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(54) **DISPLAY HAVING COLUMN SPACER STRUCTURES WITH MINIMIZED PLASTIC DEFORMATION**

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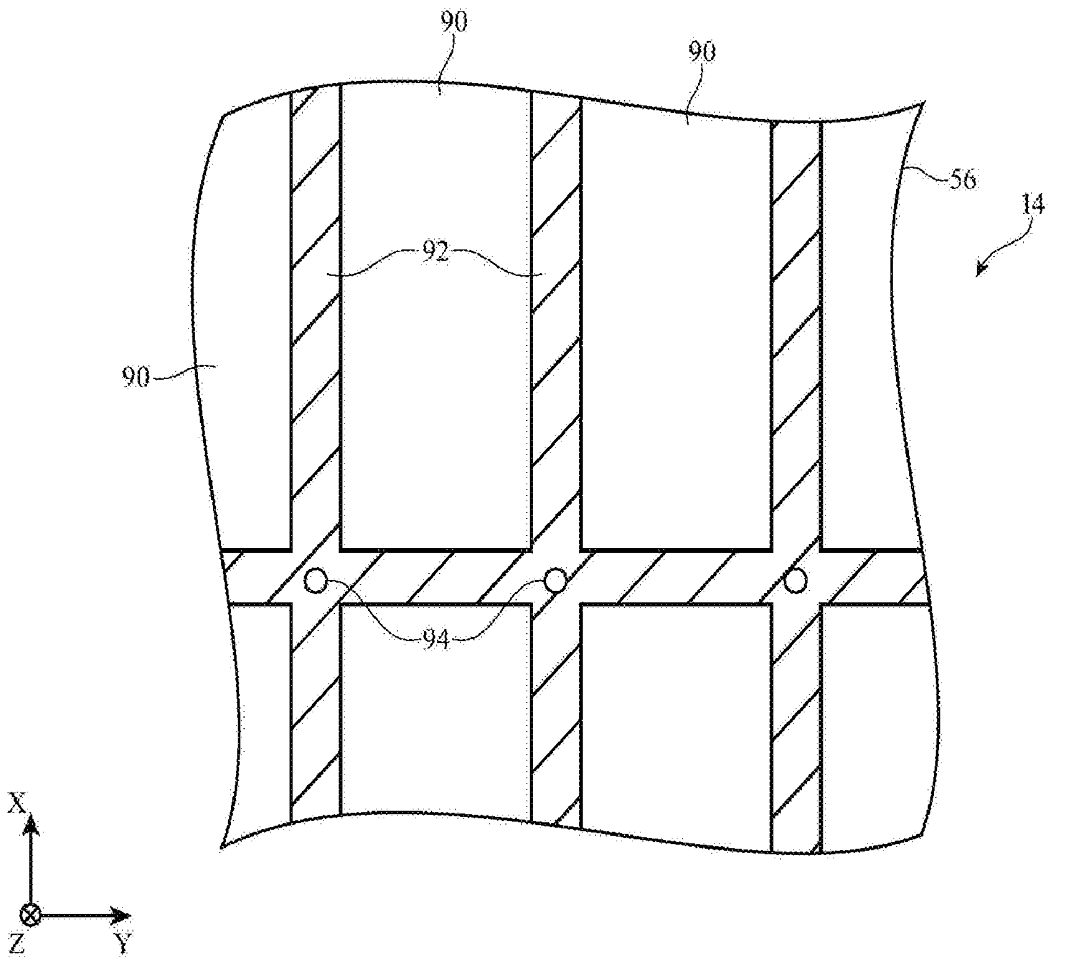
(57) **ABSTRACT**

A display may have a color filter layer and a thin-film transistor layer. A liquid crystal layer may be interposed between the color filter layer and the thin-film transistor layer. Column spacer structures may be used to maintain a desired gap for the liquid crystal layer between the color filter layer and the thin-film transistor layer. The column spacer structures may include column spacers having bases and opposing tips. The tips may penetrate into the liquid crystal layer and may bear against the thin-film transistor layer or aligned column spacer pads on the thin-film transistor layer. The color filter layer may have a glass substrate, a black matrix on the substrate, a color filter element layer on the black matrix, and an overcoat on the color filter element layer. Some or all of the column spacers may have bases that contact the black matrix layer.



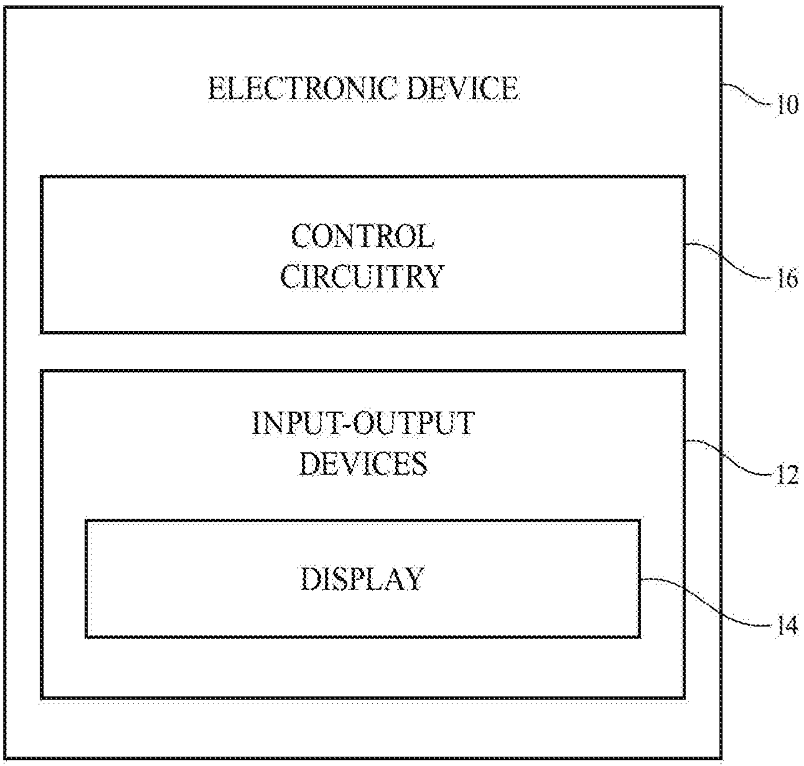

ELECTRONIC DEVICE
10
CONTROL CIRCUITRY
16
INPUT-OUTPUT DEVICES
12
DISPLAY
14

FIG. 1

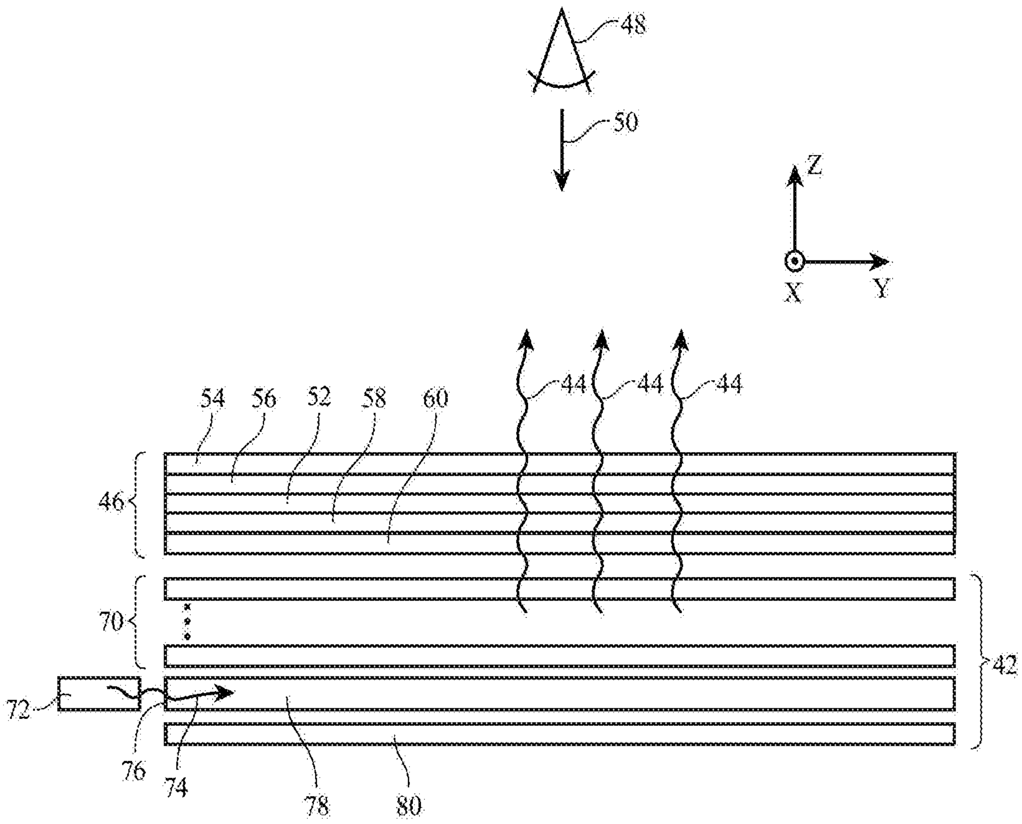


FIG. 2

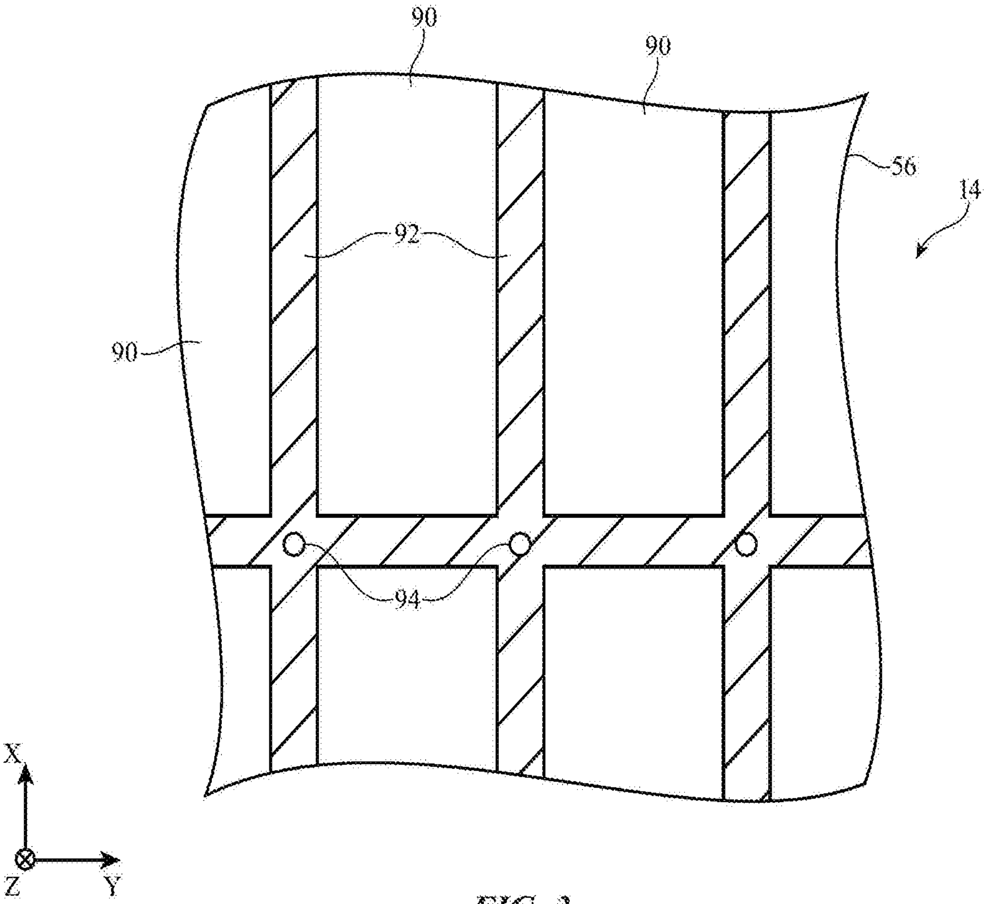


FIG. 3

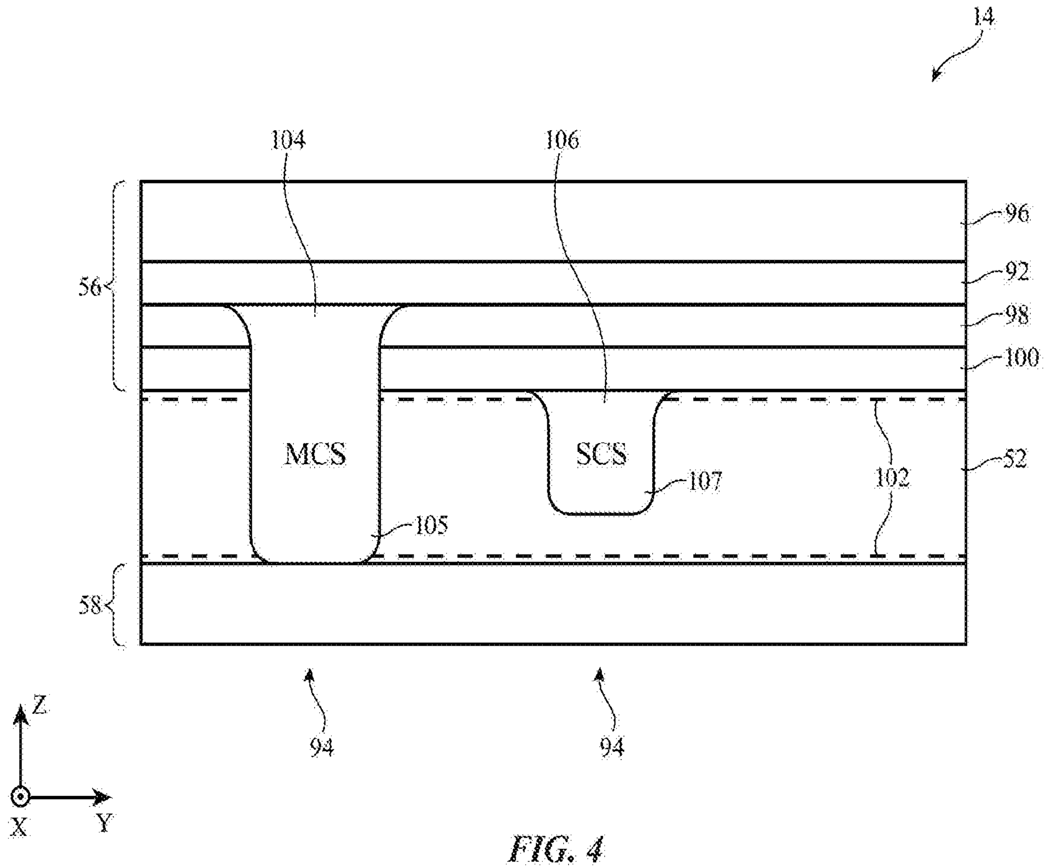


FIG. 4

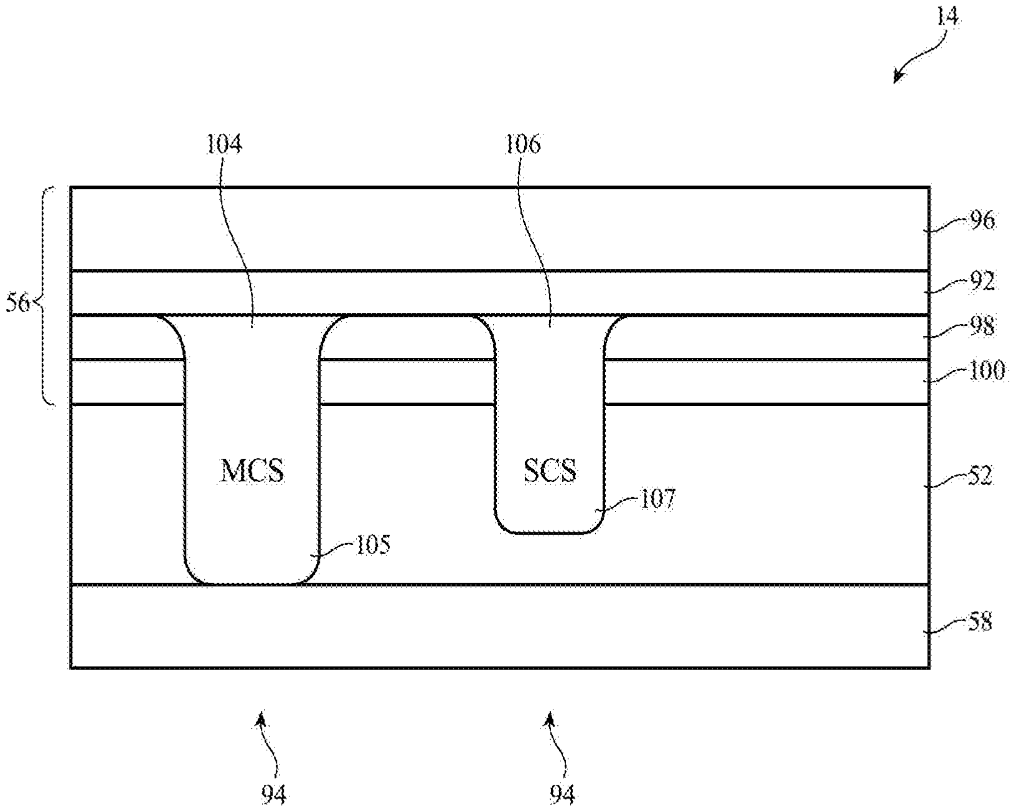


FIG. 5

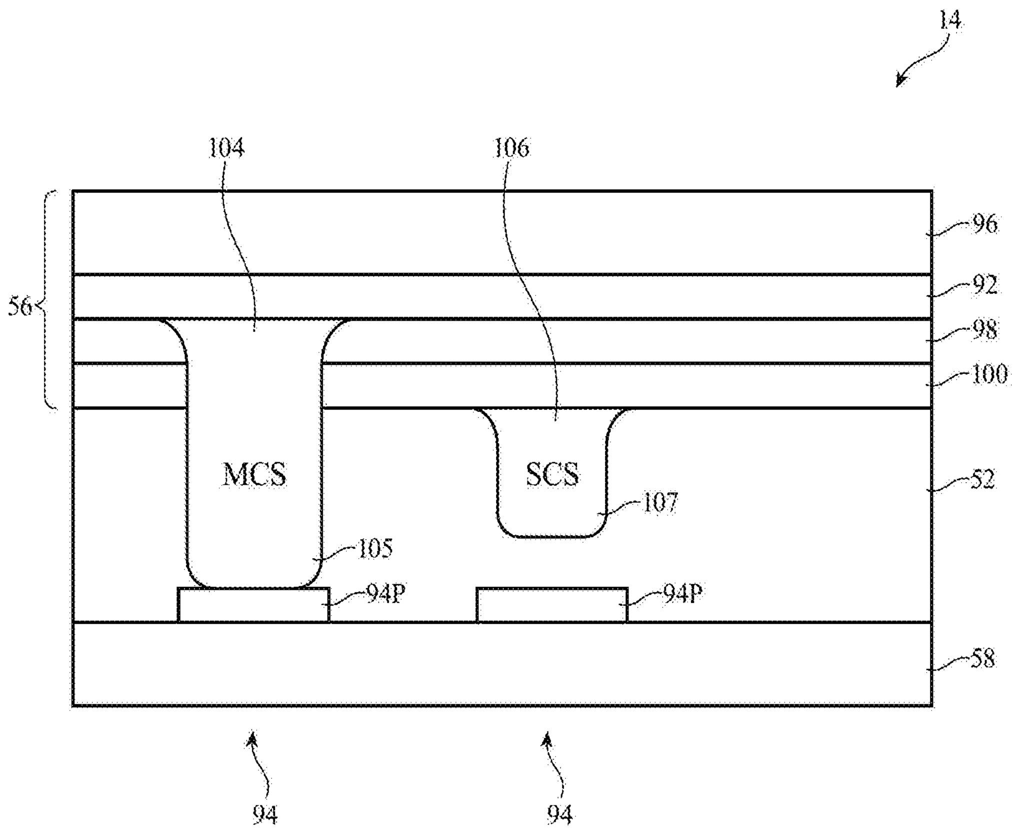


FIG. 6

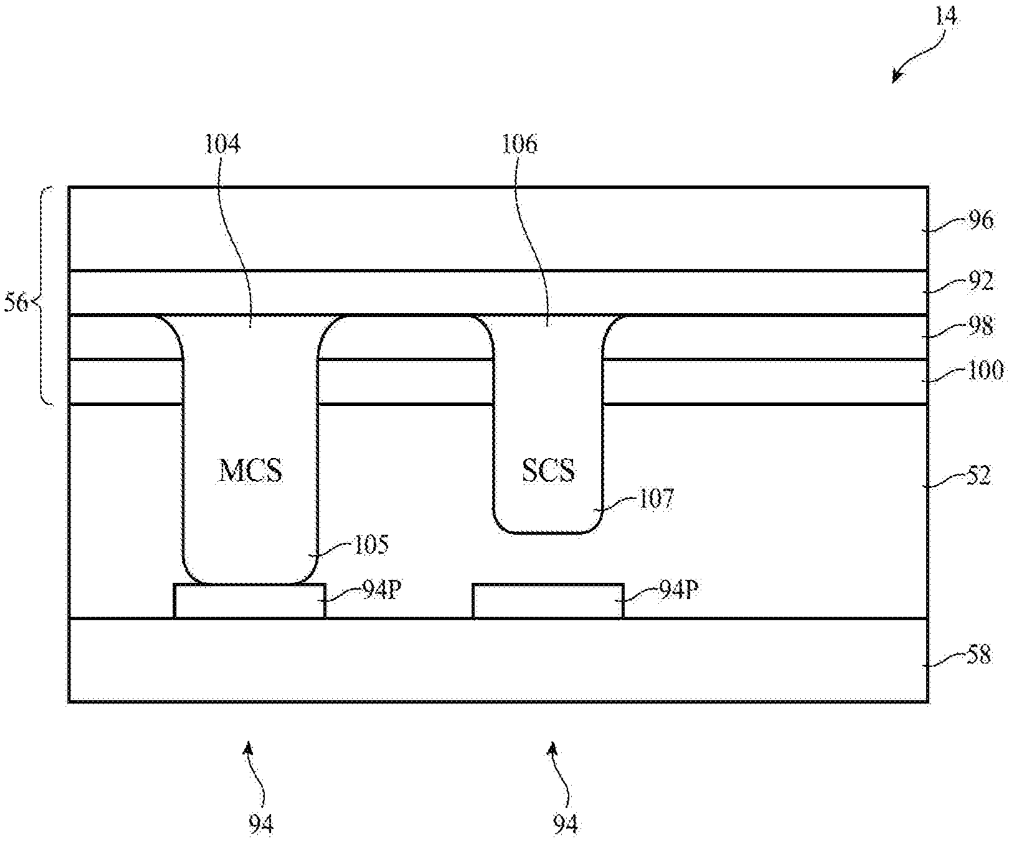


FIG. 7

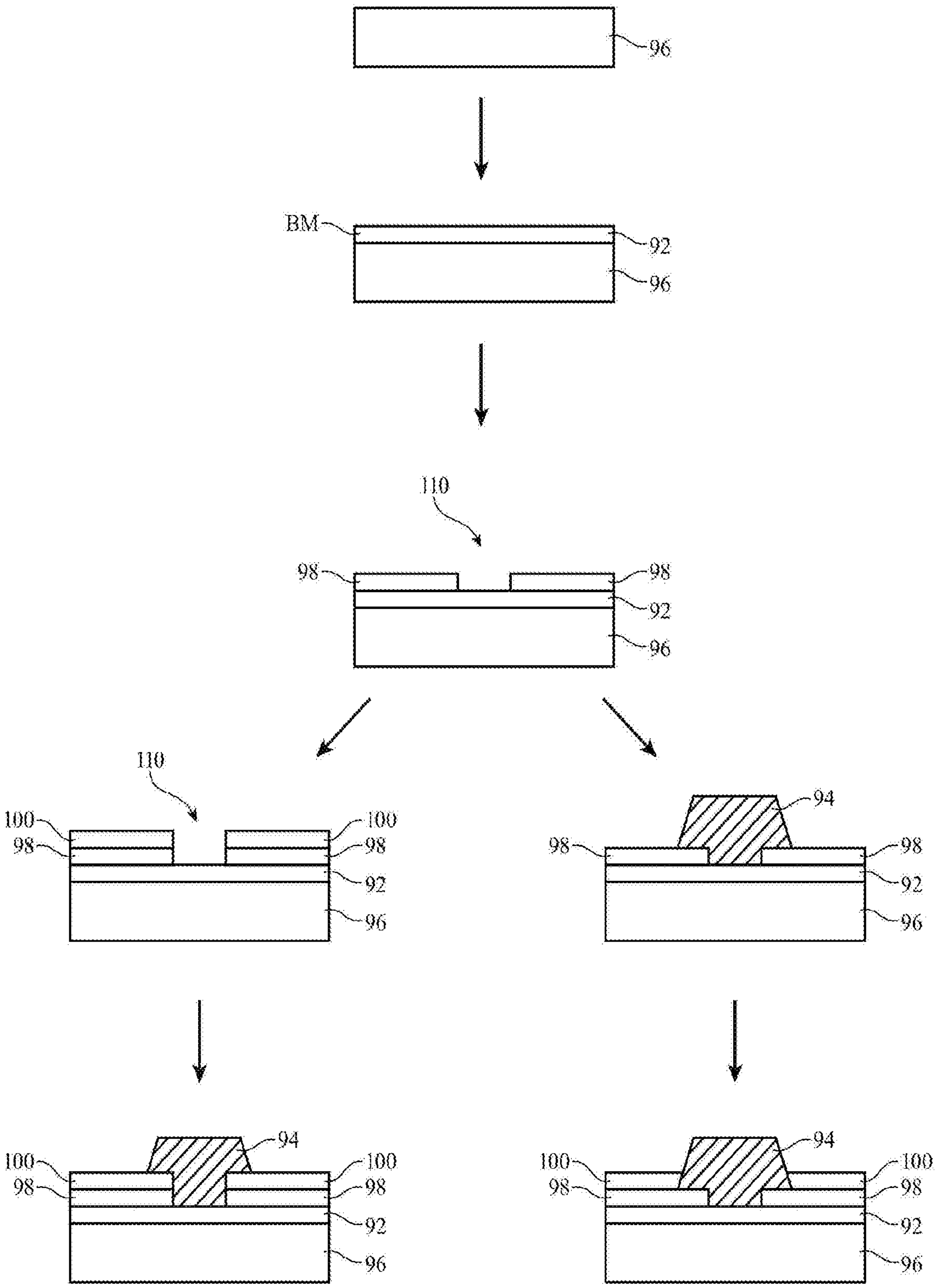

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FIG. 8

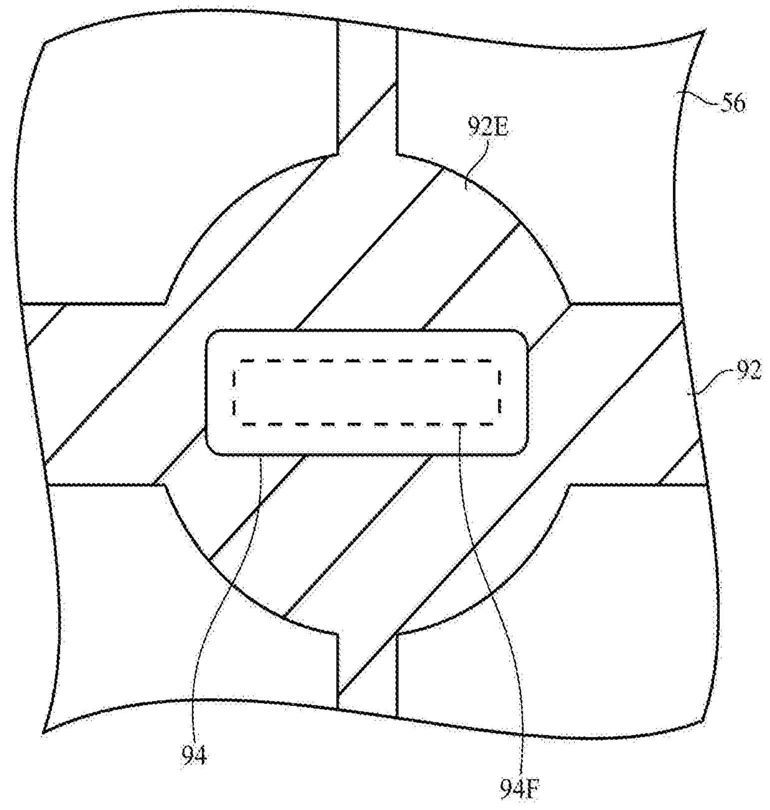

FIG. 9

DISPLAY HAVING COLUMN SPACER STRUCTURES WITH MINIMIZED PLASTIC DEFORMATION

[0001] This application claims the benefit of provisional patent application No. 62/297,378, filed Feb. 19, 2016, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

[0002] This relates generally to electronic devices, and more particularly, to electronic devices with displays.

[0003] Electronic devices often include displays. For example, cellular telephones and portable computers often include displays for presenting information to a user.

[0004] Liquid crystal displays contain a layer of liquid crystal material. Pixels in a liquid crystal display contain thin-film transistors and electrodes for applying electric fields to the liquid crystal material. The strength of the electric field in a pixel controls the polarization state of the liquid crystal material and thereby adjusts the brightness of the pixel.

[0005] Substrate layers such as color filter layers and thin-film transistor layers are used in liquid crystal displays. The thin-film transistor layer contains an array of the thin-film transistors that are used in controlling electric fields in the liquid crystal layer. The color filter layer contains an array of color filter elements such as red, blue, and green elements. The color filter elements color the light passing through the pixels and provides the display with the ability to display color images.

[0006] In an assembled display, the layer of liquid crystal material is sandwiched between the thin-film transistor layer and the color filter layer. The color filter has a black matrix formed from a layer of opaque polymer with an array of pixel openings. A color filter element layer on the black matrix layer is patterned to form color filter elements in the openings of the black matrix. A planarizing polymer overcoat layer covers the color filter elements. An array of polymer column spacers is formed on the surface of the color filter layer to maintain a desired gap between the color filter layer and the thin-film transistor layer.

[0007] During use of an electronic device, forces may sometimes be exerted on portions of a display. If an applied force is small, the column spacer structures will deform elastically and will return to their original heights after the force is removed. If, however, the applied force is substantial, the column spacers will be deformed plastically and will exhibit permanent reductions in their heights. If the amount of plastic deformation is significant, the column spacers will not be able to separate the color filter layer and thin-film layer by an appropriate gap. This can lead to undesired visible artifacts on the display such as gray spots.

[0008] It would therefore be desirable to be able to provide improved column spacer arrangements for displays.

SUMMARY

[0009] An electronic device may have a display. The display may have upper and lower polarizers. The display may also have layers such as a color filter layer and a thin-film transistor layer that are interposed between the upper and lower polarizers. A liquid crystal layer may be interposed between the color filter layer and the thin-film transistor layer.

[0010] During operation of the display, a user's finger or other external objects may press against the surface of the display. This tends to deform the outer portion of the display inwards and can compress the liquid crystal layer. Column spacer structures may be used to maintain a desired gap between the color filter layer and the thin-film transistor layer for the liquid crystal layer. To avoid undesirable permanent damage to the display, column spacer structures are preferably formed so as to exhibit minimized plastic deformation.

[0011] The column spacer structures may include column spacers having bases and opposing tips. The tips of the column spacers may penetrate into the liquid crystal layer and may bear against the thin-film transistor layer or column spacer pads on the thin-film transistor layer.

[0012] The color filter layer may have a glass substrate, a black matrix on the glass substrate, a color filter element layer on the black matrix, and an overcoat on the color filter element layer. Some or all of the column spacers may have bases that contact the black matrix layer and thereby avoid plastic deformation of the color filter element layer and overcoat layer when force is applied.

[0013] The color filter element layer and overcoat layer may be formed from polymer such as acrylic. The column spacers and the column spacer pads may also be formed from a polymer such as acrylic. To help resist undesired plastic deformation when force is applied to the display, the column spacers may have a plasticity that is less than the plasticity of the color filter element layer and overcoat layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** is a diagram of an illustrative electronic device having a display in accordance with an embodiment.

[0015] FIG. **2** is a cross-sectional side view of an illustrative display such as a liquid crystal display in accordance with an embodiment.

[0016] FIG. **3** is a diagram of an illustrative liquid crystal display in accordance with an embodiment.

[0017] FIGS. **4**, **5**, **6**, and **7** are cross-sectional side views of illustrative displays with column spacers in accordance with embodiments.

[0018] FIG. **8** is a diagram showing illustrative operations involved in forming column spacers in accordance with embodiments.

[0019] FIG. **9** is a top view of an illustrative column spacer formed on a portion of a black matrix in a display in accordance with an embodiment.

DETAILED DESCRIPTION

[0020] An illustrative electronic device of the type that may be provided with a display is shown in FIG. **1**. Electronic device **10** may be a computing device such as a laptop computer, a computer monitor containing an embedded computer, a tablet computer, a cellular telephone, a media player, or other handheld or portable electronic device, a smaller device such as a wrist-watch device, a pendant device, a headphone or earpiece device, a device embedded in eyeglasses or other equipment worn on a user's head, or other wearable or miniature device, a display, a computer display that contains an embedded computer, a computer display that does not contain an embedded computer, a gaming device, a navigation device, an embedded system such as a system in which electronic equipment with a display is mounted in a kiosk or automobile, or other electronic equipment.

[0021] As shown in FIG. **1**, electronic device **10** may have control circuitry **16**. Control circuitry **16** may include storage and processing circuitry for supporting the operation of device **10**. The storage and processing circuitry may include storage such as hard disk drive storage, nonvolatile memory (e.g., flash memory or other electrically-programmable-read-only memory configured to form a solid state drive), volatile memory (e.g., static or dynamic random-access-memory), etc. Processing circuitry in control circuitry **16** may be used to control the operation of device **10**. The processing circuitry may be based on one or more microprocessors, microcontrollers, digital signal processors, baseband processors, power management units, audio chips, application specific integrated circuits, etc.

[0022] Input-output circuitry in device **10** such as input-output devices **12** may be used to allow data to be supplied to device **10** and to allow data to be provided from device **10** to external devices. Input-output devices **12** may include buttons, joysticks, scrolling wheels, touch pads, key pads, keyboards, microphones, speakers, tone generators, vibrators, cameras, sensors, light-emitting diodes and other status indicators, data ports, etc. A user can control the operation of device **10** by supplying commands through input-output devices **12** and may receive status information and other output from device **10** using the output resources of input-output devices **12**.

[0023] Input-output devices **12** may include one or more displays such as display **14**. Display **14** may be a touch screen display that includes a touch sensor for gathering touch input from a user or display **14** may be insensitive to touch. A touch sensor for display **14** may be based on an array of capacitive touch sensor electrodes, acoustic touch sensor structures, resistive touch components, force-based touch sensor structures, a light-based touch sensor, or other suitable touch sensor arrangements. A touch sensor for display **14** may be formed from electrodes formed on a common display substrate with the pixels of display **14** or may be formed from a separate touch sensor panel that overlaps the pixels of display **14**. If desired, display **14** may be insensitive to touch (i.e., the touch sensor may be omitted).

[0024] Control circuitry **16** may be used to run software on device **10** such as operating system code and applications. During operation of device **10**, the software running on control circuitry **16** may display images on display **14**.

[0025] Display **14** may be a liquid crystal display. A cross-sectional side view of an illustrative liquid crystal display is shown in FIG. **2**. Display **14** of FIG. **2** may have a rectangular shape (i.e., display **14** may have a rectangular footprint and a rectangular peripheral edge that runs around the rectangular footprint) or may have other suitable shapes. Display **14** may be planar, as shown in FIG. **2**, or may have a curved profile.

[0026] As shown in FIG. **2**, display **14** may include backlight structures such as backlight unit **42** for producing backlight illumination such as backlight **44**. During operation, backlight **44** travels outwards (vertically upwards in dimension Z in the orientation of FIG. **3**) and passes through an array of pixels in display layers **46**. This illuminates any images that are being produced by the pixels for viewing by a user. For example, backlight **44** may illuminate images on display layers **46** that are being viewed by viewer **48** in direction **50**.

[0027] Display layers **46** may be mounted in chassis structures such as a plastic chassis structure and/or a metal chassis structure to form a display module for mounting in housing **12** or display layers **46** may be mounted directly in housing **12** (e.g., by stacking display layers **46** into a recessed portion in housing **12**). Display layers **46** may form a liquid crystal display or may be used in forming displays of other types.

[0028] In a liquid crystal display, display layers **46** may include a liquid crystal layer such a liquid crystal layer **52**. Liquid crystal layer **52** may be sandwiched between display layers such as display layers **58** and **56**. Layers **56** and **58** may be interposed between lower polarizer layer **60** and upper polarizer layer **54**.

[0029] Layers **58** and **56** may be formed from transparent substrate layers such as clear layers of glass or plastic. Layers **58** and **56** may be layers such as a thin-film transistor layer and/or a color filter layer. Conductive traces, color filter elements, transistors, and other circuits and structures may be formed on the substrates of layers **58** and **56** (e.g., to form a thin-film transistor layer and/or a color filter layer). Touch sensor electrodes may also be incorporated into layers such as layers **58** and **56** and/or touch sensor electrodes may be formed on other substrates.

[0030] With one illustrative configuration, layer **58** may be a thin-film transistor layer that includes an array of pixel circuits based on thin-film transistors and associated electrodes (pixel electrodes) for applying electric fields to liquid crystal layer **52** and thereby displaying images on display **14**. Layer **56** may be a color filter layer that includes an array of color filter elements for providing display **14** with the ability to display color images. If desired, layer **58** may be a color filter layer and layer **56** may be a thin-film transistor layer. Configurations in which color filter elements are combined with thin-film transistor structures on a common substrate layer in the upper or lower portion of display **14** may also be used.

[0031] In each of these scenarios, column spacers on layer **56** and/or layer **58** may help separate layers **56** and **58** from each other and thereby ensure a desired gap between layers **56** and **58** for liquid crystal layer **52**. The performance of display **14** may be enhanced by accurately maintaining the thickness of layer **52** in this way. Failure to maintain a desired thickness for layer **52** may lead to gray spots or other undesired visible artifacts.

[0032] Backlight structures **42** may include a light guide layer such as light guide layer **78** (sometimes referred to as a light guide structure or light guide). Light guide layer **78** may be formed from one or more stacked layers of transparent material such as clear glass or plastic (e.g., molded plastic that forms a light guide plate, a thin flexible plastic film, etc.). During operation of backlight structures **42**, light sources such as light source **72** may generate light that creates backlight **44**. Light source **72** may be an array of light-emitting diodes that runs along one or more edges of light guide layer **78** such as edge **76** of light guide layer **78** (i.e., into the page along the X axis in the orientation of FIG. **2**). Light-source **72** may emit light **74** into edge **76** of light guide layer **78**.

[0033] Light **74** may be distributed throughout light guide layer **78** due to the principal of total internal reflection.

Scattering features (protrusions, recesses, etc.) may be incorporated into light guide layer **78** (e.g., on the upper and/or lower surface of layer **78**) to scatter light from layer **78**. Light that is scattered upwards in direction Z from light guide layer **78** may serve as backlight **44** for display **14**. Light that scatters downwards may be reflected back in the upwards direction by reflector **80**. Reflector **80** may be formed from a reflective material such as a layer of plastic covered with a dielectric mirror thin-film coating. To enhance backlight performance for backlight structures **42**, backlight structures **42** may include optical films **70**. Optical films **70** may include diffuser layers for helping to homogenize backlight **44** and thereby reduce hotspots and light collimating films such as prism films (sometimes referred to as brightness enhancement films) and turning films for directing backlight **44** towards direction Z. Optical films **70** may overlap the other structures in backlight unit **42** such as light guide layer **78** and reflector **80**. For example, if light guide layer **78** has a rectangular footprint in the X-Y plane of FIG. **2**, optical films **70** and reflector **80** may have a matching rectangular footprint. If desired, films such as compensation films may be incorporated into other layers of display **14** (e.g., a reflective polarizer layer).

[0034] Display **14** may have a black matrix. The black matrix may have an array of openings corresponding to the array of pixels in display **14**. Each opening may be provided with a color filter element. The color filter elements of display **14** may be red, green, and blue color filter elements and/or may include color filter element structures of other colors. The black matrix may be formed from a patterned layer of opaque masking material such as a patterned layer of black photoimageable polymer (e.g., a dark photosensitive acrylic). Using photolithography, the black matrix layer can be patterned to form a desired array of openings for the color filter elements.

[0035] The black matrix may be formed on the underside of the substrate in color filter layer **56**. FIG. **3** is a diagram of a portion of color filter layer **56** as viewed in direction Z. As shown in FIG. **3**, black matrix **92** may have an array of openings **90** corresponding to the pixels of display **14**. Each opening **90** may be overlapped by a respective color filter element (e.g., a red, green, or blue color filter element). Black matrix **92** of FIG. **3** has intersecting horizontal and vertical strips of opaque material and forms an array of rectangular openings **90**, but black matrix **92** may, in general, have any suitable shape. The configuration of FIG. **3** is merely illustrative.

[0036] The array of color filter elements in openings **90** may be formed by patterning color filter element material onto layer **56** after black matrix **92** has been formed. For example, in an arrangement in which display **14** has red, green, and blue color filter elements, a red photoimageable polymer layer may be deposited on the black matrix layer and patterned using photolithography to form a series of red color filter elements in a set of openings **90** that correspond to red pixels. This process may then be repeated for the green and blue color filter elements, so that an array of red, green, and blue color filter elements cover all of openings **90**.

[0037] After the black matrix and color filter element layers have been patterned onto the substrate of layer **56**, a planarizing organic layer such as a polymer overcoat layer may be deposited onto layer **56** over the black matrix and color filter elements. FIG. **4** is a cross-sectional side view of display **14** showing how black matrix **92**, color filter element layer **98**, and overcoat layer **100** may be formed on the surface of substrate layer **96**.

[0038] As shown in FIG. **4**, liquid crystal alignment layers **102** may be deposited over the innermost surfaces of layers **56** and **58**. These alignment layers may be formed from a polymer such as polyimide or other suitable materials and may have a thickness of about 1000 angstroms. The black matrix layer, color filter element layer, and overcoat layer in display **14** are typically on the order of microns in thickness and are therefore substantially thicker than liquid crystal alignment layers **102**. Liquid crystal alignment layers **102** may therefore sometimes be omitted from the drawings for clarity.

[0039] Column spacers **94** may be formed on layer **56** to prevent layer **56** from directly contacting each other and thereby maintaining a desired thickness for liquid crystal layer **52**. To block column spacers **94** from view by viewer **48**, column spacers **94** may be formed at locations that overlap black matrix **92**. In the example of FIG. **3**, column spacers **94** are formed at the intersections of the horizontal and vertical black matrix lines of black matrix **92**. If desired, column spacers **92** may be formed on other portions of black matrix **92** or elsewhere on display **14**. The example of FIG. **3** is merely illustrative.

[0040] The cross-sectional side view of display **14** in FIG. **4** shows how column spacers **94** may be used to separate layers **56** and **58**. In the example of FIG. **4**, column spacers **94** are formed on upper layer **56** (e.g., a color filter layer). Configurations in which column spacer pads or other column spacer structures are formed on lower layer **58** (e.g., a thin-film transistor layer) may also be used for forming display **14**. If desired, column spacers **94** may be used in displays in which color filter and thin-film transistor structures are formed on a common substrate. The configuration of FIG. **4** is presented as an example.

[0041] Substrate layer **96** of color filter layer **56** of FIG. **4** may be a layer of clear glass, transparent plastic, or other clear substrate material. Black matrix **92** may be formed from a patterned layer of black matrix material on the inner surface of substrate layer **96**. Color filter layer **98** may include patterned red, green, and blue color filter elements or color filter elements of other suitable colors and may be formed over black matrix **92**. Overcoat layer **100** may be formed over color filter element layer **98** and may help planarize and protect the underlying color filter and black matrix layers. Liquid crystal alignment layers **102** may be formed on the inner surfaces of layers **56** and **58**.

[0042] Column spacers **94** may be formed from photoimageable polymer and may be patterned using photolithography. As shown in FIG. **4**, display **14** may have column spacers **94** such as main column spacers MCS having a height sufficient to allow main column spacers MCS to extend across liquid crystal layer **52** and may have shorter column spacers such as subspacers SCS that extend only partway across layer **52**. The height of main column spacers MCS defines the size of the gap between layers **56** and **58** and therefore defines the thickness of liquid crystal layer **52**.

[0043] Each column spacer has a tip and a base. For example, column spacer MCS has base **104** and opposing tip **105**. Base **104** is supported by layer **56**. Tip **105** protrudes into liquid crystal layer **52**. Subspacer SCS has a base such as base **106** that is supported on layer **56** and an opposing tip such as tip **107** that penetrates into liquid crystal layer **52**.

During normal operation of display **14** when no external pressure is being applied to the surface of display **14**, tips **105** of main column spacers MCS bear against thin-film transistor layer **58** and maintain a desired thickness for layer **52**, while subspacers SCS are suspended away from layer **56**.

[0044] In the event that pressure is exerted on layer **56** (e.g., downward pressure in the −Z direction), subspacers SCS can help prevent undesired contact between the opposing inner surfaces of layers **56** and **58**. Subspacers SCS are not in constant contact with layer **58**, which helps reduce wear on layer **58** and reduces the risk of scratching layers **102** and thereby producing particles that could contaminate liquid crystal layer **52**. Column spacers MCS and SCS are shown as being adjacent to one another in FIG. **4**, but may be spaced apart by any suitable distance. There may be, for example, a column spacer (i.e., a main or subspacer column spacer) in each row and column of black matrix **92** (e.g., a column spacer at each of the four corners of each pixel) or column spacers may be arranged more sparsely on display **14** (e.g., every two or three rows and/or every two or three columns of pixels or more).

[0045] The thickness of black matrix layer **92** may be about 1.5-2 microns, more than 1.4 microns, less than 2.1 microns, more than 0.1 microns, more than 0.3 microns, more than 0.8 microns, less than 5 microns, less than 4 microns, less than 3 microns, 2-10 microns, 1-7 microns, 2-8 microns, 0.5-5 microns, or other suitable thickness. The thickness of color filter layer **98** may be about 2-3 microns, more than 1.5 microns, less than 3.5 microns, more than 0.1 microns, more than 0.3 microns, more than 0.8 microns, less than 5 microns, less than 4 microns, less than 3 microns, 2-10 microns, 1-7 microns, 2-8 microns, 0.5-5 microns, or other suitable thickness. The thickness of overcoat layer **100** may be about 2-3 microns, more than 1.5 microns, less than 3.5 microns, more than 0.1 microns, more than 0.3 microns, more than 0.8 microns, less than 5 microns, less than 4 microns, less than 3 microns, 2-10 microns, 1-7 microns, 2-8 microns, 0.5-5 microns, or other suitable thickness. The thickness of the portions of main column spacers MCS that extends through layer **52** (i.e., the thickness of layer **52**) may be about 3.4 to 3.5 microns, more than 3 microns, less than 5 microns, more than 0.1 microns, more than 0.3 microns, more than 0.8 microns, less than 5 microns, less than 4 microns, less than 3 microns, 2-10 microns, 1-7 microns, 2-8 microns, 0.5-5 microns, or other suitable thickness.

[0046] Layers **92**, **98**, and **100** may be formed from a polymer such as acrylic. The polymer used in forming layers **92**, **98**, and **100** may be subject to undesirable plastic deformation if layer **56** is bent inwardly due to the application of excessive force on the surface of display **14**, thereby causing layer **56** to bend inwardly more than desired. Column spacers MCS and/or SCS may be formed from an acrylic or other polymer with less plasticity than the polymer used in forming layers **92**, **98**, and **100**, which may help reduce plastic deformation and reductions in the gap between layers **56** and **58**.

[0047] In conventional column spacer designs, the polymer that forms the main column spacers and subspacers rests on the exposed surface of the overcoat layer, so that portions of the overcoat layer, color filter layer, and black matrix plastically deform when pressure is applied. This plastic deformation permanently reduces the height of the column spacers and can lead to undesired gray spots on a display.

[0048] With arrangements of the type shown in FIG. **4**, base **104** of column spacers MCS penetrates through layers **98** and **100** and contacts black matrix **92**, so there is no possibility of deformation of layers **98** and **100** when pressure is applied to column spacer MCS. Column spacer MCS is formed from a material that has less plasticity than layers **98** and **100**, so by forming column spacer MCS so that base **104** of column spacer **104** contacts layer **92** rather than resting on layer **98** or layer **100**, the total amount of plastic deformation in the column spacer structures of display **14** when force is applied to display **14** is reduced. This reduces the likelihood of forming undesired gray spots on display **14**.

[0049] In the illustrative configuration of FIG. **4**, base **106** of subspacer SCS has been formed in contact with the surface of overcoat layer **100** (i.e., the surface of overcoat layer **100** nearest the inner side of layer **56** which is adjacent to layer **52**). As a result, portions of layers **98** and **100** under the subspacer column spacer in FIG. **4** may be subject to plastic deformation when force is applied to the subspacer column spacer. If desired, subspacer SCS may be extended to the surface of black matrix layer **92**. As shown in FIG. **5**, for example, base **106** of subspacer SCS may extend through layers **98** and **100** and may contact black matrix **92**. Configurations in which column spacers **94** are formed from a dark material (e.g., black photoimageable polymer) and penetrate through black matrix **92** to contact substrate **96** may also be used. Arrangements of the type shown in FIGS. **4** and **5** are advantageous because the presence of black matrix **92** between column spacers **94** and substrate **96** helps hide column spacers **94** from view by viewer **48**.

[0050] FIGS. **6** and **7** show versions of the respective column spacer arrangements of FIGS. **4** and **5** in which column spacers **94** have been provided with column spacer structures on layer **58** (e.g., on top of the layer of thin-film transistor circuitry on the surface of thin-film transistor layer **58** that faces layer **52**). As shown in FIGS. **6** and **7**, for example, column spacers **94** may have pads **94**P that are aligned with corresponding portions of main column spacer MCS and subspacer SCS. To help reduce plastic column spacer deformation in response to pressure on display **14**, column spacer structures such as column spacer pads **94**P of column spacers **94** of FIGS. **6** and **7** may be formed from a polymer such as an acrylic with less plasticity than layers **98** and **100** (e.g., the same material used in forming column spacers MCS and SCS). In general, any suitable material may be used in forming pads **94**P (e.g., polymer, inorganic dielectric, metal, etc.). To help reduce the generation of particles of alignment layers **102** that might contaminate layer **52**, the tips of columns spacers MCS and SCS and/or the surfaces of pads **94**P may be free of alignment layer material (i.e., layers **102** may not extend over tips **105**, tips **107**, and pads **94**P).

[0051] FIG. **8** shows illustrative steps involved in forming column spacers **94**. As shown in FIG. **8**, substrate **96** may initially be coated with a patterned black matrix layer such as black matrix **92** (e.g., by deposition of a blanket film of photoimageable black polymer and use of photolithography to pattern the deposited film). Black matrix **92** may have openings to receive color filter elements. Color filter element layer **98** (e.g., a layer with areas of red color filter elements, areas with green color filter elements, and areas with green color filter elements) may be patterned onto layer **92** (e.g., layers of different colored photoimageable color filter element polymer may be deposited as blanket films and patterned using photolithography). During the use of photolithography to pattern each colored portion of layer **98**, column spacer openings such as opening **110** of FIG. **8** may be formed. After forming column spacer openings such as opening **110** in color filter element layer **98**, processing may continue using the approach illustrated on either the left or right side of FIG. **8**.

[0052] With the arrangement shown on the left of FIG. **8**, overcoat layer **100** is deposited over color filter element layer **98** and patterned using photolithography to form openings in alignment with the openings in color filter element layer **98**. By patterning overcoat layer **100** onto layer **98** in this way, openings such as opening **110** can be formed that pass through both layer **98** and layer **92** before column spacer deposition and patterning operations are used to form column spacer **94** (shown in the lower left corner of FIG. **8**).

[0053] With the arrangement shown on the right of FIG. **8**, column spacers **94** are patterned onto layer **56** after forming openings such as opening **110** in layer **98** but before depositing overcoat layer **100**. Layer **100** may be formed from a low-viscosity acrylic and may surround column spacers **94** when layer **100** is deposited after column spacers **94** have been formed as shown on the lower right of FIG. **8**. By depositing layer **100** in this way after column spacers **94** have been formed in the openings **110** in layer **98**, layer **100** need not be formed from a photoimageable polymer. This allows a mask patterning step (photolithography step) to be omitted from the fabrication process (i.e., layer **100** can be deposited without using photolithography to form openings in alignment with the openings in layer **98** as is the case when using the approach on the left side of FIG. **8**).

[0054] FIG. **9** is a top view of a portion of layer **56** showing how black matrix **92** may have a locally enlarged portion such as portion **92**E at the intersection of each horizontal and vertical black matrix line (as an example). Column spacer **94** may be formed in the portion of color filter layer **56** that overlaps enlarged portion **92**E. When viewed in the top view orientation of FIG. **9**, the tip of column spacer **94** overlaps narrower column spacer footer portion **94**F (i.e., the column spacer base), which penetrates into opening **110** in the underlying polymer layers such as layers **98** and **92** of FIG. **8**. Column spacers **94** may have any suitable outline. For example, the shape of column spacers **94** when viewed from above (i.e., the footprint of column spacer **94**) may be circular, may be oval, may be rectangular, may be rectangular with rounded corners, or may have other shapes with straight and/or curved edges.

[0055] The foregoing is merely illustrative and various modifications can be made by those skilled in the art without departing from the scope and spirit of the described embodiments. The foregoing embodiments may be implemented individually or in any combination.

What is claimed is:

1. A display, comprising:

first and second layers that are separated by a gap, wherein the first layer has a substrate, a black matrix layer on the substrate, a color filter element layer on the black matrix layer, and an overcoat layer on the color filter element layer;

a liquid crystal layer that fills the gap; and

column spacers on the first layer that have opposing tips and bases, wherein each tip penetrates into the liquid crystal layer and wherein each base penetrates through openings in the overcoat layer and color filter element layer and contacts the black matrix layer.

2. The display defined in claim **1** wherein the column spacers are main column spacers having a first height and wherein the display further comprise subspacer column spacers having a second height that is less than the first height.

3. The display defined in claim **2** wherein the subspacer column spacers each have a subspacer base and an opposing subspacer tip that penetrates into the liquid crystal layer.

4. The display defined in claim **3** wherein the subspacer bases contact the black matrix.

5. The display defined in claim **4** wherein the first layer comprises a color filter layer and wherein the color filter element layer has an array of color filter elements of different colors that overlap openings in the black matrix.

6. The display defined in claim **3** wherein the subspacer bases rest on the overcoat layer.

7. The display defined in claim **6** wherein the first layer comprises a color filter layer and wherein the color filter element layer has an array of color filter elements of different colors that overlap openings in the black matrix.

8. The display defined in claim **3** wherein the first layer comprises a color filter layer, wherein the color filter element layer has an array of color filter elements of different colors that overlap openings in the black matrix, and wherein the second layer comprises a thin-film transistor layer.

9. A method, comprising:

patterning a black matrix layer onto a clear substrate;

forming a color filter element layer over the black matrix, wherein the color filter element layer includes color filter elements of multiple colors and has openings that overlap the black matrix layer; and

forming an array of column spacers each of which has a base that passes through a respective one of the openings in the color filter element layer and that contacts the black matrix layer.

10. The method defined in claim **9** further comprising patterning an overcoat layer onto the color filter element layer before forming the array of column spacers.

11. The method defined in claim **10** wherein patterning the overcoat layer comprises forming openings in the overcoat layer using photolithography each of which is aligned with a respective one of the openings in the color filter element layer.

12. The method defined in claim **11** wherein forming the array of column spacers comprises forming the bases of the column spacers so that each base passes through one of the openings in the overcoat layer and one of the aligned openings in the color filter element layer.

13. The method defined in claim **9** further comprising depositing an overcoat layer onto the color filter element layer after forming the array the column spacers.

14. A display, comprising:

upper and lower polarizers;

a color filter layer and a thin-film transistor layer interposed between the upper and lower polarizers; and

a liquid crystal layer between the color filter layer and the thin-film transistor layer, wherein the color filter layer has a glass substrate, a layer of opaque material on the glass substrate with openings, a color filter element layer that forms color filter elements overlapping the openings in the layer of opaque material and that has color filter element layer openings, and column spacers each having a tip that penetrates into the liquid crystal layer and an opposing base that passes through a respective one of the color filter element layer openings and that contacts the layer of opaque material.

15. The display defined in claim **14** wherein the color filter element layer has a first plasticity and wherein the column spacers have a second plasticity that is less than the first plasticity.

16. The display defined in claim **15** wherein the color filter layer further comprises an overcoat layer on the color filter element layer.

17. The display defined in claim **16** wherein the bases of the column spacers each pass through the overcoat layer.

18. The display defined in claim **15** wherein the column spacers are main column spacers that penetrate into the liquid crystal layer a first distance and wherein the color filter layer further comprises subspacers that penetrate into the liquid crystal layer a second distance that is less than the first distance.

19. The display defined in claim **18** further comprising a plurality of column spacer pads on the thin-film transistor layer each of which is aligned with a respective one of the column spacers.

20. The display defined in claim **19** wherein the column spacer pads are formed from a material with a plasticity that is less than the first plasticity.

* * * * *

patsnap

专利名称(译)	显示具有最小化塑性变形的柱间隔结构		
公开(公告)号	US20170242286A1	公开(公告)日	2017-08-24
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[标]申请(专利权)人(译)	苹果公司		
申请(专利权)人(译)	苹果公司.		
当前申请(专利权)人(译)	苹果公司.		
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发明人	LI, XIAOKAI YANG, YOUNG CHEOL YANG, SHAORUI YU, DA YAN, JIN		
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摘要(译)

显示器可以具有滤色器层和薄膜晶体管层。可以在滤色器层和薄膜晶体管层之间插入液晶层。柱状间隔物结构可用于保持滤色器层和薄膜晶体管层之间的液晶层的所需间隙。柱状间隔物结构可包括具有基部和相对尖端的柱状间隔物。尖端可以穿透到液晶层中并且可以抵靠薄膜晶体管层或薄膜晶体管层上的对准的柱状间隔物垫。滤色器层可以具有玻璃基板，基板上的黑色矩阵，黑色矩阵上的滤色器元件层，以及滤色器元件层上的外涂层。一些或所有柱间隔物可具有与黑色矩阵层接触的基底。