced parallel strips 40 joined at respective ends by relatively short cross strips 42 to define a single resistor extending between terminals 32 and 34 and being substantially electrically linear along said electrical path. Both substantially non-resistive conductor 20 and conductor 30 may be formed by the deposit of a layer of tin oxide on a glass plate. The tin oxide has the characteristic of being essentially transparent, of being substantially non-resistive when deposited in sheets, and of having linear resistance when deposited in relatively thin strips.

Confined between plates 12 and 14 and sealing member 16 is a thin layer of nematic liquid crystal material 44. While nematic liquid crystal material is illustrated in the embodiment of FIGS. 1 and 2, any field effect light scattering dielectric may be utilized. In the embodiment depicted in FIGS. 1 and 2, plates 12 and 14, conductor 20, and resistor 30 are all transparent. As will be described more particularly below, liquid crystal material 44 is likewise transparent in the absence of the application of an electric field thereto, so that where no voltage is applied to either conductor 20 or resistor 30, light may be freely transmitted through device 10. Device 10 may also operate on a reflection principle, in which case only plate 12 and conductor 20, or plate 14 and resistor 30, must be transparent. Nematic liquid crystals are characterized by rod-like organic molecules which normally tend to maintain a parallel or nearly parallel alignment. When subjected to an electric field, ions within the material are pulled toward one or the other of the poles producing the field to disrupt the substantially parallel array. The regions of turbulence thus produced cause the material to become "milky" or substantially opaque, since the material subjected to an electric field scatters light. Once the electric field is removed, the molecules reestablish their ordered patterns, and the material assumes its previous transparent condition. The time required for the return of the material to its transparent state will be referred to herein as the relaxation time. Nematic liquid crystal materials are available with varying relaxation times.

Control of electric fields applied to selected regions of liquid crystal material 44 permits the production of a number of optical effects. If a light generator is placed on one side of device 10, for example facing plate 12, and the device is viewed from the side of plate 14, light emission can be controlled. If a light reflecting material is placed on one side of device 10, for example against plate 12, and the device is viewed from the side of plate 14, then light reflection can be controlled. If the light absorbing material is placed on the side of plate 12, and the device 10 is viewed from plate 14, then light absorption can be controlled. One characteristic of the device 10 is that it may operate not only from light applied from an artificial light source, but also from ambient light.

The principle of operation of device 10 will be explained in connection with the schematic representation of FIG. 3, with like reference numerals being applied to like elements. By way of example, it is assumed that a positive voltage of 40 volts is applied to end terminal 32 of resistor 30 through lead 36. It is assumed that leads 36 and 38 are substantially non-resistive, so that the entire 40 volt voltage is supplied between end terminals 32 and 34. Further, it is assumed that resistor 30 is substantially electrically linear along its electrical path, so that voltages of 10, 20 and 30 volts are respectively present at points 46, 48 and 50 along resistor 30. Variable D.C. source 26 is adapted to selectively apply a voltage anywhere between 0 and 40 volts. It is assumed that lead 24 is substantially non-resistive, so that the voltage applied by source 26 appears uniformly along the length of non-resistive conductor 20.

If source 26 applies a D.C. voltage of 40 volts to conductor 20, then the region of liquid crystal material 44 between end terminal 32 and conductor 20 would have no electric field applied thereto due to the zero potential difference in that region. On the other hand, at point 50, the voltage difference would be 10 volts, while at end terminal 34, the voltage difference would be the full 40 volts. Thus, the portions of liquid crystal material 44 adjacent all of resistor 30 except the region of end terminal 32 would be subjected to an electric field. While the strength of the electric field required to render a particular liquid crystal material opaque varies from material to material, for the purpose of this discussion, can be assumed that all of the liquid crystal material 44 adjacent resistor 30 except that portion in the region of end terminal 32 would be rendered opaque. As the voltage from source 26 is lowered along its range, the zero potential difference point shifts. Thus, when the source voltage applied to conductor 20 equals 20 volts, the zero potential difference point is in the region adjacent point 48 on resistor 30. Under these conditions, a voltage difference of 10 volts would exist at both points 46 and 40. The 20 volt potential difference in the region of end terminal 32 would place the liquid crystal material in that region in an opaque state.

The foregoing principle is further illustrated in connection with FIG. 4, wherein arrows 52 illustrate generated light applied to device 10, while arrows 54 represent the light transmitted through the device. The region 56 of liquid crystal material 44 is transparent, and represents the region at which the potential on conductor 20 equals the potential on resistor 30. Regions 58 on either side of region 56 represent the transition between transparency and opacity, and represents the region of the liquid crystal material where the electric field is sufficient to cause some disruption, but insufficient to render the liquid crystal material opaque. If the zero potential spot was being displaced along the length of resistor 30 by the selective adjustment of the voltage of source 26, then regions 58 might also represent areas wherein the disturbed liquid crystal material was relaxing into the transparent state, and wherein disruption was in the process of causing opacity.

The regions 60 on either side of regions 58 represent areas wherein the potential difference between resistor 30 and conductor 20 is sufficient to cause the liquid crystal material therebetween to be substantially opaque.

Where source 26 is varied at a uniform rate between 0 and 40 volts, and where the rate of change of voltage is such that the liquid crystal material is permitted to relax at each zero potential point, the entire length of resistor 30 is sequentially "scanned" by a transparent window defined by the transparent region of liquid crystal material 44. Where resistor 30 is disposed in a pattern such as the pattern depicted in FIG. 1, the sequential scanning of a rectangular area is permitted. Scanning can be achieved from both directions, the zero potential point, and therefore the "window" in the liquid crystal material shifting as the voltage is both lowered and raised. By selecting the material for resistor 30 so that said resistor has a sufficiently large resistance, power dissipation therein may be held to a minimum.

The spacial area or resolution of the scanning "window" is dependent on the amount of total resistance in resistor 30, the amount of voltage applied to the resistor, the operating voltage range of the light scattering dielectric, and the length of resistor 30. While a scanning pattern based primarily on substantially parallel lines is depicted in the embodiments of FIGS. 1 and 2, any desired scanning pattern may be utilized.

A second scanning approach is depicted in FIGS. 5 – 7. Device **62** includes three transparent plates, namely, a first plate **64**, a second, middle plate **66** maintained in spaced relation with plate **64** by sealing member **68**, and a third plate **70** maintained in spaced relation to second plate **66** by sealing member **72**. Surface **74** of plate **64** has a non-resistive conductor **76** deposited thereon. A similar non-resistive conductor **78** is deposited on surface **80** of third plate **70**. A pattern of non-resistive conductors and a resistor illustrated in FIG. **6** is deposited on surface **82** of second plate **66**, while a pattern of non-resistive conductors and a resistor illustrated in FIG. **7** is deposited on surface **84** of said second plate.

Referring first to FIG. **6**, said pattern consists of a linearly extending resistor **86** disposed adjacent to and extending substantially parallel to one edge of surface **82**. Extending substantially normally from resistor **86** and electrically connected thereto are a series of parallel non-resistive conductor strips which extend from colsely spaced positions along resistor **86**. End terminal **90** of resistor **86** is connected to ground, while end terminal **92** is connected to a positive voltage source having a voltage of +V. As discussed in connection with resistor **30** of the embodiment of FIGS. **1** and **2**, each point along the electrical path of resistor **86** has a different voltage proportional to the resistance from that point to end terminals **90** and **92**. The voltage at each point at which a non-resistive conductor strip is connected, is applied to that strip. Thus, if the voltage at point **94** along resistor strip **86** were **30** volts, that voltage would appear along the entire length of the one conductor strip **88** electrically connected to resistor **86** at point **94**. As depicted in FIG. **7**, surface **84** of second plate **66** is also provided with a resistor **96** defining a resistive electrical path, but resistor **96** is aligned adjacent an edge of surface **84** such that it extends substantially parallel to conductor strips **88** on surface **82**. A series of parallel, closely-spaced non-resistive conductor strips **98** are deposited on surface **84** extending substantially normally from closely-spaced points along the length of resistor **96**. Conductor strips **98** extend substantially parallel to resistor **86** on surface **82**. Thus, a cross grid is produced in device **62** by the non-resistive conductor strips **88** and **98**. Resistor **96** is provided with end terminals **100** and **102** connected respectively to ground and a positive voltage of +V.

A first variable D.C. source **104** is connected to conductor **76**, while a second variable D.C. source **106** is connected to conductor **78**, as shown schematically in FIG. **5**. A drive control circuit **108** is operatively coupled to sources **104** and **106** for the coordinate control thereof.

A first layer of nematic liquid crystal material **110** is received and retained between first plate **64** and second plate **66**. A second layer of nematic liquid crystal material **112** is retained and received between second plate **66** and third plate **70**. Since each of the conductor strips assume the potential of the point on the associated resistor, when the potential at a point on resistor **86** equals the potential on conductor **76**, the entire region of liquid crystal material **110** coupled to the resistor at that zero potential point would be transparent, while the remaining portions of the liquid crystal material would be rendered opaque due to the electric field produced by the voltage difference in other regions. Thus, by way of example, the region **114** of liquid crystal material **110**, consisting of a linearly extending strip defined by one of conductor strips **88** would be transparent. Similarly, conductive strips **98** cooperate with conductor **78** to produce a linearly extending transparent region **115** in liquid crystal material **112**. The intersection of the two linearly extending transparent regions, represented by the dashed box **118** on the outer surface of third plate **70**, would represent a transparent window through device **62**. The precise positioning of window **118** would depend on the voltage of the variable D.C. sources **104** and **106** relative to the fixed voltage V applied to each of resistors **86** and **96**. By coordinately and continuously varying sources **104** and **106** by means of drive control circuit **108**, window **118** may be scanned along substantially the whole area of plate **70** or can be selectively positioned at desired matrix locations on said plate. In one embodiment of a continuous scan, source **104** would be continuously scanned along its entire voltage range, while source **106** would be incrementally advanced after each cycle of source **104** to place the zero potential spot at the next conductor strip **98**.

The above-described arrangements constitute mere scanning devices for scanning along predetermined paths. Where the device is to be utilized for more than mere scanning, as for the recording and forming of images it is necessary to modulate the light transmitted or reflected from the scanned region by controlling the intensity of said transmitted or reflected light. A first approach takes advantage of the relaxation time of the field effect light scattering dielectric such as the nematic liquid crystal material. Referring to FIGS. **1** and **2**, the rate of variation of the voltage applied to conductor **20** can be readily and selectively controlled in variable D.C. source **26**. If the rate of voltage change is extremely fast over an incremental voltage range, the region of the nematic liquid crystal material **44** adjacent the portion of resistor **30** associated with that voltage drop will be unable to relax, and therefore to become visible during the period of time that the zero potential difference point passes therethrough. In other words, the rate of voltage change is such that the zero potential point persists for a period of time less than the relaxation time of the material. By adjusting the rate of voltage variation relative to the relaxation time of the particular material, it is possible for each incremental spot along the scan path to be either rendered visible completely due to the complete relaxation of the material, rendered partially visible due to the partial relaxation of the material, or to remain invisible due to the lack of relaxation of the material. Thus, the precise adjustment of the rate of change in the voltage of source **26** may permit the creation of transmitted tones ranging from black through gray to white at each point along the scan path. By modulating the speed of voltage change, complete image transmission is possible. A suitable mask may be mounted on the outer surface of one of plates **12** and **14** consisting of alternating clear and blackened regions along the scan path permitting the zero voltage point to dwell in regions obscured by the blackened area of the mask so that each line of scanning will take a uniform period of time without regard to the number of darkened or light regions along the length of that line. An example of a section of such a mask utilized for full color transmission is depicted in FIG. **12**, wherein mask **120** has blackened region **122** arranged with alternating colored sections, the sections marked R representing red, the sections marked G representing green, and the sections marked B representing blue. The alternating colored and black regions would be aligned with the path of resistor **30.** In the full color embodiment of FIG. **12,** it is possible not only to control intensity, but also to control the particular color of a region by the rate of voltage change at each point along the scan path. Of course the spacing between each of the colored spots, as well as between the lines of the scan array would be small so as to permit the production of a high resolution display.

Referring now to FIG. **8,** a third embodiment of the arrangement in accordance with the invention showing a second approach for modulating light intensity is depicted. Embodiment **124** includes a first plate **126** maintained in spaced relation from a second plate **128** by a sealing member (not shown). Plates **126** and **128** together define a device similar to device **10** and would include liquid crystal material **130** therebetween, a non-resistive conductor **132** deposited on plate **126** and a resistor **134** deposited on surface **136** of second plate **128.** A second non-resistive conductor **140** would be deposited on the opposed surface **138** of second plate **128.** A third plate **142** having a third non-resistive conductor **144** deposited thereon would be maintained in spaced relation to surface **138** of plate **128,** liquid crystal material **146** being maintained therebetween. A first variable D.C. source **48** would be coupled to first conductor **132,** a voltage V_1 would be coupled to second conductor **140,** while a second variable D.C. source **150** would be applied to third conductor **144.** Resistor **134** would be connected between a voltage V_2 and ground. If the voltage from source **150** equals the voltage from source V_1, a liquid crystal material **146** is fully transparent, and applied light represented by arrows **152** would pass through transparent region **154** of liquid crystal material **130** as represented by arrows **156.** Of course, said transparent region would represent the zero potential point between the voltage of source **148** and the voltage on resistor **134.** When the voltage of source **150** is varied from the V_1 value, liquid crystal material **146,** as a unit, becomes gradually less transparent, until it is rendered opaque. By selectively adjusting the value of source **150** over a narrow range, the light which would otherwise be transmitted through the transparent scan point in liquid crystal material **130** may be modulated to produce a range of shades from black through gray to white. A drive control circuit **158** may be provided for coordinately controlling the operation of sources **148** and **150** for full image production.

Referring now to FIGS. **9A, 9B** and **9C,** a fourth embodiment of the arrangement according to the arrangement is depicted, incorporating a third modulation approach. The arrangement of FIGS. **9A, 9B** and **9C** differ from the arrangement of FIG. **8** in that second conductor **136** is replaced by a second resistor **160** arranged in a configuration corresponding to the configuration of first resistor **134.** Accordingly, like reference numerals have been applied to like elements.

A first variable D.C. source **148'** is connected to conductor **132** while a second variable D.C. source **150'** is connected to conductor **144.** A drive control circuit **158'** is connected to both of said sources for the coordinate control thereof. Resistors **134** and **160** are both connected between ground and a voltage V. Thus, the device of FIG. **9A, 9B** and **9C** consists essentially of a stack of two of the devices of FIGS. **1** and **2,** having a common plate. In each of the two stacked devices, a zero potential difference point is displaced along the length of the respective resistor by adjusting the value of the source voltage connected to the associated conductor.

The zero potential point in liquid crystal material **130** is depicted by region **162** while the zero potential point in liquid crystal material **148** is depicted by region **164.** Where, as depicted in FIG. **9A,** the zero potential difference points are out of registration, applied light represented by arrows **166** is fully blocked by opaque regions of one or both of the liquid crystal material layers and no light is transmitted. Where, as depicted in FIG. **9B,** the zero potential difference point **162'** in liquid crystal material **130** is partially in registration with the zero potential point **164'** in liquid crystal material **146,** a portion of the applied light represented by arrows **166'** is blocked, while a portion represented by arrow **168** is transmitted through the device. Finally, as illustrated in FIG. **9C,** where the zero potential difference points **162''** and **164''** are in registration, a greater quantity of light represented by arrow **168'** is transmitted through the device, and only the light outside of the region of zero potential difference point **162'',** as represented by arrows **166'',** is blocked. By the selective relative positioning of the zero potential difference points in the two layers of liquid crystal material, the amount of transmitted light can vary from no transmission through degrees of partial transmission to full transmission, thereby providing modulation of light intensity.

A fourth embodiment of the arrangement in accordance with the invention is depicted in FIG. **10.** The embodiment of FIG. **10** utilizes storage mode nematic-cholesteric liquid crystal material. This material is characterized by a memory such that when such material is subjected to an electric field the material will remain opaque for a long time, for example, as much as a month. In order to restore the storage mode material to its clear condition, an A.C. signal of a moderate frequency and moderate voltage, in one embodiment, a few kHz at about 50 volts, must be applied across the material. The degree of clearing will depend on the voltage and frequency of the applied A.C. signal. The embodiment of FIG. **10** takes advantage of the storage mode nematic-cholesteric liquid crystal material and consists of plates **170** and **172** maintained in spaced relation and having layer of such material **174** therebetween. A resistor **177** is deposited on the surface of plate **172,** which resistor is connected between ground and a positive voltage +V. A non-resistive conductor **176** is deposited on the surface of plate **170** and is connected to a variable D.C. source **178.** An A.C. source **180** is connected through a capacitor **182** connected to conductor **176.** Capacitor **182** provides D.C. isolation ot the A.C. source, which source is connected between said capacitor and ground. With this arrangement, the A.C. signal is strongest at the zero D.C. potential difference point and will clear the storage mode nematiccholesteric liquid crystal material at this point as it shifts along the length of resistor **177.** Since the degree of clearing at the zero potential difference point is dependent on the frequency and the voltage of the A.C. source, modulation of the visibility of the point is possible. Since one side of A.C. source **180** is connected through ground to resistor **177,** the impedance presented by resistor **177** at different positions of the zero potential difference point would have to be compensated for.

The foregoing deficiency is eliminated in the embodiment of FIG. **11,** wherein a pair of spaced plates **184** and **186** are provided, a non-resistive conductor **188** being deposited on the surface of plate **184.** The facing surface of plate **186** has a non-resistive conductor **190** deposited thereon, which in turn has a transparent insulating sheet **192** deposited thereon. A resistor **194** is deposited on transparent insulating sheet **192** in the desired pattern, a storage mode nematic-cholesteric liquid crystal material **196** being received in the space between resistor **194** and conductor **188.** Resistor **194** is connected between ground and a positive voltage +V, while a variable D.C. source **198** is applied to conductor **188.** An A.C. source **200** is connected between non-resistive conductors **188** and **190.** Since the voltage is applied to the non-resistive conductor **190,** it is applied uniformly across the entire length of resistor **194,** the transparent insulator **192** providing the required D.C. isolation.

While the embodiments of FIGS. **10** and **11** are provided with a moving clear spot, the rest of the device being dark, an energized "dark spot" is possible by applying an A.C. signal across the resistor and applying a variable A.C. voltage, 180° out of phase with and of the same frequency as the A.C. signal applied across the resistor, to the non-resistive conductor. This arrangement creates and controls a zero A.C. potential difference point, the rest of the device being continually driven clear. By applying an A.C. -isolated D.C. voltage to the device, for example by applying the D.C. voltage to the conductor, the zero A.C. potential difference point is affirmatively driven to the dark mode. It has also been found that some nematic liquid crystal materials can be driven clear by a suitable A.C. voltage, so the embodiments of FIGS. **10** and **11** are not limited to storage mode nematic-cholesteric liquid crystal materials.

In all of the foregoing embodiments, various plates, resistors and conductors can be formed of transparent materials if light transmission is desired, or certain of the plates, resistors and conductors can be formed of opaque materials or suitable reflectors can be provided if reliance on reflection is desired.

While the embodiment of FIGS. **5–9** are shown with a single common plate having conductors or resistors deposited on opposed faces thereof, such devices could be formed in two portions with the middle plate replaced by two separate plates positioned in side-by-side relation. Further, while the particular nematic liquid crystal material and storage mode nematic-cholesteric liquid crystal material discussed in connection with the depicted embodiments is characterized by being normally transparent and being rendered substantially opaque when subjected to a suitable electric field, any field effect light scattering dielectric, including ferroelectric ceramic crystal materials having the characteristic of undergoing a visible change when subjected to an electric field may be incorporated in the devices in accordance with the invention.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in carrying out the above process and in the article set forth without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A device for rendering selected regions of field effect light scattering dielectrics visually distinguishable from other regions thereof by selective alteration of the light scattering capabilities thereof comprising first and second base members aligned in spaced relation along an axis; a resistor mounted on said first base member facing said second base member and defining a resistive electrical path of predetermined length and a zig-zag configuration, said electrical path including an array of substantially parallel, closely spaced segments; a substantially non-resistive conductor mounted on said second base member facing and overlapping said resistor in the direction of said axis; a field effect light scattering dielectric positioned between said first and second base members at least in the region of said resistor and conductor, at least one of said first and second base members and the one of said resistor and conductor mounted thereon being substantially transparent; and means for applying a first voltage across at least the portion of the electrical path of said resistor defining said array and for applying a second variable voltage to said conductor, said means permitting selective setting of said second voltage to displace along the portion of said electrical path of said resistor defining said array the point on said electrical path at which the voltage equals said second voltage to render the region of said dielectric adjacent said zero potential difference point visually distinguishable from other regions thereof.

2. A device as recited in claim **1,** wherein said dielectric is a liquid crystal material of a type rendered substantially opaque when subjected to a D.C. electric field and rendered substantially transparent when subjected to an A.C. field, said first and second voltages being D.C. voltages for producing D.C. electric fields, and including means for applying an A.C. electrical field to said dielectric simultaneous with the application of said D.C. electrical fields for rendering the region of said dielectric adjacent said zero potential difference point substantially transparent.

3. A device as recited in claim **2,** wherein said liquid crystal material is a storage mode nematic-cholesteric liquid crystal material.

4. A device as recited in claim **1,** wherein said dielectric is a liquid crystal material of a type rendered substantially opaque when subjected to a D.C. electric field and rendered substantially transparent when subjected to an A.C. electric field, said first and second voltages being A.C. voltages of substantially the same frequency and substantially 180° out of phase for producing A.C. electric fields, and including means for applying a D.C. electric field to said dielectric simultaneous with the application of said A.C. electric fields for rendering the region of said dielectric adjacent said zero potential difference point substantially opaque.

5. A device as recited in claim **4,** wherein said liquid crystal material is a storage mode nematic-cholesteric liquid crystal material.

6. A device as recited in claim 1, wherein said portion of said electrical path of said resistor has a substantially linear resistance.

7. A device as recited in claim 1, wherein said dielectric is a nematic liquid crystal material.

8. A device as recited in claim 1, wherein said dielectric is a ferroelectric ceramic crystal material.

9. A device as recited in claim 1, wherein both said conductor and resistor and both of said base members are substantially transparent.

10. A device as recited in claim 1, wherein said voltage means is adapted to permit the continuous adjustment of said second voltage along a range of values corresponding to the voltage drop across said length of said resistor.

11. A device as recited in claim 1, wherein said voltage means is adapted to permit selective control of the rate of varying of said second voltage, the degree to which the region of said dielectric adjacent each zero potential difference point along said electrical path is visually distinguishable from other regions thereof depending on the period of time during which said zero potential difference point remains substantially adjacent said region.

12. A device as recited in claim 11, including mask means aligned with said portion of said electrical path of said resistor defining said array, said mask means including alternate transparent and opaque regions, said opaque regions masking zero potential points in registration therewith to render them visually indistinguishable.

13. A device as recited in claim 12, wherein said transparent regions of said mask means are selectively colored for the selective coloring of the visually distinguishable regions of said dielectric.

14. A device as recited in claim 11, including mask means aligned with said portion of said electrical path of said resistor defining said array, said mask means including alternating regions of at least three colors for selectively coloring the visually distinguishable regions of said dielectric.

15. A device for rendering selected regions of field effect light scattering dielectrics visually distinguishable by selective alteration of the light scattering capabilities thereof comprising first and second base members aligned in spaced relation along an axis; a resistor mounted on said first base member facing said second base member along said axis and defining a resistive electrical path of predetermined length and configuration; a plurality of parallel substantially non-resistive conductor strips mounted on said first member and extending, in a direction substantially transverse to said axis, from and electrically connected to a plurality of points spaced along the length of said electrical path of said resistor; a substantially non-resistive conductor mounted on said second base member so as to face and overlap at least said conductor strips along said axis; a field effect light scattering dielectric positioned between said first and second base members at least in the region of said conductor strips and conductor, at least one of said first and second base members and the resistor, conductor strips or conductor mounted thereon being substantially transparent; and means for applying a first voltage across said electrical path of said resistor and for applying a second variable voltage to said conductor, said voltage means permitting selective setting of said second voltage to displace, along said electrical path, the point on said electrical path at which the voltage equals said second voltage, each of said conductor strips substantially assuming the voltage of the associated point on said electrical path so as to render the region of said dielectric adjacent the conductor strip associated with said zero potential difference point on said electrical path visually distinguishable from other regions thereof.

16. A device as recited in claim 15, including first and second of said devices aligned on said axis and overlapping in the direction of said axis, said first device being oriented relative to said second device about said axis so that a projection of the conductor strips of said first device in the direction of said axis intersects the conductor strips of said second device, at least all of the base members, resistors, conductive strips and conductors of said first and second devices except one outer base member and the resistor, conductive strips or conductor mounted thereon as viewed along said axis being transparent whereby a selected aligned region of the respective dielectrics of said first and second devices representing the intersection of the second zero potential difference strip regions of said first and second devices is rendered visually distinguishable from other regions thereof.

17. A device as recited in claim 16, including control circuit means for coordinately controling the voltage means of said first and second devices for coordinately setting the respective second voltages of said first and second devices to select the aligned region to be rendered visually distinguishable.

18. A device as recited in claim 16, wherein said first and second devices are aligned so that the projection of the conductive strips of said first device along said axis intersects the conductor strips of said second device at a substantially right angle.

19. A device as recited in claim 18, wherein the respective resistors of said first and second devices are formed so that each of said electrical paths extend along a straight line, the projection of the electrical path of the resistor of said first device along said axis on the electrical path of the resistor of said second device intersecting said electrical path of said second device at substantially a right angle.

20. A device as recited in claim 16, wherein one of the first and second base members of said first device is formed integral with one of said first and second base members of said second device.

21. A device for rendering selected regions of field effect light scattering dielectrics visually distinguishable from other regions thereof by selective alteration of the light scattering capabilities thereof comprising first, second, third and fourth base members aligned along an axis with said first and second base members in spaced relation and said third and fourth base members in spaced relation along said axis; a resistor mounted on said first base member facing said second base member along said axis and defining a resistive electrical path of predetermined length and configuration; a substantially non-resistive conductor mounted on said second base member so as to face and overlap said resistor in the direction of said axis; a first field effect light scattering dielectric positioned between said first and second base members at least in the region of said resistor and conductor; means for applying a first voltage across said electrical path of said resistor and for applying a second variable voltage to said conduc-

tor, said means permitting selective setting of said second voltage to displace along said electrical path the point on said electrical path at which the voltage equals said second voltage to render the region of said dielectric adjacent said zero potential difference point visually distinguishable from other regions thereof; a second substantially non-resistive conductor mounted on said third base member facing said fourth base member along said axis and overlapping said resistor in the direction of said axis; a third substantially non-resistive conductor mounted on said fourth base member so as to face and overlap said third conductor in the direction of said axis; a second field effect light scattering dielectric positioned intermediate said third and fourth base members in the region of said second and third conductors, at least all but one outer, as viewed along said axis, of said first, second, third and fourth base members and the resistor or conductor mounted thereon being substantially transparent; and second means for applying a selectively variable third voltage between said second and third conductors for the application of an electric field of selected strength to said second dielectric for the selective control of the light transmission capability thereof, whereby the selective setting of said third voltage modulates the degree to which the region of said first-mentioned dielectric adjacent the zero potential difference point on the electrical path of said resistor is rendered visually distinguishable.

22. A device as recited in claim **21,** wherein at least one of said first and second base members and one of said third and fourth base members are formed integral with each other.

23. A device as recited in claim **21,** including control circuit means for the coordinate regulation of said first and second voltage means for the selective control of the third voltage applied by said second means at each zero potential difference point along the electrical path of said resistor.

24. A device for rendering selected regions of field effect light scattering dielectrics visually distinguishable from other regions thereof by selective alteration of the light scattering capabilities thereof comprising first, second, third and fourth base members aligned along an axis with said first and second base members in spaced relation and said third and fourth base members in spaced relation along said axis; a resistor mounted on said first base member facing said second base member along said axis and defining a resistive electrical path of predetermined length and configuration; a substantially non-resistive conductor mounted on said second base member so as to face and overlap said resistor in the direction of said axis; a first field effect light scattering dielectric positioned between said first and second base members at least in the region of said resistor and conductor; means for applying a first voltage across said electrical path of said resistor and for applying a second variable voltage to said conductor, said means permitting selective setting of said second voltage to displace along said electrical path the point on said electrical path at which the voltage equals said second voltage to render the region of said dielectric adjacent said zero potential difference point visually distinguishable from other regions thereof; a second resistor mounted on said third base member and facing said fourth base member along said axis and defining a resistive electrical path of predetermined length and configuration corresponding to and overlapping in the direction of said axis the electrical path of said first-mentioned resistor; a second conductor mounted on said fourth base member so as to face and overlap said second resistor in the direction of said axis; a second field effect light scattering dielectric positioned between said third and fourth base members in the region of said second resistor and said second conductor, all but the outer, as viewed in the direction of said axis, of said first, second, third and fourth base members and the resistor or conductor mounted thereon being substantially transparent; and means for applying a third voltage across the electrical path of said second resistor and for applying a fourth variable voltage to said second conductor, said means permitting selective setting of said fourth voltage to displace along the electrical path of said second resistor the point on said electrical path at which the voltage equals said fourth voltage, the respective overlapping regions, as viewed in the direction of said axis, of said first and second dielectrics being rendered visually distinguishable to the extent that the respective zero potential difference points on the electrical paths of said firstmentioned and second resistors overlap.

25. A device as recited in claim **24,** wherein one of said first and second base members and one of said second and third base members are integrally formed.

26. A device as recited in claim **24,** including control circuit means operatively coupled to said first and second means for coordinately controlling said second and fourth voltages for selectively controlling the degree of overlapping in the direction of said axis of the respective zero potential difference points on the electrical paths of said first-mentioned and second resistors.

27. A device for rendering selected regions of field effect light scattering dielectrics visually distinguishable from other regions thereof by selective alteration of the light scattering capabilities thereof comprising first and second base members aligned in spaced relation along an axis; a resistor mounted on said first base member facing said second base member along said axis and defining a resistive electrical path of predetermined length and configuration; a substantially non-resistive conductor mounted on said second base member so as to face and overlap said resistor in the direction of said axis; a field effect light scattering dielectric positioned between said first and second base members at least in the region of said resistor and conductor, at least one of said first and second base members and the resistor or conductor mounted thereon being substantially transparent; means for applying a first voltage across the electrical path of said resistor and for applying a second variable voltage to said conductor, said means permitting selective setting of said second voltage to displace along said electrical path the point on said electrical path at which the voltage equals said second voltage to render the region of said dielectric adjacent said zero potential difference point visually distinguishable from other regions thereof, said field effect light scattering dielectric being a liquid crystal material of a type rendered substantially opaque when subjected to a D.C. electric field and rendered substantially transparent when subjected to an A.C. field, said first and second voltages being D.C. voltages for producing D.C. electric fields, and means for applying an A.C. electric field to said dielectric for rendering the region of said dielectric adjacent said zero potential point substantially transparent.

28. A device as recited in claim 27, wherein said means for applying said A.C. electric field includes an A.C. source adapted to produce an A.C. signal of an amplitude and frequency selected to render said dielectric substantially transparent; and means for connecting said A.C. source between said resistor and said conductor, said connecting means including means for providing D.C. isolation for said A.C. source.

29. A device as recited in claim 27, wherein said means for applying said A.C. electric field includes a layer of electrically insulating material mounted on said first base member intermediate said first base member and said resistor; a second substantially non-resistive conductor mounted on said first base member intermediate said first base member and said layer of insulating material and overlapping, in the direction of said axis, said resistor; an A.C. source adapted to produce an A.C. signal of an amplitude and frequency selected to render said dielectric substantially transparent; and means for connecting said A.C. source between said first and second conductors for applying said A.C. field to said dielectric.

30. A device as recited in claim 28, wherein said dielectric is a storage mode nematic-cholesteric liquid crystal material.

31. A device as recited in claim 29, wherein said dielectric is a storage mode nematic-cholesteric liquid crystal material.

32. A device as recited in claim 29, wherein said A.C. source is adjustable to control the degree of visibility of said zero potential difference point.

33. A device for rendering selected regions of field effect light scattering dielectrics visually distinguishable from other regions thereof by selective alteration of the light scattering capabilities thereof comprising first and second base members aligned in spaced relation along an axis; a resistor mounted on said first base member facing said second base member along said axis and defining a resistive electrical path of predetermined length and configuration; a substantially non-resistive conductor mounted on said second base member so as to face and overlap said resistor in the direction of said axis; a field effect light scattering dielectric positioned between said first and second base members at least in the region of said resistor and conductor, at least one of said first and second base members and the resistor or conductor mounted thereon being substantially transparent; means for applying a first voltage across the electrical path of said resistor and for applying a second variable voltage to said conductor, said means permitting selective setting of said second voltage to displace along said electrical path the point on said electrical path at which the voltage equals said second voltage to render the region of said dielectric adjacent said zero potential difference point visually distinguishable from other regions thereof, said field effect light scattering dielectric being a liquid crystal material of a type rendered substantially opaque when subjected to a D.C. electric field and rendered substantially transparent when subjected to an A.C. field, said first and second voltages being A.C. voltages of substantially the same frequency and substantially 180° out of phase with each other for producing A.C. electric fields; and means for applying a D.C. field to said dielectric simultaneous with the application of said A.C. fields for rendering the region of said dielectric adjacent said zero potential difference point on said electrical path of said resistor substantially opaque.

34. A device as recited in claim 33, wherein said means for applying said D.C. electric field includes a D.C. source; and means for connecting said D.C. source between said resistor and said conductor, said connecting means including means for D.C. isolating said D.C. source from said A.C. voltages.

35. A device as recited in claim 33, wherein said means for applying a D.C. field includes a layer of insulating material mounted on said first base member intermediate said first base member and said resistor; a second substantially non-resistive conductor mounted on said first base member intermediate said layer of insulating material and said first base member and overlapping in the direction of said axis said resistor; a D.C. source; and means connecting D.C. source between said first-mentioned and second conductors for applying a D.C. electric field to said dielectric simultaneous with the application of said A.C. electric fields for rendering the region of said dielectric adjacent said zero potential difference point substantially opaque.

36. A device as recited in claim 34, wherein said dielectric is a storage mode nematic-cholesteric liquid crystal material.

37. A device as recited in claim 35, wherein said dielectric is a storage mode nematic-cholesteric liquid crystal material.

38. A device as recited in claim 35, wherein said D.C. source is variable for the selective control of the degree of visibility of said zero potential difference point.

39. A device for rendering selective regions of field effect light scattering dielectrics visually distinguishable from other regions thereof by selective alteration of the light scattering capabilities thereof comprising first and second base members positioned in spaced relation along an axis; a resistor mounted on said first base member facing said second base member along said axis and defining a resistive electrical path of predetermined length and configuration; a substantially non-resistive conductor mounted on said second base member so as to face and overlap said resistor in the direction of said axis; a field effect light scattering dielectric positioned between said first and second base members at least in the region of said resistor and conductor, at least one of said first and second base members and the resistor or conductor mounted thereon being substantially transparent; and means applying a first voltage across said electrical path of said resistor and for applying a second variable voltage to said conductor, said means permitting selective variation of said second voltage at selected rates of voltage variation to displace along said electrical path the point on said electrical path at which the voltage equals said second voltage to selectively render each region of said dielectric adjacent each zero potential difference point along said electrical path visually distinguishable from other regions thereof when the rate of voltage variation is less than a predetermined value and not visually distinguishable from other regions thereof when the rate of voltage variation exceeds said predetermined value.

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