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(57) **ABSTRACT**

An electronic device may be provided having an organic light-emitting diode display and control circuitry for operating the display. The display may include one or more display layers interposed between the control circuitry and a display layer having thin-film transistors. The electronic device may include a coupling structure interposed between the layer of thin-film transistors and the control circuitry that electrically couples the layer of thin-film transistors to the control circuitry. The coupling structure may include a dielectric member having a conductive via, a flexible printed circuit having a bent portion, or a conductive via formed in an encapsulation layer of the display. The display may include a layer of opaque masking material. The layer of opaque masking material may be formed on an encapsulation layer, an organic emissive layer, a thin-film transistor layer, or a glass layer of the organic light-emitting diode display.

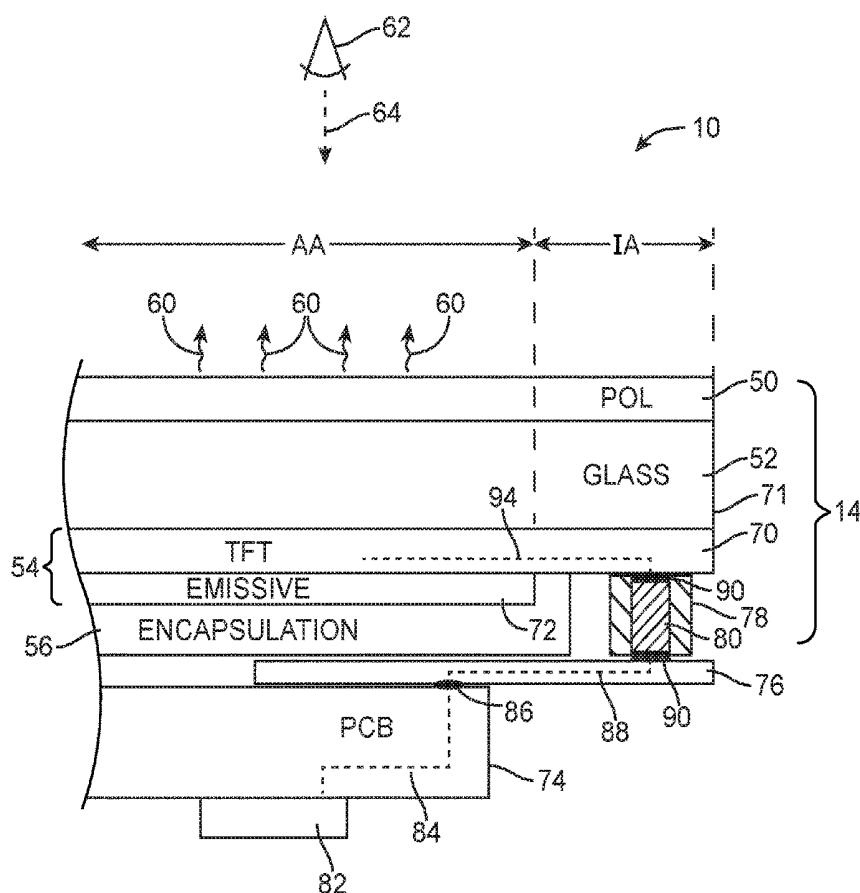
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### Related U.S. Application Data

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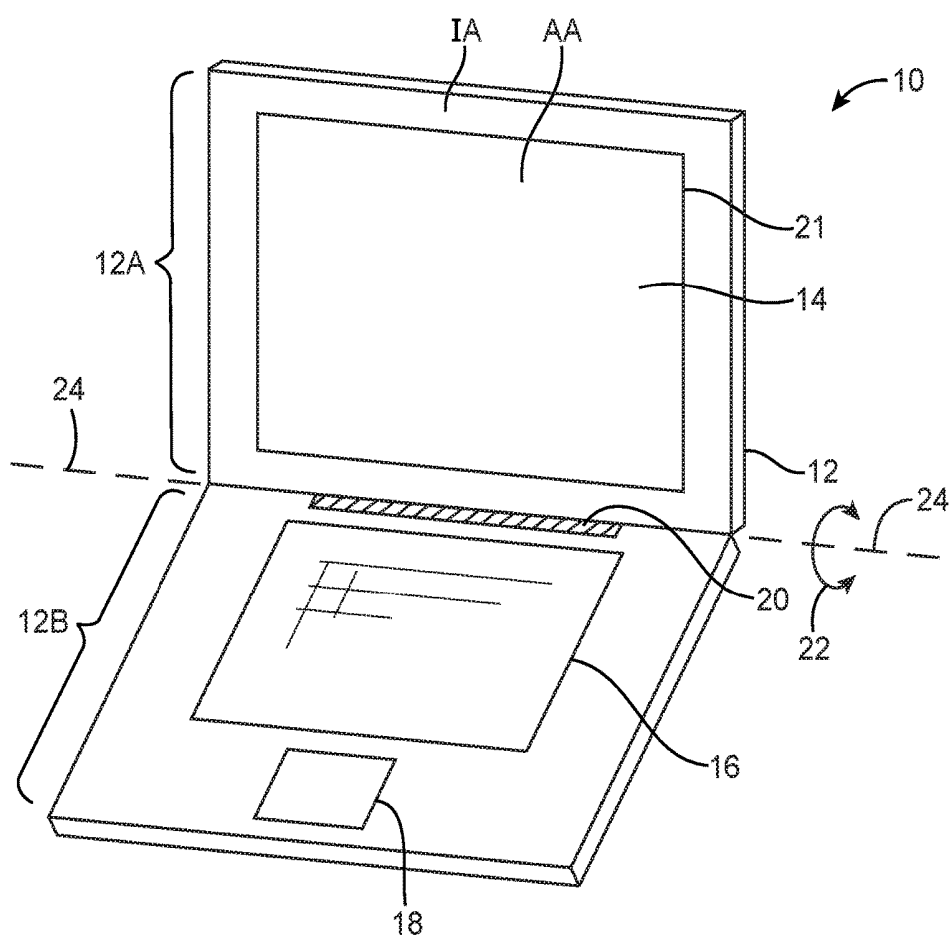


FIG. 1

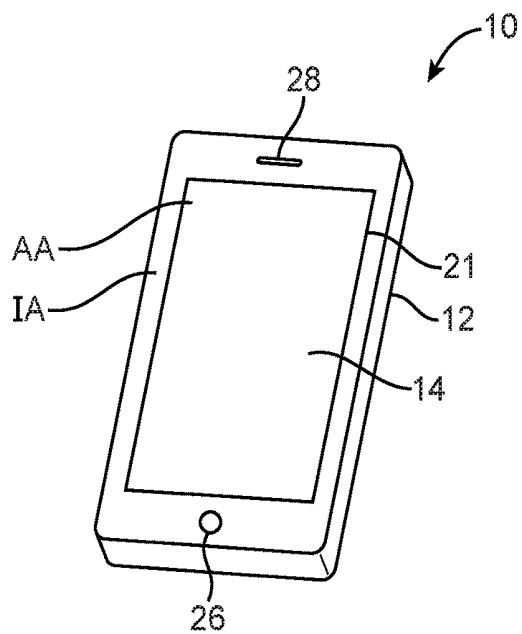


FIG. 2

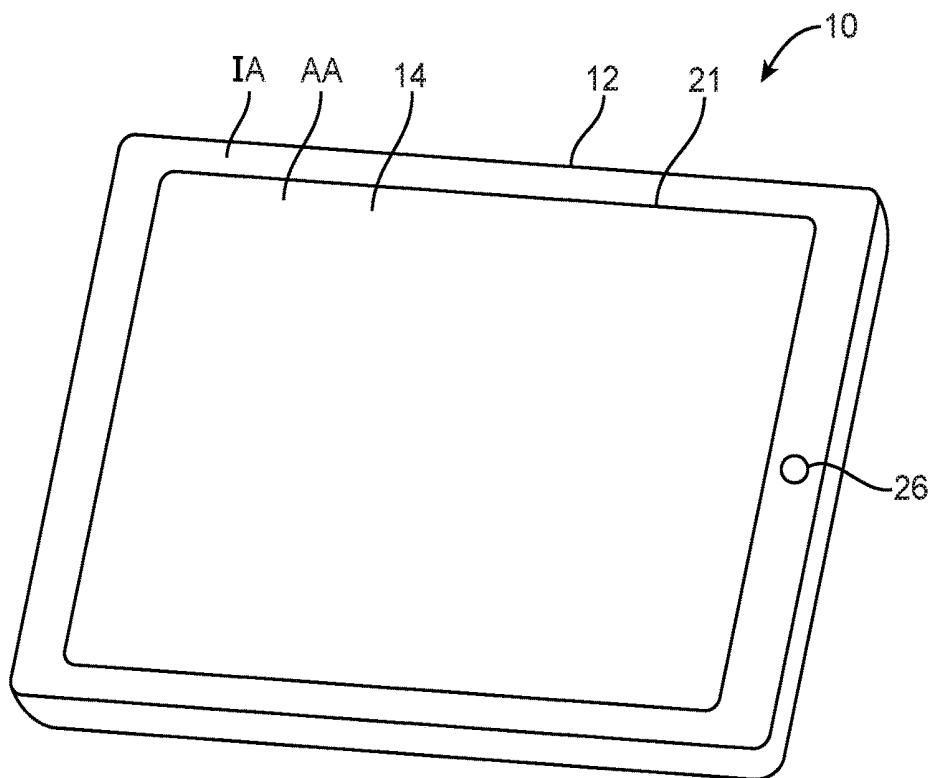


FIG. 3

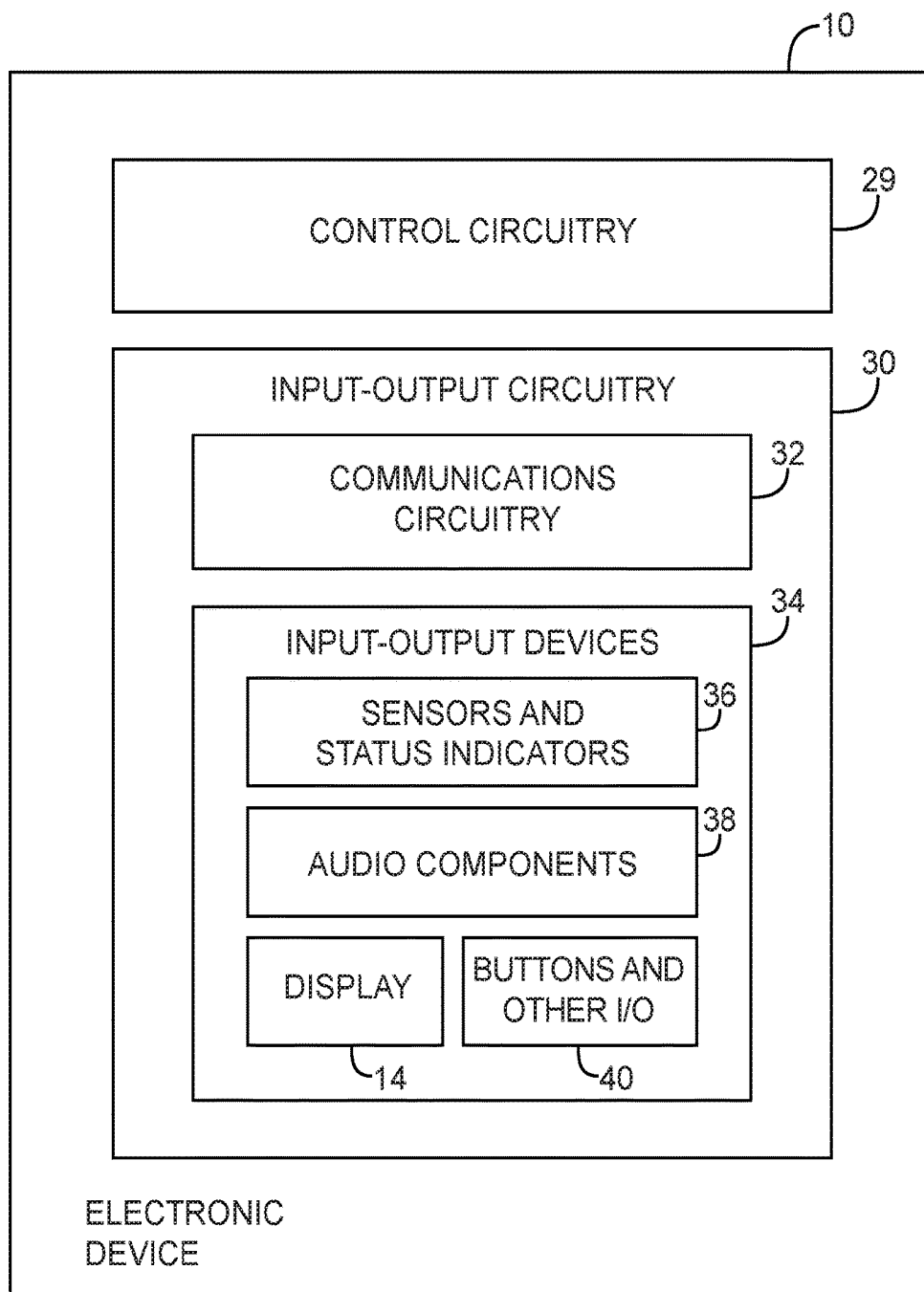


FIG. 4

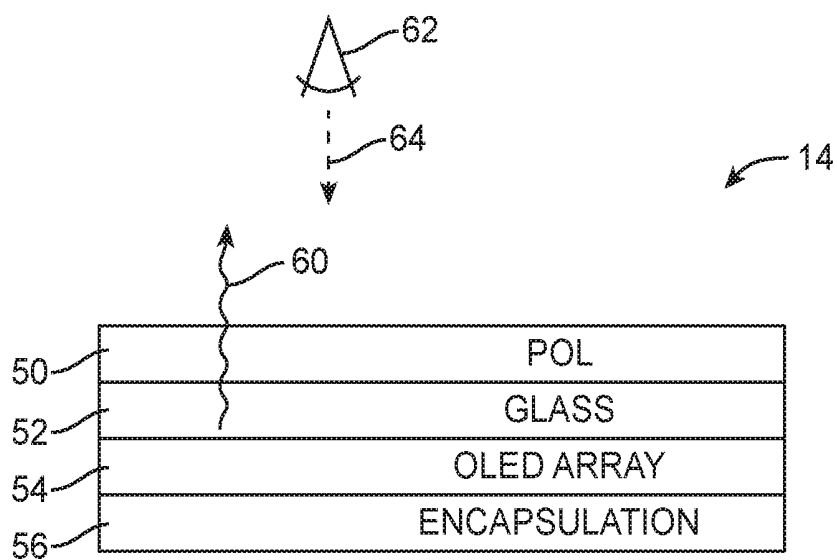


FIG. 5A

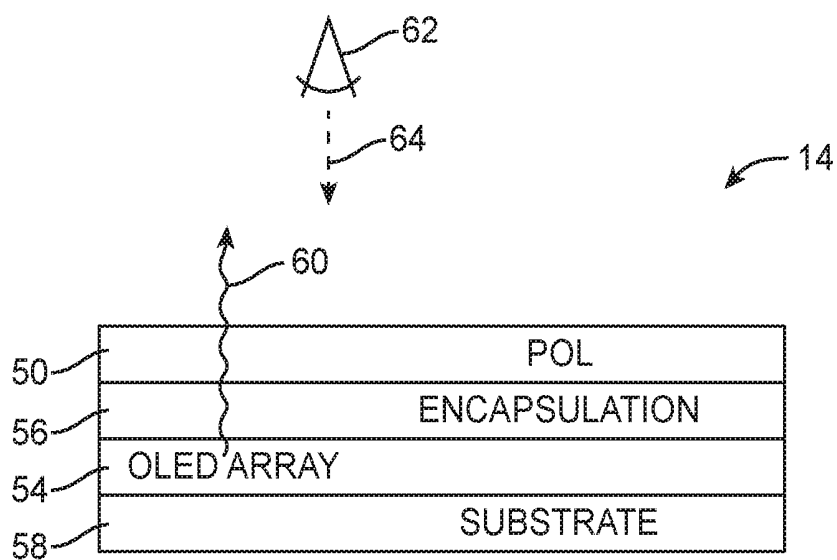


FIG. 5B

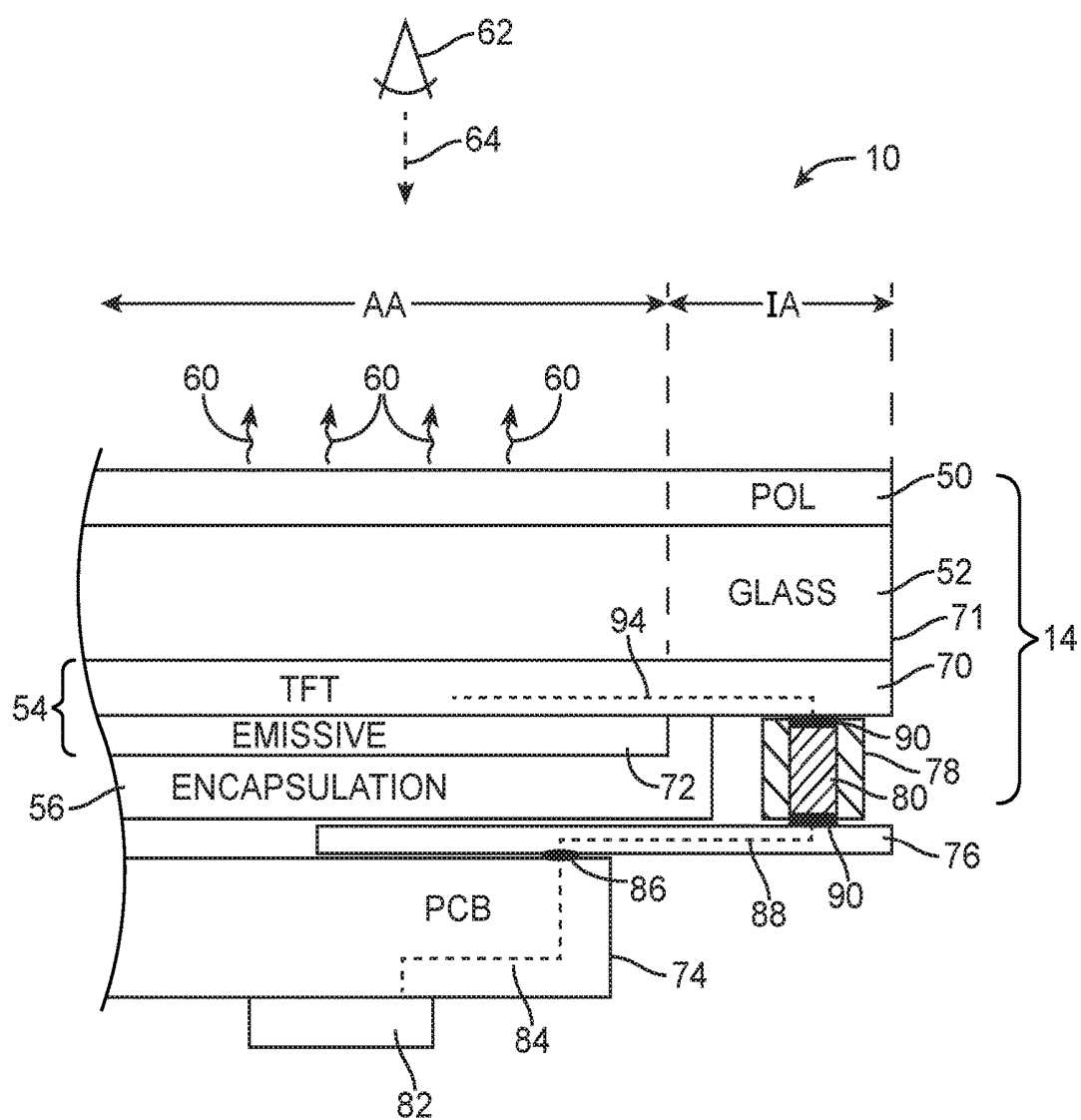


FIG. 6

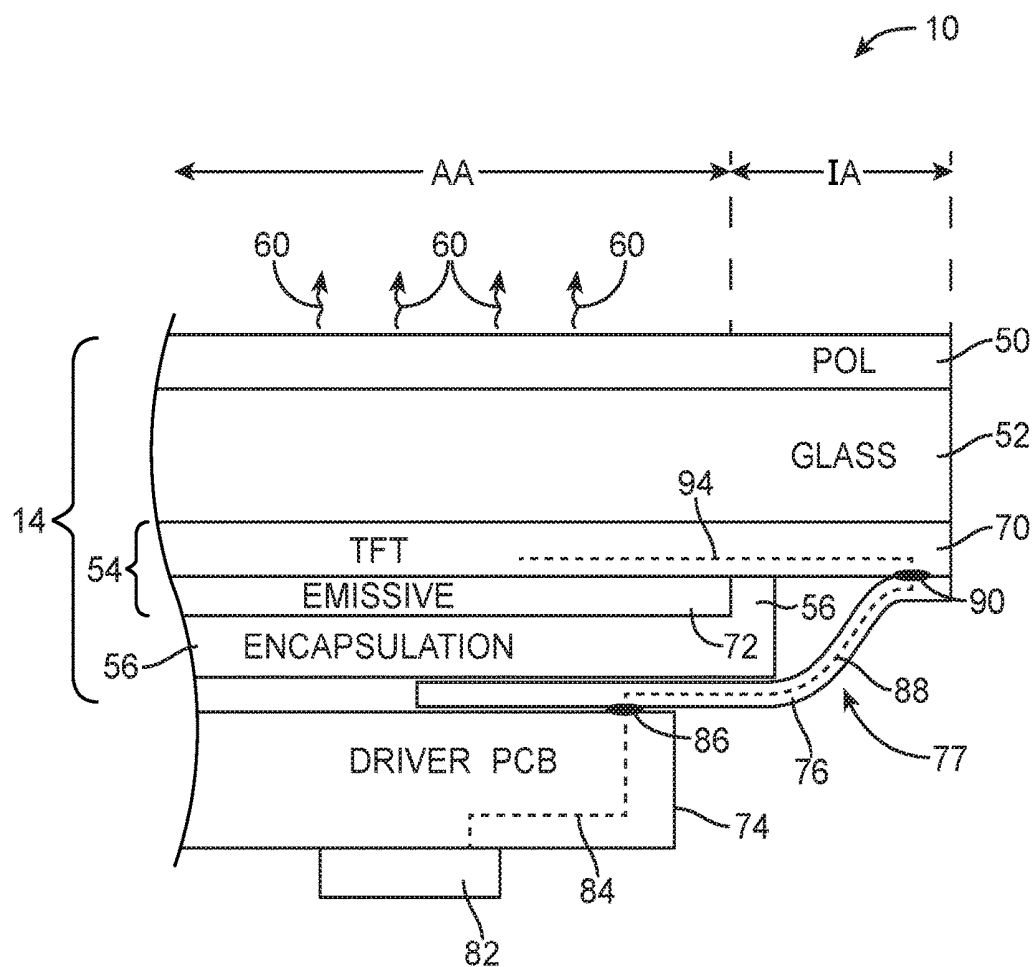


FIG. 7

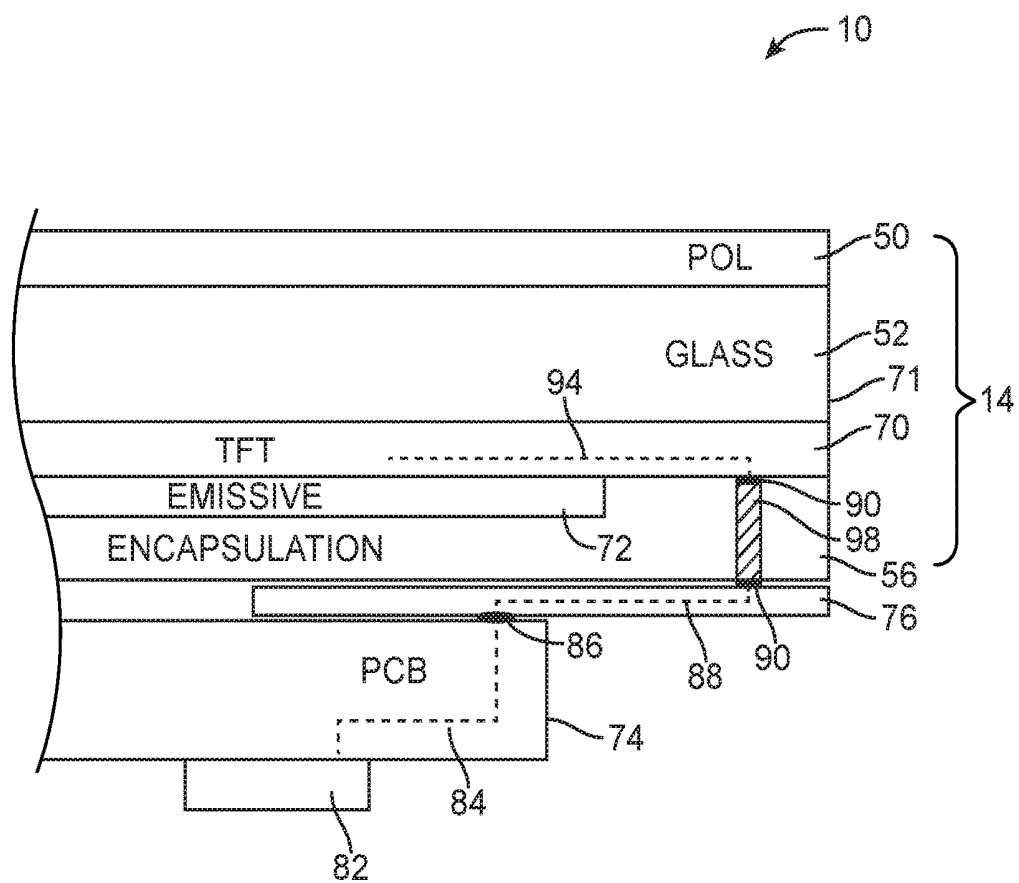


FIG. 8



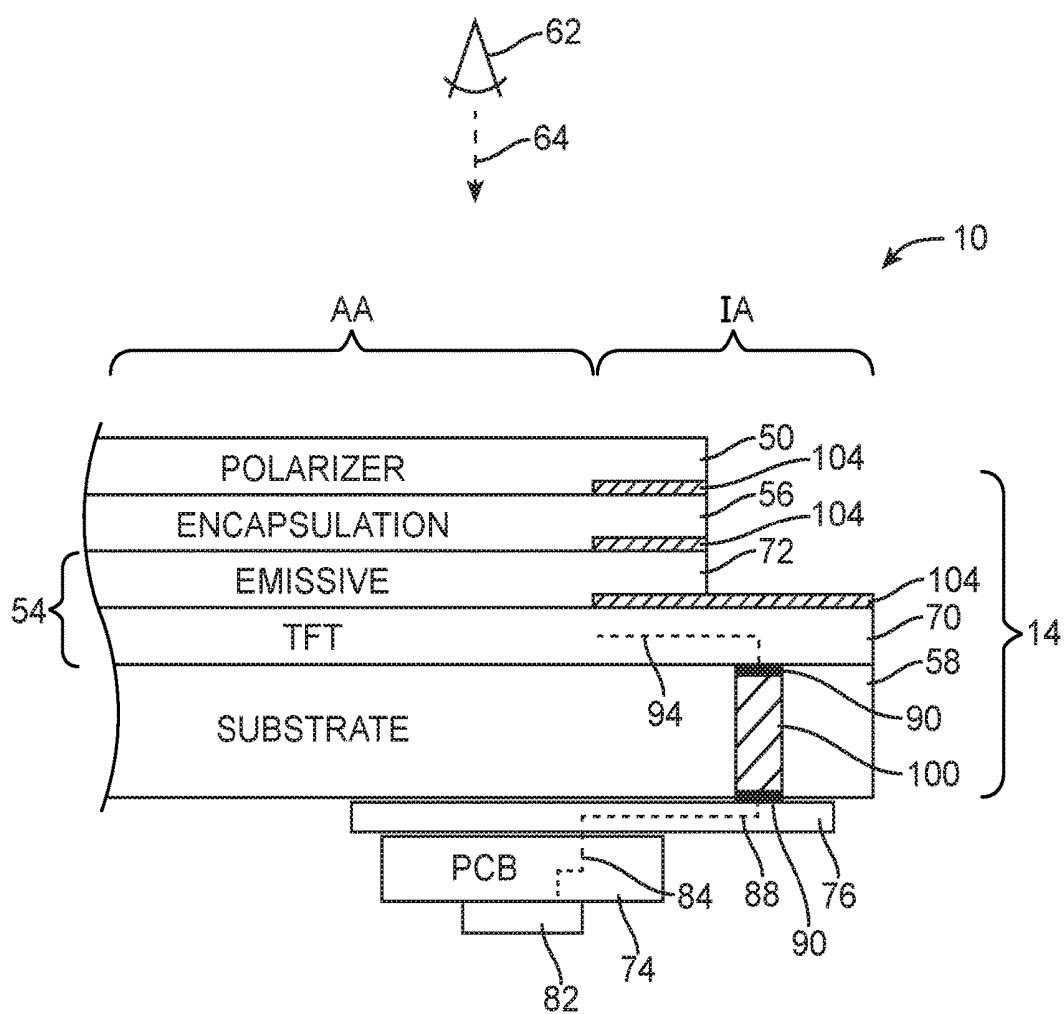


FIG. 9

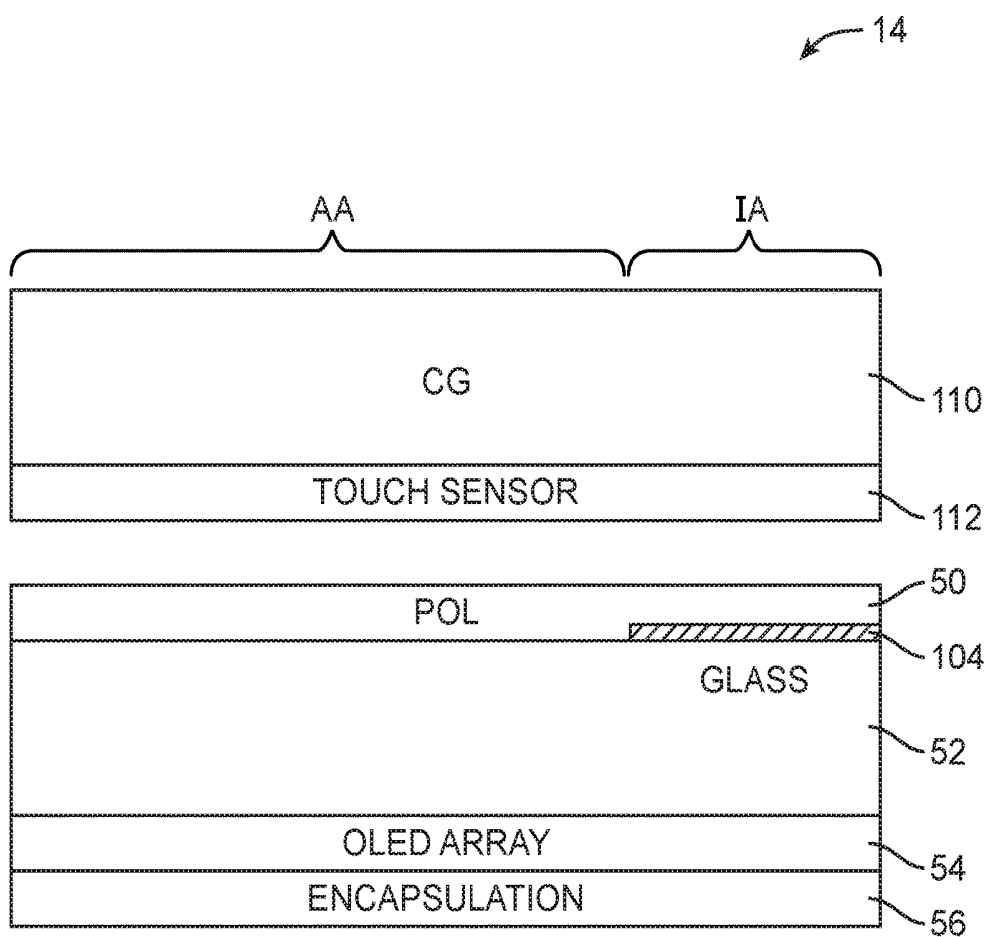


FIG. 10

## NARROW BORDER ORGANIC LIGHT-EMITTING DIODE DISPLAY

[0001] This application is a continuation of U.S. patent application Ser. No. 14/948,157, filed Nov. 20, 2015, which is a continuation of U.S. patent application Ser. No. 13/588,831, filed Aug. 17, 2012, now U.S. Pat. No. 9,214,507, each of which are hereby incorporated by reference herein in their entireties. This application claims the benefit of and claims priority to U.S. patent application Ser. No. 14/948,157, filed Nov. 20, 2015, and U.S. patent application Ser. No. 13/588,831, filed Aug. 17, 2012, now U.S. Pat. No. 9,214,507.

### 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. An electronic device may have a housing such as a housing formed from plastic or metal. Components for the electronic device such as display components may be mounted in the housing.

[0004] It can be challenging to incorporate a display into the housing of an electronic device. Size and weight are often important considerations in designing electronic devices. If care is not taken, displays may be bulky or may be surrounded by overly large borders. The housing of an electronic device can be adjusted to accommodate a bulky display with large borders, but this can lead to undesirable enlargement of the size and weight of the housing and unappealing device aesthetics.

[0005] It would therefore be desirable to be able to provide improved ways to provide displays for electronic devices.

### SUMMARY

[0006] An electronic device may be provided with an organic light-emitting diode display. The display may include an organic light-emitting diode layer that includes an array of thin-film transistors and a layer of organic light-emitting material.

[0007] The electronic device may include control circuitry that generates control signals for operating the organic light-emitting diode display. The display may include at least one display layer interposed between the array of thin-film transistors and the control circuitry. The electronic device may include one or more coupling structures that electrically couple the array of thin-film transistors to the control circuitry.

[0008] The coupling structures may include a dielectric member that includes a conductive via interposed between a portion of the array of thin-film transistors and the control circuitry.

[0009] The control circuitry may include a flexible printed circuit attached to a printed circuit board and, if desired, a display driver integrated circuit attached to the printed circuit board.

[0010] The layer of organic light-emitting material and an encapsulation layer that covers the layer of organic light-emitting material may be interposed between the array of thin-film transistors and the control circuitry.

[0011] The coupling member may include a flexible printed circuit having a bent portion or may include a

conductive via in the encapsulation layer that extends from a first surface of the encapsulation layer to a second surface of the encapsulation layer.

[0012] The display may include an organic light-emitting diode layer having opposing first and second surfaces, an encapsulation layer formed on the first surface, and a substrate layer such as a polyimide layer formed on the second surface. A conductive via may be provided in the substrate layer that couples the organic light-emitting diode layer to the control circuitry.

[0013] The display may include an active area for displaying images and an inactive area and layer of opaque masking material formed on a display layer in the inactive area. The opaque masking material may be interposed between a portion of the encapsulation layer and a portion of the organic light-emitting diode layer, may be formed between a light-polarizing layer for the and the encapsulation layer, or may be formed on the layer of thin-film transistor circuitry.

[0014] The display may include a transparent substrate layer such as a glass layer having opposing first and second surfaces, the organic light-emitting diode layer may be formed on the on the first surface, a light-polarizing layer may be formed on the second surface, and the opaque masking material may be interposed between a portion of the transparent substrate layer and a portion of the light-polarizing layer.

[0015] Further features of the invention, its nature and various advantages will be more apparent from the accompanying drawings and the following detailed description of the preferred embodiments.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a perspective view of an illustrative electronic device such as a laptop computer with a display in accordance with an embodiment of the present invention.

[0017] FIG. 2 is a perspective view of an illustrative electronic device such as a handheld electronic device with a display in accordance with an embodiment of the present invention.

[0018] FIG. 3 is a perspective view of an illustrative electronic device such as a tablet computer with a display in accordance with an embodiment of the present invention.

[0019] FIG. 4 is a schematic diagram of an illustrative electronic device with a display in accordance with an embodiment of the present invention.

[0020] FIG. 5A is a cross-sectional side view of an illustrative bottom emission organic light-emitting diode display in accordance with an embodiment of the present invention.

[0021] FIG. 5B is a cross-sectional side view of a top emission organic light-emitting diode display in accordance with an embodiment of the present invention.

[0022] FIG. 6 is a cross-sectional side view of a portion of an illustrative display having an organic light-emitting diode array and a gap-filling member in accordance with an embodiment of the present invention.

[0023] FIG. 7 is a cross-sectional side view of a portion of an illustrative display having an organic light-emitting diode array and a bent flexible circuit substrate in accordance with an embodiment of the present invention.

[0024] FIG. 8 is a cross-sectional side view of a portion of an illustrative display having an organic light-emitting diode

array and an extended encapsulation layer with a conductive via in accordance with an embodiment of the present invention.

**[0025]** FIG. 9 is a cross-sectional side view of a portion of an illustrative display having an organic light-emitting diode array and an opaque mask showing various display layers on which the opaque mask may be formed in accordance with an embodiment of the present invention.

**[0026]** FIG. 10 is a cross-sectional side view of a portion of an illustrative display having an organic light-emitting diode array and an opaque mask formed on a glass layer of the display in accordance with an embodiment of the present invention.

#### DETAILED DESCRIPTION

**[0027]** Electronic devices may include displays. The displays may be used to display images to a user. Illustrative electronic devices that may be provided with displays are shown in FIGS. 1, 2, and 3.

**[0028]** FIG. 1 shows how electronic device 10 may have the shape of a laptop computer having upper housing 12A and lower housing 12B with components such as keyboard 16 and touchpad 18. Device 10 may have hinge structures 20 that allow upper housing 12A to rotate in directions 22 about rotational axis 24 relative to lower housing 12B. Display 14 may be mounted in upper housing 12A. Upper housing 12A, which may sometimes be referred to as a display housing or lid, may be placed in a closed position by rotating upper housing 12A towards lower housing 12B about rotational axis 24.

**[0029]** FIG. 2 shows how electronic device 10 may be a handheld device such as a cellular telephone, music player, gaming device, navigation unit, or other compact device. In this type of configuration for device 10, housing 12 may have opposing front and rear surfaces. Display 14 may be mounted on a front face of housing 12. Display 14 may, if desired, have a display cover layer or other exterior layer that includes openings for components such as button 26. Openings may also be formed in a display cover layer or other display layer to accommodate a speaker port (see, e.g., speaker port 28 of FIG. 2).

**[0030]** FIG. 3 shows how electronic device 10 may be a tablet computer. In electronic device 10 of FIG. 3, housing 12 may have opposing planar front and rear surfaces. Display 14 may be mounted on the front surface of housing 12. As shown in FIG. 3, display 14 may have a cover layer or other external layer with an opening to accommodate button 26 (as an example).

**[0031]** Peripheral portions of display 14 may be provided with an opaque masking layer. As shown in FIGS. 1, 2, and 3, display 14 may be characterized by a central active region such as active region AA in which an array of display pixels is used in displaying information for a user. Active region AA may be surrounded by an inactive region such as inactive border region IA. Active region AA may have a rectangular shape bordered by rectangular line 21. Inactive region IA may have a rectangular ring shape that surrounds active region AA (as an example). Portions of display 14 in inactive region IA may be covered with an opaque masking material such as a layer of black ink (e.g., a polymer filled with carbon black) or a layer of opaque metal. The opaque masking layer may help hide components in the interior of device 10 in inactive region IA from view by a user.

**[0032]** The illustrative configurations for device 10 that are shown in FIGS. 1, 2, and 3 are merely illustrative. In

general, electronic device 10 may be 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, or other wearable or miniature device, a television, 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, equipment that implements the functionality of two or more of these devices, or other electronic equipment.

**[0033]** Housing 12 of device 10, which is sometimes referred to as a case, may be formed of materials such as plastic, glass, ceramics, carbon-fiber composites and other fiber-based composites, metal (e.g., machined aluminum, stainless steel, or other metals), other materials, or a combination of these materials. Device 10 may be formed using a unibody construction in which most or all of housing 12 is formed from a single structural element (e.g., a piece of machined metal or a piece of molded plastic) or may be formed from multiple housing structures (e.g., outer housing structures that have been mounted to internal frame elements or other internal housing structures).

**[0034]** Display 14 may be a touch sensitive display that includes a touch sensor or may be insensitive to touch. Touch sensors for display 14 may be formed from an array of capacitive touch sensor electrodes, a resistive touch array, touch sensor structures based on acoustic touch, optical touch, or force-based touch technologies, or other suitable touch sensor components.

**[0035]** Displays for device 10 may, in general, include image pixels formed from light-emitting diodes (LEDs), organic LEDs (OLEDs), plasma cells, electrowetting pixels, electrophoretic pixels, liquid crystal display (LCD) components, or other suitable image pixel structures. In some situations, it may be desirable to use OLED components to form display 14, so configurations for display 14 in which display 14 is an organic light-emitting diode display are sometimes described herein as an example. Other types of display technology may be used in device 10 if desired.

**[0036]** A display cover layer may cover the surface of display 14 or a display layer such as a color filter layer or other portion of a display may be used as the outermost (or nearly outermost) layer in display 14. A display cover layer or other outer display layer may be formed from a transparent glass sheet, a clear plastic layer, or other transparent member.

**[0037]** Touch sensor components such as an array of capacitive touch sensor electrodes formed from transparent materials such as indium tin oxide may be formed on the underside of a display cover layer, may be formed on a separate display layer such as a glass or polymer touch sensor substrate, or may be integrated into other display layers (e.g., substrate layers such as a thin-film transistor layer).

**[0038]** A schematic diagram of an illustrative configuration that may be used for electronic device 10 is shown in FIG. 4. As shown in FIG. 4, electronic device 10 may include control circuitry 29. Control circuitry 29 may include storage and processing circuitry for controlling the operation of device 10. Control circuitry 29 may, for example, include storage such as hard disk drive storage, nonvolatile memory (e.g., flash memory or other electri-

cally-programmable-read-only memory configured to form a solid state drive), volatile memory (e.g., static or dynamic random-access-memory), etc. Control circuitry 29 may include processing circuitry based on one or more microprocessors, microcontrollers, digital signal processors, base-band processors, power management units, audio codec chips, application specific integrated circuits, etc.

[0039] Control circuitry 29 may be used to run software on device 10, such as operating system software and application software. Using this software, control circuitry 29 may present information to a user of electronic device 10 on display 14. When presenting information to a user on display 14, sensor signals and other information may be used by control circuitry 29 in making adjustments to the strength of OLED illumination that is used for display 14.

[0040] Input-output circuitry 30 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 circuitry 30 may include communications circuitry 32. Communications circuitry 32 may include wired communications circuitry for supporting communications using data ports in device 10. Communications circuitry 32 may also include wireless communications circuits (e.g., circuitry for transmitting and receiving wireless radio-frequency signals using antennas).

[0041] Input-output circuitry 30 may also include input-output devices 34. A user can control the operation of device 10 by supplying commands through input-output devices 34 and may receive status information and other output from device 10 using the output resources of input-output devices 34.

[0042] Input-output devices 34 may include sensors and status indicators 36 such as an ambient light sensor, a proximity sensor, a temperature sensor, a pressure sensor, a magnetic sensor, an accelerometer, and light-emitting diodes and other components for gathering information about the environment in which device 10 is operating and providing information to a user of device 10 about the status of device 10.

[0043] Audio components 38 may include speakers and tone generators for presenting sound to a user of device 10 and microphones for gathering user audio input.

[0044] Display 14 may be used to present images for a user such as text, video, and still images. Sensors 36 may include a touch sensor array that is formed as one of the layers in display 14.

[0045] User input may be gathered using buttons and other input-output components 40 such as touch pad sensors, buttons, joysticks, click wheels, scrolling wheels, touch sensors such as sensors 36 in display 14, key pads, keyboards, vibrators, cameras, and other input-output components.

[0046] Cross-sectional side views of configurations that may be used for display 14 of device 10 (e.g., for display 14 of the devices of FIG. 1, FIG. 2, or FIG. 3 or other suitable electronic devices) is shown in FIGS. 5A and 5B. FIG. 5A is a cross-sectional side view of an illustrative bottom emission organic light-emitting diode display. FIG. 5B is a cross-sectional side view of an illustrative top emission organic light-emitting diode display.

[0047] In a configuration for display 14 of the type shown in FIG. 5A, display 14 may have a transparent substrate layer such as glass layer 52. A layer of organic light-emitting diode structures such as organic light-emitting diode layer 54 may be formed on the underside of glass layer 52. An

encapsulation layer such as encapsulation layer 56 may be used to encapsulate organic light-emitting diode layer 54. Encapsulation layer 56 may be formed from a layer of metal foil, metal foil covered with plastic, other metal structures, a glass layer, a thin-film encapsulation layer formed from a material such as silicon nitride, a layered stack of alternating polymer and ceramic materials, or other suitable material for encapsulating organic light-emitting diode layer 54. Encapsulation layer 56 may be used to protect organic light-emitting diode layer 54 from environmental exposure by preventing water and oxygen from reaching organic emissive materials within organic light-emitting diode layer 54.

[0048] Organic light-emitting diode layer 54 may contain an array of thin-film transistors. The thin-film transistors may be formed from semiconductors such as amorphous silicon, polysilicon, or compound semiconductors (as examples). Signal lines (e.g., a grid of horizontal and vertical metal lines) may be used in applying control signals to the array of thin-film transistors. During operation, signals may be applied to the organic light-emitting diodes in layer 54 using the signal lines so that an image may be created on display 14. Image light 60 from the organic light-emitting diode pixels in layer 54 may be emitted upwards through transparent glass layer 52 for viewing in direction 64 by viewer 62. Circular polarizer 50 may suppress reflections from the metal signal lines in layer 54 that might otherwise be visible to viewer 62.

[0049] In a configuration for display 14 of the type shown in FIG. 5B, display 14 may have a substrate layer such as substrate layer 58. Substrate layer 58 may be a polyimide layer that is temporarily carried on a glass carrier during manufacturing or may be a layer formed from glass or other suitable substrate materials.

[0050] Organic light-emitting diode layer 54 may be formed on the upper surface of substrate 58. An encapsulation layer such as encapsulation layer 56 may be used to encapsulate organic light-emitting diode layer 54. During operation, individually controlled pixels in organic light-emitting diode layer 54 may be used to generate image light 60 for viewing in direction 64 by viewer 62. Circular polarizer 50 may suppress reflections from metal signal lines in layer 54. If desired an array of color filter elements may be included in polarizer layer 50.

[0051] FIG. 6 is a cross-sectional side view of a bottom-emissive organic light-emitting diode display of the type shown in FIG. 5A showing how the size of inactive area IA may be minimized by forming control circuitry such as control circuitry 28 (FIG. 4) for the display behind a portion of the display. As shown in FIG. 6, control circuitry 28 may include component 82 and printed circuit 74 that are coupled to display 14. Printed circuit 74 may, for example, be a printed circuit board. Printed circuit 74 may be a dedicated printed circuit for controlling operation of display 14 or may be a printed circuit board such as a mother board that is used in controlling multiple components within device 10.

[0052] As shown in FIG. 6, control circuitry for display (e.g., printed circuit 74 and component 82) may be formed behind display 14 so that the control circuitry is not visible to a viewer such as viewer 62 viewing display 14 in direction 64 and without extending beyond edge 71 of display 14. In this way, the size of inactive area IA may be reduced in comparison with conventional displays in which a display driver integrated circuit is formed along the edge of the display.

[0053] Component 82 may, for example, be a display driver integrated circuit that is used to generate control signals to be conveyed to thin-film transistors in thin-film-transistor layer 70 of OLED layer 54. Printed circuit 74 and/or component 82 may be used to generate information to be displayed on display 14 (e.g., display data). The information to be displayed may be conveyed from control circuitry such as printed circuit 74 to thin-film-transistors in layer 70 using a signal path such as a signal path 88 formed from conductive metal traces in printed circuit 76 (as an example).

[0054] Printed circuit 76 may, for example be a flexible printed circuit (e.g., a flexible printed circuit cable). Printed circuit 76 may be used in routing signals between printed circuit 74 and thin-film-transistor layer 70. If desired, display driver integrated circuit 82 may be mounted on printed circuit 74 or flexible printed circuit 76. Printed circuit 74 may be formed from a rigid printed circuit board (e.g., a layer of fiberglass-filled epoxy) or a flexible printed circuit (e.g., a flexible sheet of polyimide). Printed circuit 76 may be formed from a rigid printed circuit board (e.g., a layer of fiberglass-filled epoxy) or a flexible printed circuit (e.g., a flexible sheet of polyimide). In one suitable example that is sometimes described herein, printed circuit 76 is implemented as a flexible printed circuit.

[0055] Signal path 88 may be coupled to signal path 84 in printed circuit board 74 using conductive contact 86. Conductive contact 86 may be formed from a conductive adhesive, solder, or other suitable conductive structures or materials.

[0056] Organic-light-emitting diode layer 54 may include thin-film transistor (TFT) layer 70 and a layer of organic light-emitting material such as emissive layer 72. TFT layer 70 may include an array of thin-film transistors. The thin-film transistors may be formed from semiconductors such as amorphous silicon, polysilicon, or compound semiconductors (as examples). Organic emissive layer 72 may be formed from organic plastics such as polyfluorene or other organic emissive materials. Encapsulation layer 56 may cover emissive layer 72 and, if desired, some or all of TFT layer 70.

[0057] Signal lines 94 (e.g., a grid of horizontal and vertical metal lines) may be used in applying control signals to the array of thin-film transistors in TFT layer 70. Signals applied to the thin-film transistors in TFT layer 70 may selectively cause portions of emissive layer 72 to emit display light such as light 66. In this way, images may be created on display 14.

[0058] Thin-film transistors in TFT layer 70 may be formed in active area AA. Signal lines 94 may be used to route signals received from printed circuit 74 in inactive area IA to the thin-film transistors in TFT layer 70.

[0059] However, in some situations, emissive layer 72 and encapsulation layer 56 may form a gap between flexible printed circuit 76 and TFT layer 70. In order to couple signal lines 94 in TFT layer 70 to signal lines 88 in printed circuit 76, a dielectric spacer such as gap-filling member 78 may be provided that has a conductive via such as via 80.

[0060] Conductive via 80 in spacer 78 may be used to route signals to TFT layer 70 from printed circuit 76 (or from other components such as integrated circuit 82).

[0061] Conductive contacts 90 (e.g., contacts formed from conductive adhesive, anisotropic conductive adhesive, sol-

der, etc.) may be used to couple via 80 to conductive contacts on flexible printed circuit 76 and TFT layer 70.

[0062] Gap-filling member 78 may be formed from a polymer material or other dielectric material in which a conductive via can be formed. Via 80 may be formed in member 78 by forming an opening (e.g., by mechanical drilling or laser drilling) in member 78 and forming a conductive coating or a conductive filler material (e.g., conductive paste, conductive adhesive, conductive foam, or other suitable conductive material) within the opening. However, this is merely illustrative. If desired, member 78 may be formed from additional layers of flexible printed circuit material (e.g., polyimide) or additional layers of rigid printed circuit material (e.g., glass infused epoxy).

[0063] As examples, member 78 may be formed from a portion of printed circuit board 74 that extends beyond encapsulation layer 56 under TFT layer 70 and includes additional layers of printed circuit board material, member 78 may be a portion of flexible printed circuit 76 having additional layers of flexible printed circuit material or member 78 and flexible printed circuit 76 may be formed from a common printed circuit having rigid and flexible portions (e.g., flexible circuit 76 may be a flex tail that extends from a layer of flexible printed circuit material in a rigid printed circuit that forms member 78).

[0064] If desired, printed circuit 74 may be coupled to via 80 of member 78 without using an interposed flexible printed circuit. Printed circuit 74 may extend under member 78 so that conductive contact 90 couples via 80 to a conductive contact on a surface of printed circuit 74.

[0065] FIG. 7 is a cross-sectional side view of a bottom-emissive organic light-emitting diode display of the type shown in FIG. 5A showing how the size of inactive area IA may be minimized by forming control circuitry for the display behind a portion of the display without using a gap-filling member. As shown in FIG. 7, flexible printed circuit 76 may be used as a coupling structure by providing flexible printed circuit 76 with a bent portion such as curved portion 77 that carries traces 88 in flexible circuit 76 from contact 86 to contact 90. Flexible printed circuit 76 may be coupled to traces 94 using conductive material 90.

[0066] FIG. 8 is a cross-sectional side view of a bottom-emissive organic light-emitting diode display of the type shown in FIG. 5A showing how the size of inactive area IA may be minimized by forming control circuitry for the display behind a portion of the display using a conductive via formed in the encapsulation layer. As shown in FIG. 8, encapsulation layer 56 may extend substantially to edge 71 of display 14 and may include a conductive via such as via 98 formed through the encapsulation layer. Conductive via 98 may be connected between traces 94 of TFT layer 70 and traces 88 of flexible printed circuit 76 using, for example, conductive coupling material 90 (e.g., anisotropic conductive adhesive, solder or other suitable conductive material).

[0067] Via 98 may be formed in encapsulation layer 56 by forming an opening (e.g., by mechanical drilling, laser drilling, wet or dry etching, or other suitable processes) in encapsulation layer 56 and forming a conductive coating or a conductive filler material such as conductive paste within the opening.

[0068] Providing an organic light-emitting diode display such as display 14 with control circuitry that is formed behind the display so that one or more display layers (e.g., encapsulation layer 56 and/or emissive layer 72) is inter-

posed between the thin-film transistors and the control circuitry as described above in connection with FIGS. 6, 7, and 8 (as examples) may help reduce or eliminate inactive area IA along one or more peripheral portions of the display.

[0069] In configurations in which organic light-emitting diode display 14 includes an inactive area IA, portions of the display in the inactive area may be provided with an opaque masking material in the inactive area. The opaque masking material may be configured to block portions of the device in the inactive region of the display from being seen by a viewer such as viewer 62 viewing display 14 in direction 64 as shown in FIG. 9. FIG. 9 is a cross-sectional side view of a top-emissive organic light-emitting diode display of the type shown in FIG. 5B showing various locations within an OLED display where opaque masking material 104 may be formed.

[0070] Opaque masking material 104 may be formed from an opaque metal such as chrome oxide (sometimes referred to as black chrome), a polymer material infused with an opaque dye or pigment (e.g., carbon black), opaque photo-patternable material (i.e., material that can be formed over glass 52 and selectively patterned using light), other suitably opaque or mostly opaque materials, or any combination of these materials.

[0071] As shown in FIG. 9, opaque masking material 104 may be formed on a portion of TFT layer 70. Opaque masking material that is formed on top of TFT layer 70 may be uncovered by other display materials or a portion of the opaque masking material may be covered by organic emissive layer 72 and/or encapsulation layer 56. However, this is merely illustrative. If desired, opaque masking material 104 may be formed between OLED layer 54 and encapsulation layer 56 or opaque masking material 104 may be formed between encapsulation layer 56 and upper polarizer layer 50. If desired, opaque masking material 104 may be formed at any or all of the locations shown in FIG. 9.

[0072] In configurations of the type shown in FIG. 9, opaque masking material 104 may be used to hide a conductive via such as via 100 formed in substrate 58 of display 14. As shown in FIG. 9, via 100 may be connected between signal paths 94 in TFT layer 70 and signal paths 88 in flexible printed circuit 76.

[0073] Via 100 may be formed in substrate 58 by drilling (e.g., laser drilling) an opening in substrate 58 and lining or filling the opening with conductive material. Conductive material 90 may be used to electrically couple signal lines in TFT layer 70 to signal lines in flexible printed circuit 76 through via 100. TFT layer 70 and via 100 may be formed on substrate 58 by forming thin-film transistors on a first surface of substrate 58, laser drilling an opening in substrate 58 and plating, lining, or filling the opening with conductive material.

[0074] If desired, display 14 of FIG. 9 may be coupled to printed circuit 74 without the use of flexible printed circuit 76 by forming signal lines (e.g., patterned conductive metal traces) along a back surface of substrate 58 (i.e., a surface opposite to the surface on which TFT layer 70 is formed). These types of back-surface traces may be used to couple via 100 to printed circuit 74.

[0075] If desired, a layer of touch-sensitive circuitry (e.g., an array of capacitive touch sensor electrodes, a resistive touch array, touch sensor structures based on acoustic touch, optical touch, force-based touch technologies, or other suitable touch sensor components) may be formed on an upper

surface of encapsulation layer 56 (e.g., between encapsulation layer 56 and polarization layer 50). However, this is merely illustrative. If desired, touch-sensitive circuitry for display 14 may be formed on polarizer layer 50 or may be formed separately from display layers 50, 56, 54, and 58. As an example, touch-sensitive circuitry for display 14 may be formed on an outer cover layer as shown in FIG. 10.

[0076] FIG. 10 is a cross-sectional side view of a bottom-emissive organic light-emitting diode display of the type shown in FIG. 5A having a layer of opaque masking material. As shown in FIG. 10, display 14 may be optionally provided with a cover layer such as cover layer 110. Cover layer 110 may be formed from glass, plastic, or other suitable transparent material. Cover layer 110 may be rigid or flexible and may sometimes be referred to as a cover glass (CG) layer. Touch-sensor circuitry 112 may be formed on an inner layer of cover layer 112. However, this is merely illustrative. If desired, touch-sensor circuitry 112 may be formed on polarizer layer 50, between polarizer layer 50 and glass layer 52 or may be formed as a separate layer of display 14.

[0077] Opaque masking material 104 may be formed between a portion of glass layer 52 and a corresponding portion of upper (circular) polarizer 50 in inactive region IA of display 14. During manufacturing of display 14, opaque masking material 104 may be applied to a top (outer) surface of glass 52 and patterned (e.g., photo-patterned) or may be painted or otherwise applied to glass 52.

[0078] In some configurations, opaque masking material 104 may be formed from a material (e.g., black chrome) that can withstand relatively high temperatures associated with display assembly processes such as thin-film-transistor polysilicon deposition processes that may be used in formatting of OLED array 54 on glass 52. In configurations which opaque masking material 104 is formed from this type of high temperature material, opaque masking material may be formed on a bottom side of glass layer 52 (i.e., interposed between a portion of OLED array 54 and glass layer 52).

[0079] The foregoing is merely illustrative of the principles of this invention and various modifications can be made by those skilled in the art without departing from the scope and spirit of the invention.

What is claimed is:

1. A display having an active area surrounded by an inactive border area, the display comprising:

- a substrate;
- an array of thin-film transistors formed on the substrate in the active area;
- a layer of organic emissive material formed over the array of thin-film transistors in the active area;
- a display driver integrated circuit; and
- a via in the inactive area that extends through the substrate to couple the array of thin-film transistors to the display driver integrated circuit.

2. The display defined in claim 1, wherein the array of thin-film transistors and the layer of organic emissive material form an array of organic light-emitting diodes that displays images in the active area.

3. The display defined in claim 1, further comprising:

- an encapsulation layer that overlaps the layer of organic emissive material, wherein the layer of organic emissive material and the array of thin-film transistors are between the encapsulation layer and the substrate.

4. The display defined in claim 3, further comprising:  
a polarizer that overlaps the encapsulation layer, wherein the encapsulation layer, the layer of organic emissive material, and the array of thin-film transistors are between the polarizer and the substrate.
5. The display defined in claim 1, wherein the array of thin-film transistors is formed in a thin-film transistor layer that extends into the inactive border area and overlaps the via.
6. The display defined in claim 5, wherein the layer of organic emissive material does not overlap the via.
7. The display defined in claim 6, further comprising:  
an encapsulation layer that encapsulates the layer of organic emissive material and does not overlap the via;  
and  
a circular polarizer formed on the encapsulation layer.
8. The display defined in claim 7, wherein the layer of organic emissive material, the encapsulation layer, and the circular polarizer extend into the inactive border area.
9. The display defined in claim 8, further comprising:  
opaque masking material in the inactive border area that overlaps the thin-film transistor layer, the layer of organic emissive material, the encapsulation layer, and the circular polarizer.
10. A display having an active region surrounded by an inactive region, the display comprising:  
a display substrate having first and second opposing surfaces;  
an array of light-emitting diodes on the first surface of the display substrate that emits light to display images in the active region;  
control circuitry mounted to the second surface of the display substrate that sends control signals to the array of light-emitting diodes on the first surface of the display substrate; and  
a conductive via that extends through the display substrate from the first surface to the second surface in the inactive region, wherein the conductive via transmits the control signals from the control circuitry to the array of light-emitting diodes.
11. The display defined in claim 10, wherein the control circuitry comprises a display driver integrated circuit and wherein a trace on the second surface conveys signals between the display driver integrated circuit and the conductive via.
12. The display defined in claim 11, further comprising a grid of signal lines on the first surface of the display substrate that route the control signals from the conductive via to the array of light-emitting diodes.
13. The display defined in claim 10, further comprising:  
an opaque masking layer in the inactive region that overlaps the conductive via.
14. The display defined in claim 13, further comprising:  
an array of thin-film transistors on the first surface of the display substrate; and  
a layer of light-emitting material formed over the array of thin-film transistors, wherein the array of thin-film transistors and the layer of light-emitting material form the array of light-emitting diodes, and wherein the opaque masking layer is interposed between the array of thin-film transistors and the layer of light-emitting material.
15. An electronic device, comprising:  
an organic light-emitting diode display having an active area that displays images surrounded by an inactive area;  
control circuitry that provides control signals to the organic light-emitting diode display and that overlaps the active area; and  
a conductive via in the inactive area that conveys the control signals from the control circuitry to the organic light-emitting diode display.
16. The electronic device defined in claim 15, wherein the organic light-emitting diode display comprises:  
a thin-film transistor layer that receives the control signals;  
an organic emissive layer formed over the thin-film transistor layer, wherein the organic emissive layer emits light to display the images; and  
an encapsulation layer formed over the organic emissive layer.
17. The electronic device defined in claim 16, further comprising:  
an opaque masking layer interposed between the organic emissive layer and the encapsulation layer in the inactive area.
18. The electronic device defined in claim 16, further comprising:  
a polarizer formed over the encapsulation layer; and  
an opaque masking layer interposed between the encapsulation layer and the polarizer in the inactive area.
19. The electronic device defined in claim 16, wherein the organic light-emitting diode display comprises a substrate having first and second opposing surfaces, wherein the thin-film transistor layer and the organic emissive layer are formed on the first surface, and wherein the control circuitry is mounted on the second surface.
20. The electronic device defined in claim 19, wherein the control circuitry comprises a display driver integrated circuit, the electronic device further comprising:  
a signal path on the second surface that conveys the control signals from the display driver integrated circuit to the conductive via.

\* \* \* \* \*



[illegible]