



(51) International Patent Classification:

G02B 6/00 (2006.01) **G02F 1/13357** (2006.01)
G02B 26/00 (2006.01)

(21) International Application Number:

PCT/US2010/021678

(22) International Filing Date:

21 January 2010 (21.01.2010)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

12/365,755 4 February 2009 (04.02.2009) US
12/399,798 6 March 2009 (06.03.2009) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: SHAPED FRONTLIGHT REFLECTOR FOR USE WITH DISPLAY

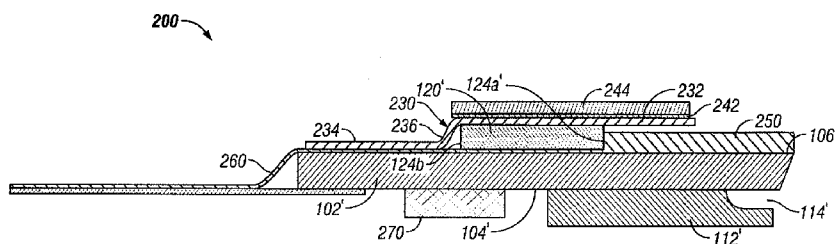


FIG. 9

(57) Abstract: In order to minimize the footprint of a display module, a frontlight system positioned over a first surface of a substrate may be used. The frontlight system may include an edgebar positioned over the first surface of a display substrate, and a Z-shaped reflector having a first planar portion overlying the edgebar and a second planar portion adhered to the first surface of the substrate or layers overlying the first surface of the substrate. Such a reflector may be located wholly within the footprint of the display substrate, minimizing the footprint of the display module.

SHAPED FRONTLIGHT REFLECTOR FOR USE WITH DISPLAY

BACKGROUND OF THE INVENTION

Description of the Related Art

[0001] Microelectromechanical systems (MEMS) include micro mechanical elements, actuators, and electronics. Micromechanical elements may be created using deposition, etching, and or other micromachining processes that etch away parts of substrates and/or deposited material layers or that add layers to form electrical and electromechanical devices. One type of MEMS device is called an interferometric modulator. As used herein, the term interferometric modulator or interferometric light modulator refers to a device that selectively absorbs and/or reflects light using the principles of optical interference. In certain embodiments, an interferometric modulator may comprise a pair of conductive plates, one or both of which may be transparent and/or reflective in whole or part and capable of relative motion upon application of an appropriate electrical signal. In a particular embodiment, one plate may comprise a stationary layer deposited on a substrate and the other plate may comprise a metallic membrane separated from the stationary layer by an air gap. As described herein in more detail, the position of one plate in relation to another can change the optical interference of light incident on the interferometric modulator. Such devices have a wide range of applications, and it would be beneficial in the art to utilize and/or modify the characteristics of these types of devices so that their features can be exploited in improving existing products and creating new products that have not yet been developed.

SUMMARY OF THE INVENTION

[0002] In one aspect, a display module is provided, including a light-transmissive substrate including a first surface and a second surface, an edgebar in optical communication with a light source, where the edgebar is located over the first surface of the substrate, a frontlight film adjacent the edgebar and in optical communication with the edge bar, where the frontlight film is configured to direct light through the light-transmissive substrate, and a reflector, the reflector including a first substantially planar portion overlying the edgebar and a second substantially planar portion located over the first surface of the substrate and laterally displaced from the edgebar.

[0003] In another aspect, an edgebar subassembly configured for use in a display module is provided, the edgebar subassembly including an edgebar configured to receive light through a first surface and reflect light through a second surface orthogonal to the first surface, and a reflector configured to retain the edgebar, the reflector including a first substantially planar portion configured to overlie the edgebar, and a second substantially planar portion configured to be adhered to an underlying layer, where a lower surface of the second substantially planar portion is substantially coplanar with a lower surface of the edgebar, and the edgebar is retained by the reflector.

[0004] In another aspect, a method of assembling a display module is provided, the method including providing a substrate having a first and second surface, the substrate including a display array formed over the first surface and a light-guiding layer located over the second surface, where the light-guiding layer is located opposite the display array, positioning an edgebar relative to the substrate such that a first surface of the edgebar is positioned adjacent a side surface of the light-guiding layer, and providing a reflector over the first surface of the substrate such that the reflector retains the edgebar in place, the reflector including a first substantially planar portion overlying the edgebar and a second substantially planar portion displaced from the edgebar and adhered to an underlying layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1 is an isometric view depicting a portion of one embodiment of an interferometric modulator display in which a movable reflective layer of a first interferometric modulator is in a relaxed position and a movable reflective layer of a second interferometric modulator is in an actuated position.

[0006] Figure 2 is a system block diagram illustrating one embodiment of an electronic device incorporating a 3x3 interferometric modulator display.

[0007] Figure 3 is a diagram of movable mirror position versus applied voltage for one exemplary embodiment of an interferometric modulator of Figure 1.

[0008] Figure 4 is an illustration of a set of row and column voltages that may be used to drive an interferometric modulator display.

[0009] Figure 5A and 5B illustrate one exemplary timing diagram for row and column signals that may be used to write a frame of display data to the 3x3 interferometric modulator display of Figure 2.

[0010] Figure 6A and 6B are system block diagrams illustrating an embodiment of a visual display device comprising a plurality of interferometric modulators.

[0011] Figure 7A is a cross section of the device of Figure 1.

[0012] Figure 7B is a cross section of an alternative embodiment of an interferometric modulator.

[0013] Figure 7C is a cross section of another alternative embodiment of an interferometric modulator.

[0014] Figure 7D is a cross section of yet another alternative embodiment of an interferometric modulator.

[0015] Figure 7E is a cross section of an additional alternative embodiment of an interferometric modulator.

[0016] Figure 8A is a cross-sectional view of an embodiment of a display module in which an edgebar is located adjacent a side surface of the display substrate.

[0017] Figure 8B is a top plan view of a cross-section of the display module of Figure 8A, taken along the line 8B-8B of Figure 8A.

[0018] Figure 9 is a partial cross-section of another embodiment of a display module which includes a Z-shaped reflector overlying an edgebar.

[0019] Figure 10 is a perspective exploded assembly view of a display module which includes a Z-shaped reflector overlying an edgebar.

[0020] Figure 11A is a perspective view of the reflector of Figure 10.

[0021] Figure 11B is a bottom plan view of the reflector of Figure 11A.

[0022] Figure 11C is a side elevation view of the reflector of Figure 11A.

[0023] Figure 12 is a perspective view of an edgebar suitable for use with the reflector of Figure 11A.

[0024] Figure 13A is a perspective exploded assembly view of an edgebar subassembly comprising the reflector of Figure 11A.

[0025] Figure 13B is a perspective view of the assembled edgebar subassembly of Figure 13A.

[0026] Figure 13C is a perspective view from below the assembled edgebar subassembly of Figure 13A.

[0027] Figure 14A is a perspective exploded assembly view from beneath the LED subassembly of Figure 10.

[0028] Figure 14B is a bottom plan view of the LED subassembly of Figure 14A.

[0029] Figure 14C is a perspective view from above the LED subassembly of Figure 14A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0030] The following detailed description is directed to certain specific embodiments. However, the teachings herein can be applied in a multitude of different ways. In this description, reference is made to the drawings wherein like parts are designated with like numerals throughout. The embodiments may be implemented in any device that is configured to display an image, whether in motion (e.g., video) or stationary (e.g., still image), and whether textual or pictorial. More particularly, it is contemplated that the embodiments may be implemented in or associated with a variety of electronic devices such as, but not limited to, mobile telephones, wireless devices, personal data assistants (PDAs), hand-held or portable computers, GPS receivers/navigators, cameras, MP3 players, camcorders, game consoles, wrist watches, clocks, calculators, television monitors, flat panel displays, computer monitors, auto displays (e.g., odometer display, etc.), cockpit controls and/or displays, display of camera views (e.g., display of a rear view camera in a vehicle), electronic photographs, electronic billboards or signs, projectors, architectural structures, packaging, and aesthetic structures (e.g., display of images on a piece of jewelry). MEMS devices of similar structure to those described herein can also be used in non-display applications such as in electronic switching devices.

[0031] In embodiments in which interferometric modulators are used as display devices, it may be desirable to minimize the footprint of the display module as much as possible. One component which may increase the footprint of the display module is an edgebar utilized in a frontlighting system. By positioning the edgebar and associated reflector entirely on the same side of the display glass or other substrate, the footprint of the display module can be reduced by avoiding the inclusion of additional rigid components which extend beyond the perimeter of the display glass.. A substantially Z-shaped reflector having a first planar portion overlying the edgebar and a

second planar portion adhered to the substrate or other underlying layer is suitable for use with a display module configured in this manner.

[0032] One interferometric modulator display embodiment comprising an interferometric MEMS display element is illustrated in Figure 1. In these devices, the pixels are in either a bright or dark state. In the bright (“relaxed” or “open”) state, the display element reflects a large portion of incident visible light to a user. When in the dark (“actuated” or “closed”) state, the display element reflects little incident visible light to the user. Depending on the embodiment, the light reflectance properties of the “on” and “off” states may be reversed. MEMS pixels can be configured to reflect predominantly at selected colors, allowing for a color display in addition to black and white.

[0033] Figure 1 is an isometric view depicting two adjacent pixels in a series of pixels of a visual display, wherein each pixel comprises a MEMS interferometric modulator. In some embodiments, an interferometric modulator display comprises a row/column array of these interferometric modulators. Each interferometric modulator includes a pair of reflective layers positioned at a variable and controllable distance from each other to form a resonant optical gap with at least one variable dimension. In one embodiment, one of the reflective layers may be moved between two positions. In the first position, referred to herein as the relaxed position, the movable reflective layer is positioned at a relatively large distance from a fixed partially reflective layer. In the second position, referred to herein as the actuated position, the movable reflective layer is positioned more closely adjacent to the partially reflective layer. Incident light that reflects from the two layers interferes constructively or destructively depending on the position of the movable reflective layer, producing either an overall reflective or non-reflective state for each pixel.

[0034] The depicted portion of the pixel array in Figure 1 includes two adjacent interferometric modulators 12a and 12b. In the interferometric modulator 12a on the left, a movable reflective layer 14a is illustrated in a relaxed position at a predetermined distance from an optical stack 16a, which includes a partially reflective layer. In the interferometric modulator 12b on the right, the movable reflective layer 14b is illustrated in an actuated position adjacent to the optical stack 16b.

[0035] The optical stacks 16a and 16b (collectively referred to as optical stack 16), as referenced herein, typically comprise several fused layers, which can include an

electrode layer, such as indium tin oxide (ITO), a partially reflective layer, such as chromium, and a transparent dielectric. The optical stack 16 is thus electrically conductive, partially transparent and partially reflective, and may be fabricated, for example, by depositing one or more of the above layers onto a transparent substrate 20. The partially reflective layer can be formed from a variety of materials that are partially reflective such as various metals, semiconductors, and dielectrics. The partially reflective layer can be formed of one or more layers of materials, and each of the layers can be formed of a single material or a combination of materials.

[0036] In some embodiments, the layers of the optical stack 16 are patterned into parallel strips, and may form row electrodes in a display device as described further below. The movable reflective layers 14a, 14b may be formed as a series of parallel strips of a deposited metal layer or layers (orthogonal to the row electrodes of 16a, 16b) to form columns deposited on top of posts 18 and an intervening sacrificial material deposited between the posts 18. When the sacrificial material is etched away, the movable reflective layers 14a, 14b are separated from the optical stacks 16a, 16b by a defined gap 19. A highly conductive and reflective material such as aluminum may be used for the reflective layers 14, and these strips may form column electrodes in a display device. Note that Figure 1 may not be to scale. In some embodiments, the spacing between posts 18 may be on the order of 10-100 μm , while the gap 19 may be on the order of <1000 Angstroms.

[0037] With no applied voltage, the gap 19 remains between the movable reflective layer 14a and optical stack 16a, with the movable reflective layer 14a in a mechanically relaxed state, as illustrated by the pixel 12a in Figure 1. However, when a potential (voltage) difference is applied to a selected row and column, the capacitor formed at the intersection of the row and column electrodes at the corresponding pixel becomes charged, and electrostatic forces pull the electrodes together. If the voltage is high enough, the movable reflective layer 14 is deformed and is forced against the optical stack 16. A dielectric layer (not illustrated in this Figure) within the optical stack 16 may prevent shorting and control the separation distance between layers 14 and 16, as illustrated by actuated pixel 12b on the right in Figure 1. The behavior is the same regardless of the polarity of the applied potential difference.

[0038] Figures 2 through 5 illustrate one exemplary process and system for using an array of interferometric modulators in a display application.

[0039] Figure 2 is a system block diagram illustrating one embodiment of an electronic device that may incorporate interferometric modulators. The electronic device includes a processor 21 which may be any general purpose single- or multi-chip microprocessor such as an ARM[®], Pentium[®], 8051, MIPS[®], Power PC[®], or ALPHA[®], or any special purpose microprocessor such as a digital signal processor, microcontroller, or a programmable gate array. As is conventional in the art, the processor 21 may be configured to execute one or more software modules. In addition to executing an operating system, the processor may be configured to execute one or more software applications, including a web browser, a telephone application, an email program, or any other software application.

[0040] In one embodiment, the processor 21 is also configured to communicate with an array driver 22. In one embodiment, the array driver 22 includes a row driver circuit 24 and a column driver circuit 26 that provide signals to a display array or panel 30. The cross section of the array illustrated in Figure 1 is shown by the lines 1-1 in Figure 2. Note that although Figure 2 illustrates a 3x3 array of interferometric modulators for the sake of clarity, the display array 30 may contain a very large number of interferometric modulators, and may have a different number of interferometric modulators in rows than in columns (e.g., 300 pixels per row by 190 pixels per column).

[0041] Figure 3 is a diagram of movable mirror position versus applied voltage for one exemplary embodiment of an interferometric modulator of Figure 1. For MEMS interferometric modulators, the row/column actuation protocol may take advantage of a hysteresis property of these devices as illustrated in Figure 3. An interferometric modulator may require, for example, a 10 volt potential difference to cause a movable layer to deform from the relaxed state to the actuated state. However, when the voltage is reduced from that value, the movable layer maintains its state as the voltage drops back below 10 volts. In the exemplary embodiment of Figure 3, the movable layer does not relax completely until the voltage drops below 2 volts. There is thus a range of voltage, about 3 to 7 V in the example illustrated in Figure 3, where there exists a window of applied voltage within which the device is stable in either the relaxed or actuated state. This is referred to herein as the “hysteresis window” or “stability window.” For a display array having the hysteresis characteristics of Figure 3, the row/column actuation protocol can be designed such that during row strobing, pixels in the strobed row that are to be actuated are exposed to a voltage difference of about 10

volts, and pixels that are to be relaxed are exposed to a voltage difference of close to zero volts. After the strobe, the pixels are exposed to a steady state or bias voltage difference of about 5 volts such that they remain in whatever state the row strobe put them in. After being written, each pixel sees a potential difference within the “stability window” of 3-7 volts in this example. This feature makes the pixel design illustrated in Figure 1 stable under the same applied voltage conditions in either an actuated or relaxed pre-existing state. Since each pixel of the interferometric modulator, whether in the actuated or relaxed state, is essentially a capacitor formed by the fixed and moving reflective layers, this stable state can be held at a voltage within the hysteresis window with almost no power dissipation. Essentially no current flows into the pixel if the applied potential is fixed.

[0042] As described further below, in typical applications, a frame of an image may be created by sending a set of data signals (each having a certain voltage level) across the set of column electrodes in accordance with the desired set of actuated pixels in the first row. A row pulse is then applied to a first row electrode, actuating the pixels corresponding to the set of data signals. The set of data signals is then changed to correspond to the desired set of actuated pixels in a second row. A pulse is then applied to the second row electrode, actuating the appropriate pixels in the second row in accordance with the data signals. The first row of pixels are unaffected by the second row pulse, and remain in the state they were set to during the first row pulse. This may be repeated for the entire series of rows in a sequential fashion to produce the frame. Generally, the frames are refreshed and/or updated with new image data by continually repeating this process at some desired number of frames per second. A wide variety of protocols for driving row and column electrodes of pixel arrays to produce image frames may be used.

[0043] Figures 4 and 5 illustrate one possible actuation protocol for creating a display frame on the 3x3 array of Figure 2. Figure 4 illustrates a possible set of column and row voltage levels that may be used for pixels exhibiting the hysteresis curves of Figure 3. In the Figure 4 embodiment, actuating a pixel involves setting the appropriate column to $-V_{\text{bias}}$, and the appropriate row to $+\Delta V$, which may correspond to -5 volts and +5 volts respectively. Relaxing the pixel is accomplished by setting the appropriate column to $+V_{\text{bias}}$, and the appropriate row to the same $+\Delta V$, producing a zero volt potential difference across the pixel. In those rows where the row voltage is held at zero

volts, the pixels are stable in whatever state they were originally in, regardless of whether the column is at $+V_{\text{bias}}$, or $-V_{\text{bias}}$. As is also illustrated in Figure 4, voltages of opposite polarity than those described above can be used, e.g., actuating a pixel can involve setting the appropriate column to $+V_{\text{bias}}$, and the appropriate row to $-\Delta V$. In this embodiment, releasing the pixel is accomplished by setting the appropriate column to $-V_{\text{bias}}$, and the appropriate row to the same $-\Delta V$, producing a zero volt potential difference across the pixel.

[0044] Figure 5B is a timing diagram showing a series of row and column signals applied to the 3x3 array of Figure 2 which will result in the display arrangement illustrated in Figure 5A, where actuated pixels are non-reflective. Prior to writing the frame illustrated in Figure 5A, the pixels can be in any state, and in this example, all the rows are initially at 0 volts, and all the columns are at +5 volts. With these applied voltages, all pixels are stable in their existing actuated or relaxed states.

[0045] In the Figure 5A frame, pixels (1,1), (1,2), (2,2), (3,2) and (3,3) are actuated. To accomplish this, during a “line time” for row 1, columns 1 and 2 are set to -5 volts, and column 3 is set to +5 volts. This does not change the state of any pixels, because all the pixels remain in the 3-7 volt stability window. Row 1 is then strobed with a pulse that goes from 0, up to 5 volts, and back to zero. This actuates the (1,1) and (1,2) pixels and relaxes the (1,3) pixel. No other pixels in the array are affected. To set row 2 as desired, column 2 is set to -5 volts, and columns 1 and 3 are set to +5 volts. The same strobe applied to row 2 will then actuate pixel (2,2) and relax pixels (2,1) and (2,3). Again, no other pixels of the array are affected. Row 3 is similarly set by setting columns 2 and 3 to -5 volts, and column 1 to +5 volts. The row 3 strobe sets the row 3 pixels as shown in Figure 5A. After writing the frame, the row potentials are zero, and the column potentials can remain at either +5 or -5 volts, and the display is then stable in the arrangement of Figure 5A. The same procedure can be employed for arrays of dozens or hundreds of rows and columns. The timing, sequence, and levels of voltages used to perform row and column actuation can be varied widely within the general principles outlined above, and the above example is exemplary only, and any actuation voltage method can be used with the systems and methods described herein.

[0046] Figures 6A and 6B are system block diagrams illustrating an embodiment of a display device 40. The display device 40 can be, for example, a cellular or mobile telephone. However, the same components of display device 40 or slight

variations thereof are also illustrative of various types of display devices such as televisions and portable media players.

[0047] The display device 40 includes a housing 41, a display 30, an antenna 43, a speaker 45, an input device 48, and a microphone 46. The housing 41 is generally formed from any of a variety of manufacturing processes, including injection molding, and vacuum forming. In addition, the housing 41 may be made from any of a variety of materials, including but not limited to plastic, metal, glass, rubber, and ceramic, or a combination thereof. In one embodiment the housing 41 includes removable portions (not shown) that may be interchanged with other removable portions of different color, or containing different logos, pictures, or symbols.

[0048] The display 30 of exemplary display device 40 may be any of a variety of displays, including a bi-stable display, as described herein. In other embodiments, the display 30 includes a flat-panel display, such as plasma, EL, OLED, STN LCD, or TFT LCD as described above, or a non-flat-panel display, such as a CRT or other tube device,. However, for purposes of describing the present embodiment, the display 30 includes an interferometric modulator display, as described herein.

[0049] The components of one embodiment of exemplary display device 40 are schematically illustrated in Figure 6B. The illustrated exemplary display device 40 includes a housing 41 and can include additional components at least partially enclosed therein. For example, in one embodiment, the exemplary display device 40 includes a network interface 27 that includes an antenna 43 which is coupled to a transceiver 47. The transceiver 47 is connected to a processor 21, which is connected to conditioning hardware 52. The conditioning hardware 52 may be configured to condition a signal (e.g. filter a signal). The conditioning hardware 52 is connected to a speaker 45 and a microphone 46. The processor 21 is also connected to an input device 48 and a driver controller 29. The driver controller 29 is coupled to a frame buffer 28, and to an array driver 22, which in turn is coupled to a display array 30. A power supply 50 provides power to all components as required by the particular exemplary display device 40 design.

[0050] The network interface 27 includes the antenna 43 and the transceiver 47 so that the exemplary display device 40 can communicate with one ore more devices over a network. In one embodiment the network interface 27 may also have some processing capabilities to relieve requirements of the processor 21. The antenna 43 is any antenna for transmitting and receiving signals. In one embodiment, the antenna transmits

and receives RF signals according to the IEEE 802.11 standard, including IEEE 802.11(a), (b), or (g). In another embodiment, the antenna transmits and receives RF signals according to the BLUETOOTH standard. In the case of a cellular telephone, the antenna is designed to receive CDMA, GSM, AMPS, W-CDMA, or other known signals that are used to communicate within a wireless cell phone network. The transceiver 47 pre-processes the signals received from the antenna 43 so that they may be received by and further manipulated by the processor 21. The transceiver 47 also processes signals received from the processor 21 so that they may be transmitted from the exemplary display device 40 via the antenna 43.

[0051] In an alternative embodiment, the transceiver 47 can be replaced by a receiver. In yet another alternative embodiment, network interface 27 can be replaced by an image source, which can store or generate image data to be sent to the processor 21. For example, the image source can be a digital video disc (DVD) or a hard-disc drive that contains image data, or a software module that generates image data.

[0052] Processor 21 generally controls the overall operation of the exemplary display device 40. The processor 21 receives data, such as compressed image data from the network interface 27 or an image source, and processes the data into raw image data or into a format that is readily processed into raw image data. The processor 21 then sends the processed data to the driver controller 29 or to frame buffer 28 for storage. Raw data typically refers to the information that identifies the image characteristics at each location within an image. For example, such image characteristics can include color, saturation, and gray-scale level.

[0053] In one embodiment, the processor 21 includes a microcontroller, CPU, or logic unit to control operation of the exemplary display device 40. Conditioning hardware 52 generally includes amplifiers and filters for transmitting signals to the speaker 45, and for receiving signals from the microphone 46. Conditioning hardware 52 may be discrete components within the exemplary display device 40, or may be incorporated within the processor 21 or other components.

[0054] The driver controller 29 takes the raw image data generated by the processor 21 either directly from the processor 21 or from the frame buffer 28 and reformats the raw image data appropriately for high speed transmission to the array driver 22. Specifically, the driver controller 29 reformats the raw image data into a data flow having a raster-like format, such that it has a time order suitable for scanning across the

display array 30. Then the driver controller 29 sends the formatted information to the array driver 22. Although a driver controller 29, such as a LCD controller, is often associated with the system processor 21 as a stand-alone Integrated Circuit (IC), such controllers may be implemented in many ways. They may be embedded in the processor 21 as hardware, embedded in the processor 21 as software, or fully integrated in hardware with the array driver 22.

[0055] Typically, the array driver 22 receives the formatted information from the driver controller 29 and reformats the video data into a parallel set of waveforms that are applied many times per second to the hundreds and sometimes thousands of leads coming from the display's x-y matrix of pixels.

[0056] In one embodiment, the driver controller 29, array driver 22, and display array 30 are appropriate for any of the types of displays described herein. For example, in one embodiment, driver controller 29 is a conventional display controller or a bi-stable display controller (e.g., an interferometric modulator controller). In another embodiment, array driver 22 is a conventional driver or a bi-stable display driver (e.g., an interferometric modulator display). In one embodiment, a driver controller 29 is integrated with the array driver 22. Such an embodiment is common in highly integrated systems such as cellular phones, watches, and other small area displays. In yet another embodiment, display array 30 is a typical display array or a bi-stable display array (e.g., a display including an array of interferometric modulators).

[0057] The input device 48 allows a user to control the operation of the exemplary display device 40. In one embodiment, input device 48 includes a keypad, such as a QWERTY keyboard or a telephone keypad, a button, a switch, a touch-sensitive screen, a pressure- or heat-sensitive membrane. In one embodiment, the microphone 46 is an input device for the exemplary display device 40. When the microphone 46 is used to input data to the device, voice commands may be provided by a user for controlling operations of the exemplary display device 40.

[0058] Power supply 50 can include a variety of energy storage devices as are well known in the art. For example, in one embodiment, power supply 50 is a rechargeable battery, such as a nickel-cadmium battery or a lithium ion battery. In another embodiment, power supply 50 is a renewable energy source, a capacitor, or a solar cell, including a plastic solar cell, and solar-cell paint. In another embodiment, power supply 50 is configured to receive power from a wall outlet.

[0059] In some implementations control programmability resides, as described above, in a driver controller which can be located in several places in the electronic display system. In some cases control programmability resides in the array driver 22. The above-described optimization may be implemented in any number of hardware and/or software components and in various configurations.

[0060] The details of the structure of interferometric modulators that operate in accordance with the principles set forth above may vary widely. For example, Figures 7A-7E illustrate five different embodiments of the movable reflective layer 14 and its supporting structures. Figure 7A is a cross section of the embodiment of Figure 1, where a strip of metal material 14 is deposited on orthogonally extending supports 18. In Figure 7B, the moveable reflective layer 14 of each interferometric modulator is square or rectangular in shape and attached to supports at the corners only, on tethers 32. In Figure 7C, the moveable reflective layer 14 is square or rectangular in shape and suspended from a deformable layer 34, which may comprise a flexible metal. The deformable layer 34 connects, directly or indirectly, to the substrate 20 around the perimeter of the deformable layer 34. These connections are herein referred to as support posts. The embodiment illustrated in Figure 7D has support post plugs 42 upon which the deformable layer 34 rests. The movable reflective layer 14 remains suspended over the gap, as in Figures 7A-7C, but the deformable layer 34 does not form the support posts by filling holes between the deformable layer 34 and the optical stack 16. Rather, the support posts are formed of a planarization material, which is used to form support post plugs 42. The embodiment illustrated in Figure 7E is based on the embodiment shown in Figure 7D, but may also be adapted to work with any of the embodiments illustrated in Figures 7A-7C as well as additional embodiments not shown. In the embodiment shown in Figure 7E, an extra layer of metal or other conductive material has been used to form a bus structure 44. This allows signal routing along the back of the interferometric modulators, eliminating a number of electrodes that may otherwise have had to be formed on the substrate 20.

[0061] In embodiments such as those shown in Figure 7, the interferometric modulators function as direct-view devices, in which images are viewed from the front side of the transparent substrate 20, the side opposite to that upon which the modulator is arranged. In these embodiments, the reflective layer 14 optically shields the portions of the interferometric modulator on the side of the reflective layer opposite the substrate 20, including the deformable layer 34. This allows the shielded areas to be configured and

operated upon without negatively affecting the image quality. For example, such shielding allows the bus structure 44 in Figure 7E, which provides the ability to separate the optical properties of the modulator from the electromechanical properties of the modulator, such as addressing and the movements that result from that addressing. This separable modulator architecture allows the structural design and materials used for the electromechanical aspects and the optical aspects of the modulator to be selected and to function independently of each other. Moreover, the embodiments shown in Figures 7C-7E have additional benefits deriving from the decoupling of the optical properties of the reflective layer 14 from its mechanical properties, which are carried out by the deformable layer 34. This allows the structural design and materials used for the reflective layer 14 to be optimized with respect to the optical properties, and the structural design and materials used for the deformable layer 34 to be optimized with respect to desired mechanical properties.

[0062] In certain embodiments, an array of interferometric modulators may be utilized as a display array in a display module. The array of interferometric modulators may be formed on or over a first surface of a light-transmissive or substantially transparent substrate, and the array may be viewable through a second surface of the substrate opposite the first surface.

[0063] As the interferometric modulator array may be a reflective display, illumination may be provided by a frontlight system configured to allow light to propagate throughout a light-transmissive guiding layer located between the interferometric modulator array and the viewer, typically by means of total internal reflection (TIR), and reflect the light towards the array at multiple locations throughout the frontlight film to provide substantially even illumination across the surface of the array. Light reflected towards the interferometric modulator array may then be interferometrically modulated and reflected back through the light-guiding layer and towards the viewer.

[0064] In certain embodiments, the light-transmissive substrate may serve as the light-guiding layer, and in other embodiments a separate light-guiding layer may be provided. In particular embodiments, as will be discussed in greater detail below, the light-guiding layer may comprise a dedicated frontlight film located on, or over, a surface of the substrate. The light-guiding layer may comprise reflective features either within or adjacent the light-guiding layer to reflect the light towards the interferometric modulator array.

[0065] Figures 8A and 8B illustrate an embodiment of a display module **100** in which the substrate serves as a light-guiding layer. As noted above and described in greater detail below in the specification, a dedicated light-guiding layer may be provided adjacent the substrate in other embodiments. It can be seen in Figure 8A that a display module **100** comprises a substrate **102** which supports an array of interferometric modulators **110** located on the first surface **104** of the substrate. A backplate **112** sealed to the first surface **104** of the substrate **100** overlies and protects the array of interferometric modulators **110**. The array of interferometric modulator **110** is viewable by a viewer through the second surface **106** of the substrate **100**.

[0066] In certain embodiments, the frontlight system comprises a point light source, such as an LED. It will be understood that, although described as a point source, the light source may comprise one or more LEDs or other light sources adjacent one another. Light emitted from the light source may be directed into an edgebar, wherein the edgebar is configured to convert a point light source into a line light source. In Figure 8B, it can be seen that the display module **100** includes a light source in the form of LED **140** positioned adjacent a side surface **126b** of an edgebar **120**.

[0067] An edgebar, such as edgebar **120** of Figures 8A and 8B, may be positioned proximate the light-guiding layer such that light will be reflected from the edgebar into the light-guiding layer, and propagate throughout the light-guiding layer before being reflected towards the interferometric modulator array. Thus, a light source such as an LED or other point light source may be positioned adjacent an entry surface or region of the edgebar so that light emitted from the light source will enter edgebar. An exit surface or region of the edgebar may be positioned adjacent an entry surface of the light-guiding layer or layers so that light can be directed out of the edgebar and into the light-guiding layer.

[0068] In certain embodiments, the edge bar may be positioned to the side of the light-transmissive substrate, and be secured in place via a frame. A front surface adjacent the light-transmissive substrate may thus serve as the exit region of the edge bar, and a surface or portion of a surface orthogonal to the exit surface may serve as the entry region. In a particular embodiment, all or a portion of a side surface (rather than an upper or lower surface) of the edgebar serves as the entry region. A light source in the form of an LED may thus be positioned adjacent the side surface of such an edgebar.

[0069] In the embodiment of Figure 8A, it can be seen that the edgebar **120** of display module **100** is positioned adjacent a side surface **108** of the substrate **102**, which serves as the light-guiding layer. Front surface **124a** of the edgebar **120** is in optical communication with the substrate **102**, such that the front surface **124a** serves as an exit region of the edgebar **120**. The portion of side edgebar surface **126b** adjacent the LED **140** serves as the edgebar entry region.

[0070] Because light from the point light source may enter the edgebar at a wide range of angles, an undesirable amount of light loss may occur when light is not totally internally reflected. As can be seen in Figures 8A and 8B, a reflector such as reflector **130** may be positioned adjacent one or more surfaces of the edgebar which do not serve as entry or exit regions. In particular embodiments, one or more reflectors may be positioned adjacent all or substantially all of such surfaces, so as to minimize light loss from the edgebar.

[0071] A reflector may be provided which covers all or most of the remaining surfaces of the edgebar, and which may extend over at least a portion of the substrate without blocking a portion of the interferometric modulator array. When a side surface of the edgebar serves as the entry region of the edgebar, the reflector may cover at least the upper and lower surfaces of the edgebar, as well as the back surface of the edgebar located opposite the exit surface. Such a reflector may be referred to as a “C-shaped” reflector, although it will be understood that the reflector may also cover the side surface opposite the entry region and light source.

[0072] With respect to Figure 8A, it can be seen that the reflector **130** covers at least a portion of the upper edgebar surface **122a**, the back edgebar surface **124b**, and the lower edgebar surface **122b**, forming a C-shape when seen in cross-section. It can also be seen in Figure 8B that the reflector **130** covers at least a portion of side edgebar surface **126a** as well as a portion of side edgebar surface **126b** which does not serve as the edgebar entry portion.

[0073] The reflector **130** is illustrated as extending partially onto the substrate **102**, but in some embodiments may extend only over the edge bar or may extend over a portion of the substrate **102** larger or smaller than the embodiment of Figure 8, and the upper and lower portions of the reflector **130** may have different lengths. Driver circuitry (not shown) may also be placed on a surface of the display module, and may in certain

embodiments be placed on the same side of the substrate as the interferometric modulator array. As discussed above, a frame (not shown) may in certain embodiments be used to secure the reflector **130** and edgebar **120** in place.

[0074] In the illustrated embodiment, light emitted from the LED **140** enters edgebar **120** through side surface **126b**, and is reflected by components within edgebar **120** through front surface **124a**. Light then propagates through substrate **102**, which serves as the light-guiding layer, until it is reflected towards array **110**. The reflection of the light towards interferometric modulator array **110** may be done by reflective elements located either within the light guiding layer or on or adjacent the upper surface **104** of the light guiding layer. In certain embodiments, an additional layer (not shown) having such reflective elements may be formed on the upper surface **104** of substrate **102**.

[0075] It can be seen that the placement of the edgebar **120** along a side surface **106** of the substrate extends the footprint of the display module **100**. In embodiments such as display modules for electronic devices, it may be desirable to minimize the footprint of the display by modifying the placement of the edgebar **120** and the shape of the reflector **130**.

[0076] Figure 9 is a partial cross-section of an alternate embodiment of a display module **200**. The display module comprises a substrate **102'** having a backplate **112'** secured to a first side **104'** of the substrate **102'** to form a cavity **114'** for protecting an array of interferometric modulators (not shown). An edgebar **120'** is located over a second side **106** of the substrate **102'**, and is positioned adjacent a frontlight film **250** which extends over the second surface **106** of the substrate **102'** at least over a portion of the interferometric modulator array.

[0077] A reflector **230** overlies the edgebar **120'** and extends beyond the back edge **124b'** towards the edge of the substrate **102'**. In contrast to the reflector **130** of Figures 8A-8B, the reflector **230** may be located on a single side of the substrate **102**. The reflector **230** comprises a first substantially planar portion **232** overlying the edgebar **120**, and a second planar portion **234**. It can be seen that the second planar portion **204** is laterally displaced from the edgebar **120'** such that the second planar portion **204** does not overlie the edgebar **120'**, but rather extends over a portion of the substrate **102'** located between the edgebar **120'** and the edge of the substrate. A transition portion **236** which in the illustrated embodiment is curved connects the first planar portion **232** and the second

planar portion **234**. It can be seen that the first planar portion **232** may extend over at least a portion of the frontlight film **250** so as to reflect additional light towards the frontlight film **250**, further minimizing light loss from the edgebar **120'**. In certain embodiments, the first planar portion **232** does not extend to a point where a view of the interferometric modulator array would be obscured.

[0078] The display module **200** may comprise an LED or other light source (not shown in Figure 9) located adjacent a side surface of the edgebar **120'** in a manner similar to that depicted in Figure 8B. Electrical connection with the LED may be provided by a flexible printed circuit (FPC) **242** which may be located over the first planar portion **232** of reflector **230**, and mechanical support for the LED may be provided by a stiffener member **244** overlying the FPC **242**. The LED may thus be suspended beneath the FPC **242** and stiffener **244** such that the LED abuts or is positioned adjacent to a side surface of the edgebar **120'**.

[0079] It can also be seen that, in the illustrated embodiment, a layer **260** of reflective material such as reflective tape is located between the edgebar **120'** and the second surface **106** of the substrate **102'**. The reflective tape serves as a reflector to prevent light loss from the bottom of the edgebar **120'**. In addition, the reflective tape shields driver integrated circuit **270** from light emitted by the LED or escaping from the edgebar **120'**, allowing the IC **270** to be mounted directly on or over the first side **104'** of substrate **102'** adjacent the interferometric modulator array (not shown). This positioning may facilitate the forming of electrical connections between the IC **270** and the interferometric modulator array. In the absence of the underlying reflective tape, light emitted by the LED could interfere with the operation of the IC (e.g., by causing the IC to reset).

[0080] Figure 10 is an exploded assembly view of a display module **300** similar to the module **200** of Figure 9. The display module **300** includes a substrate **102''** having an interferometric modulator array and protective backplate **114''** adhered to the underside of the substrate **102''**. An IC **270'** may be adhered to the underside of the substrate **102''**, along with one end of a flex tape **372** which may comprise printed circuitry or other electrical connections for interfacing with external components. Adhesive layers **380a** and **380b** may be provided to secure certain elements in place

during the assembly process. An opaque film **382** may be provided in order to shield the IC **270'** from stray light.

[0081] Overlying the substrate **102** are frontlight film **250'** and reflective tape **260'**, and a protective film **390** may be formed over the frontlight film **250'** and reflective tape **260'**. In certain embodiments, the protective film **390** may comprise a layer which can be removed after assembly of the display module. In such an embodiment, the protective film **390** may not underlie any other components of the display module **300** which would inhibit removal of the film.

[0082] An edgebar subassembly **320**, comprising an edgebar and a reflector overlies the reflective tape **260'**. In the illustrated embodiment, the edgebar subassembly **320** comprises an edgebar secured to a reflector via a heat stake. The edgebar subassembly is discussed in greater detail below. An LED subassembly **340** comprising a stiffener **244'** and an LED flexible printed circuit **242'** may support an underlying LED (not shown). The assembled module may be secured within a protective frame **392**.

[0083] Figures 11A–11C are various views of a reflector **330** used in the edgebar subassembly **320** of Figure 10. The reflector **330** comprises a first planar portion **402** configured to overlie an edgebar, and a second planar portion **404** configured to be positioned adjacent the edgebar. The first planar portion **402** is connected to the second planar portion **404** by a transition portion **406** which extends in a direction generally upward from the second planar portion **404** to the first planar portion **402**. As can best be seen in Figure 11C, the transition portion **406** in the illustrated embodiment comprises curved portions where the transition portion **406** meets the first planar portion **402** and the second planar portion **404**.

[0084] The reflector **330** also comprises tabs extending generally downward from the sides of the first planar portion **402**. In particular, it can be seen that a first side **418a** of the first planar portion **402** comprises a tab **410** extending downward from the second planar portion from a position adjacent the transition portion **406**, whereas the opposite side **418b** of the first planar portion **402** comprises a tab **412** spaced apart from the transition region **406**. Opposite tab **412** on side **418b** is an open area **414** extending between the transition region and the edge of downwardly extending tab **412**. This open area **414** allows an LED or other light source to be positioned adjacent an edgebar retained within reflector **330** so as to emit light into the edgebar.

[0085] It will be understood that the particular configuration of reflector **330** is an exemplary configuration, and that the configuration of reflector **330** can be varied in a variety of ways. For example, in other embodiments side **418a** of the reflector **330** may comprise a longer downwardly extending tab or a pair of downwardly extending tabs, rather than the single downwardly extending tab **410** located adjacent transition region **406** depicted in Figures 11A-11C. In other embodiments, no tab **412** may be located on side **418b** of the reflector **330**.

[0086] Reflector **330** also comprises an aperture **416** extending through the first planar portion. This aperture **416** can be used to secure an edgebar relative to the reflector **330**. Figure 12 depicts an edgebar **420** suitable for use with reflector **330**. As can be seen, the edgebar **420** comprises an upwardly extending portion **422**. At least the upwardly extending portion **422** of edgebar **420** comprises a material which is deformable when heated. The edgebar **420** also includes a tab **424** extending from a side portion of the edgebar **420**.

[0087] Figures 13A-13C illustrate various views of an edgebar assembly **320** in which an edgebar **420** is secured relative to a reflector **330**. In particular, Figure 13A illustrates in perspective an exploded assembly view of edgebar assembly **320**, in which it can be seen that the edgebar assembly **320** comprises a reflector **330** overlying an edgebar **420** and an adhesive layer **322**. The first planar portion **402** of reflector **330** overlies the edgebar **330**, and the adhesive layer **322** underlies the second planar portion **402**. By adhering the second planar portion **404** to an underlying layer, the reflector **330** can be fixedly coupled to the underlying layers, constraining the first planar portion **402** and the edgebar **420** secured beneath the first planar portion **402** without the need to directly adhere the edgebar **420** to any underlying layers.

[0088] It can also be seen that the upwardly extending portion of edgebar **420** has been deformed after heating such that it flattens and extends outward. Although depicted in an exploded view, this deformation may occur after the upwardly extending portion **422** (see Figure 12) is inserted through aperture **419** in the first planar portion **402** of reflector **330** (see Figure 11A). The upwardly extending portion may then deform outward to a size greater than that of the aperture **419**, forming heat stake **422a** and securing the edgebar **420** relative to the reflector **330**.

[0089] In Figure 13B it can be seen that the space **414** along side **418b** of reflector **330** is dimensioned to permit side surface **426** of edgebar **420** to extend into space **414** such that side surface **426** is exposed. As discussed above, an LED or other light source may be positioned adjacent the side surface **426** to permit light from the LED to enter edgebar **426**.

[0090] In Figure 13C it can be seen that the tab **424** extending from the other side surface of edgebar **420** may be configured to interact with downwardly extending tab **410** of reflector **330** to hold the edgebar in place. It can also be seen that the edgebar **420** comprises a front surface **428** which will face the frontlight film (not shown) through which light will exit after being directed towards the front surface **428**.

[0091] In certain embodiments, a reflector such as reflector **330** may comprise a reflective material, such as stainless steel, although a wide variety of other reflective materials or materials coated with a reflective coating may be used. In an embodiment in which the reflector comprises stainless steel, the reflectivity of the reflector may be maintained or increased through an electropolishing process. In certain embodiments, the reflector may be shaped by a stamping process, although a variety of other manufacturing processes may be used.

[0092] In certain embodiments, the edgebar need not abut a facing surface of the reflector along the length of a particular side. Rather, the edgebar may abut the reflector at least at a few points sufficient to hold the edgebar in place, but may be spaced apart from the reflector at other points. By spacing the edgebar at least slightly apart from the interior surfaces of the reflector at certain points, total internal reflection of light incident upon those portions of the edgebar may be maintained, reducing light loss which could occur if the light were to be partially absorbed by the reflector.

[0093] Figures 14A-14C depict the LED FPC subassembly **340** of Figure 10. In particular, Figure 14A illustrates in perspective an exploded assembly view of the LED subassembly **340**. The LED subassembly **340** comprises a stiffener **244'**, an LED flexible printed circuit **242'**, and an LED **140'**. The LED subassembly **340** also includes an adhesive layer **342a** configured to adhere the stiffener **244'** to the LED FPC **242'**, and an adhesive layer **342b** configured to adhere the LED subassembly **340** to an underlying structure such as an edgebar subassembly. An adhesive region **342c** may also be provided to secure an outwardly extending portion **243** of LED FPC **242'** in place. As can be seen

in Figure 14C, the outwardly extending portion **243** may comprise connectors in the form of anode **344a** and cathode **344b** for forming an electrical connection with LED **140'**.

[0094] In the illustrated embodiment, the stiffener **244'** comprises a longitudinally extending portion **246** extending substantially parallel to the edgebar (not shown) when the LED FPC subassembly is adhered or otherwise secured to an underlying reflector subassembly. The stiffener **244** also includes a laterally extending portion **247** on the side of the stiffener **244'** where the LED **140'** will be attached. In the illustrated embodiment, the longitudinally extending portion **246** is substantially longer than the laterally extending portion **247**, but it will be understood that in other embodiments, the length of either of portions **246** and **247** may be altered, and that in other embodiments, the stiffener **244'** may take a different shape, such as a substantially rectangular shape.

[0095] Because the stiffener **244'** may be selected only on the basis of its mechanical properties, such as stiffness, a wide variety of materials may be used, including materials which are not reflective or not highly reflected. In one embodiment, the stiffener **244'** may comprise stainless steel, but other suitable materials may be used. It will also be understood that depending on the material and thickness of the stiffener **244'**, the size and shape of the stiffener may be altered.

[0096] It will be understood that various combinations of the above embodiments are possible. It is also to be recognized that, depending on the embodiment, the acts or events of any methods described herein can be performed in other sequences, may be added, merged, or left out altogether (e.g., not all acts or events are necessary for the practice of the methods), unless the text specifically and clearly states otherwise.

[0097] For example, in certain embodiments, a reflector may comprise a first planar portion overlying an edgebar and a second planar portion displaced from the edgebar in a direction parallel to the edgebar, such that the second planar portion is located opposite a point source, and the second planar portion and the light source are located on opposite sides of the edgebar. In other embodiments, the substrate may be optically opaque, such that the IMODs are formed on the surface **106'** in Figure 9 and the backplate **112'** is of optically transparent material, so that the IMODs are viewed through the backplate **112'** (ie, it may be better to refer to the plate **112'** as a frontplate in such embodiments). The frontplate **112'** is attached to the surface **106'** and is interposed between the frontlight and the substrate. Other alterations to the above description are possible.

[0098] While the above detailed description has shown, described, and pointed out novel features of the invention as applied to various embodiments, it will be understood that various omissions, substitutions, and changes in the form and details of the device or process illustrated may be made by those skilled in the art without departing from the spirit of the invention. As will be recognized, the present invention may be embodied within a form that does not provide all of the features and benefits set forth herein, as some features may be used or practiced separately from others.

WHAT IS CLAIMED IS:

1. A display module, comprising:
 - a light-transmissive substrate comprising a first surface and a second surface;
 - an edgebar in optical communication with a light source, wherein the edgebar is located over the first surface of the substrate;
 - a frontlight film adjacent the edgebar and in optical communication with the edge bar, wherein the frontlight film is configured to direct light through the light-transmissive substrate; and
 - a reflector, the reflector comprising a first substantially planar portion overlying the edgebar and a second substantially planar portion located over the first surface of the substrate and laterally displaced from the edgebar.
2. The display module of Claim 1, wherein the edgebar comprises a front surface facing a side surface of the frontlight film and a second surface oriented substantially orthogonally to the front surface.
3. The display module of Claim 2, wherein the first planar portion of the reflector extends over the front surface of the edgebar.
4. The display module of Claim 3, wherein the first planar portion of the reflector is oriented substantially orthogonally to the front surface of the edgebar.
5. The display module of Claim 2, further comprising a light source located adjacent the second surface of the edgebar and configured to emit light into the edgebar.
6. The display module of Claim 5, wherein the light source comprises at least one LED.
7. The display module of Claim 6, wherein said at least one LED is supported by a stiffener which extends over at least a portion of the first planar portion of the reflector.
8. The display module of Claim 1, wherein the reflector comprises at least one aperture extending therethrough, and wherein the edgebar comprises a connector portion which extends through said aperture.
9. The display module of Claim 8, wherein the connector portion comprises a distal section located on the opposite side of the reflector from the remainder of the edgebar, and wherein at least a portion of the distal section has a cross-sectional size which is larger than the cross-sectional size of the aperture.

10. The display module of Claim 8, wherein the connector portion comprises a heat stake.

11. The display module of Claim 1, further comprising a layer of reflective material located between the edgebar and the substrate.

12. The display module of Claim 11, further comprising a driver IC located over the second surface of the substrate, wherein the layer of reflective material is disposed between the edgebar and the driver IC.

13. The display module of Claim 1, further comprising a display array disposed over the second surface of the substrate, wherein the display array is positioned opposite the frontlight film.

14. The display module of Claim 13, wherein the display array comprises an array of interferometric modulators.

15. The display module of Claim 13, further comprising:
a processor that is configured to communicate with said display array, said processor being configured to process image data; and
a memory device that is configured to communicate with said processor.

16. The display module of Claim 15, further comprising a driver circuit configured to send at least one signal to said display array.

17. The display module of Claim 16, further comprising a controller configured to send at least a portion of said image data to said driver circuit.

18. The display module of Claim 15, further comprising an image source module configured to send said image data to said processor.

19. The display module of Claim 18, wherein said image source module comprises at least one of a receiver, transceiver, and transmitter.

20. The display module of Claim 15, further comprising an input device configured to receive input data and to communicate said input data to said processor.

21. An edgebar subassembly configured for use in a display module, the edgebar subassembly comprising:

an edgebar configured to receive light through a first surface and reflect light through a second surface orthogonal to said first surface; and

a reflector configured to retain the edgebar, the reflector comprising:

a first substantially planar portion configured to overlie the edgebar; and

a second substantially planar portion configured to be adhered to an underlying layer;

wherein a lower surface of the second substantially planar portion is substantially coplanar with a lower surface of the edgebar, and the edgebar is retained by the reflector.

22. The edgebar subassembly of Claim 21, wherein the second planar portion of the reflector is laterally displaced with respect to the edgebar.

23. The edgebar subassembly of Claim 21, wherein the lower surface of the edgebar is substantially orthogonal to each of the first and second surfaces of the edgebar.

24. The edgebar subassembly of Claim 21, wherein the reflector comprises an aperture extending through the reflector, additionally comprising a heat stake extending from the edgebar through said aperture to retain the edgebar relative to the reflector.

25. A method of assembling a display module, comprising:

providing a substrate having a first and second surface, the substrate comprising a display array formed over said first surface and a light-guiding layer located over said second surface, wherein the light-guiding layer is located opposite the display array;

positioning an edgebar relative to the substrate such that a first surface of the edgebar is positioned adjacent a side surface of the light-guiding layer; and

providing a reflector over said first surface of the substrate such that the reflector retains the edgebar in place, the reflector comprising a first substantially planar portion overlying the edgebar and a second substantially planar portion displaced from the edgebar and adhered to an underlying layer.

26. The method of Claim 25, additionally comprising forming a reflective layer over the first surface of the substrate prior to securing the reflector over the first surface of the substrate, wherein the reflective layer is disposed between the edgebar and the substrate.

27. The method of Claim 25, additionally comprising positioning a light source adjacent to a second surface of the edgebar, wherein the second surface of the edgebar is substantially orthogonal to the first surface of the edgebar.

28. The method of Claim 27, wherein positioning a light source adjacent to a second surface of the edgebar comprises adhering an LED subassembly to an upper

surface of the first planar portion of the reflector, wherein the LED subassembly comprises:

- at least one LED;
- a flexible circuit board in electrical communication with the LED; and
- a stiffener overlying the flexible circuit board.

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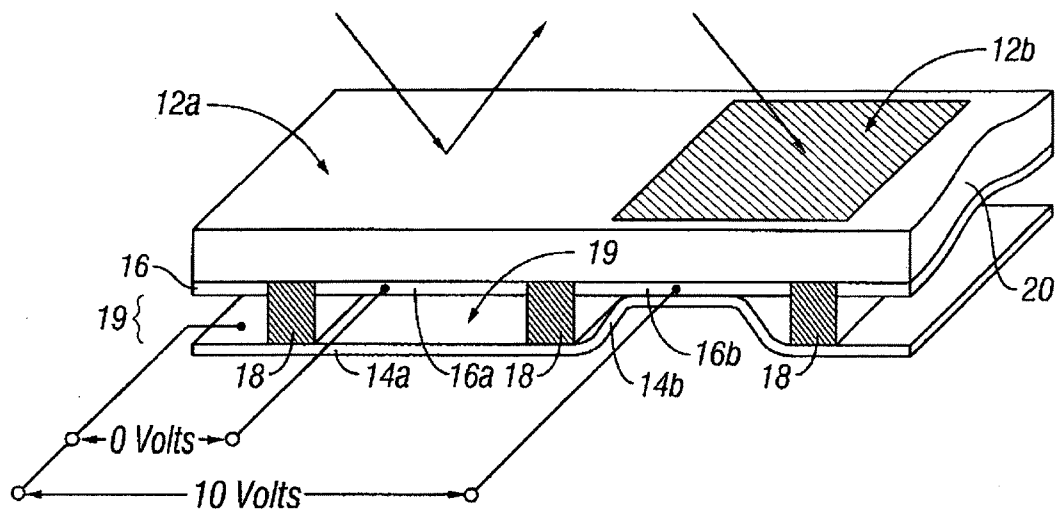


FIG. 1

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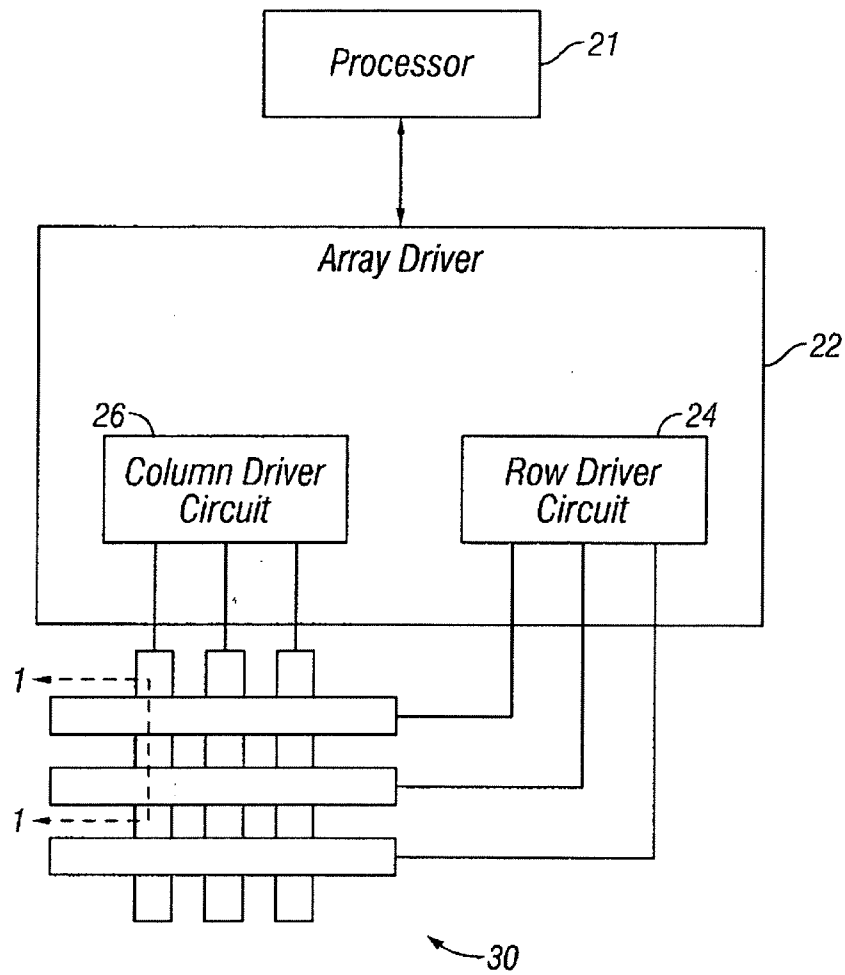


FIG. 2

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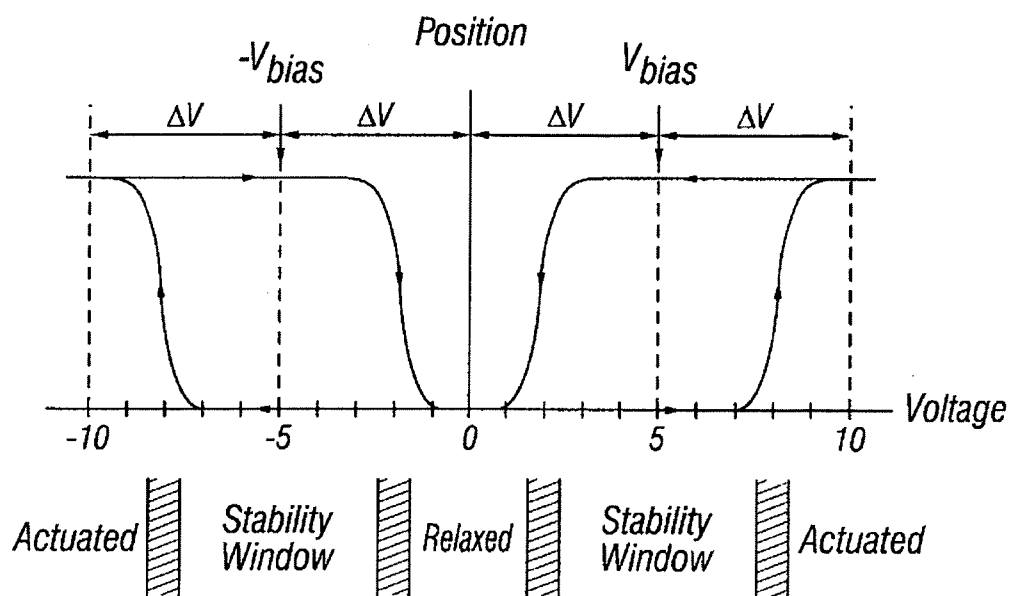


FIG. 3

		Column Output Signals	
		$+V_{bias}$	$-V_{bias}$
Row Output Signals	0	Stable	Stable
	$+\Delta V$	Relax	Actuate
	$-\Delta V$	Actuate	Relax

FIG. 4

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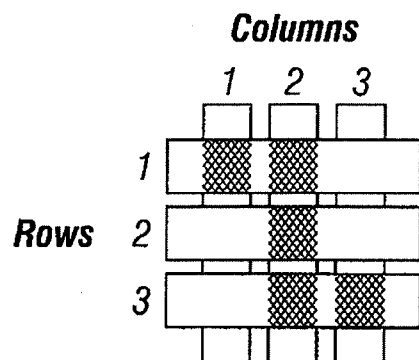


FIG. 5A

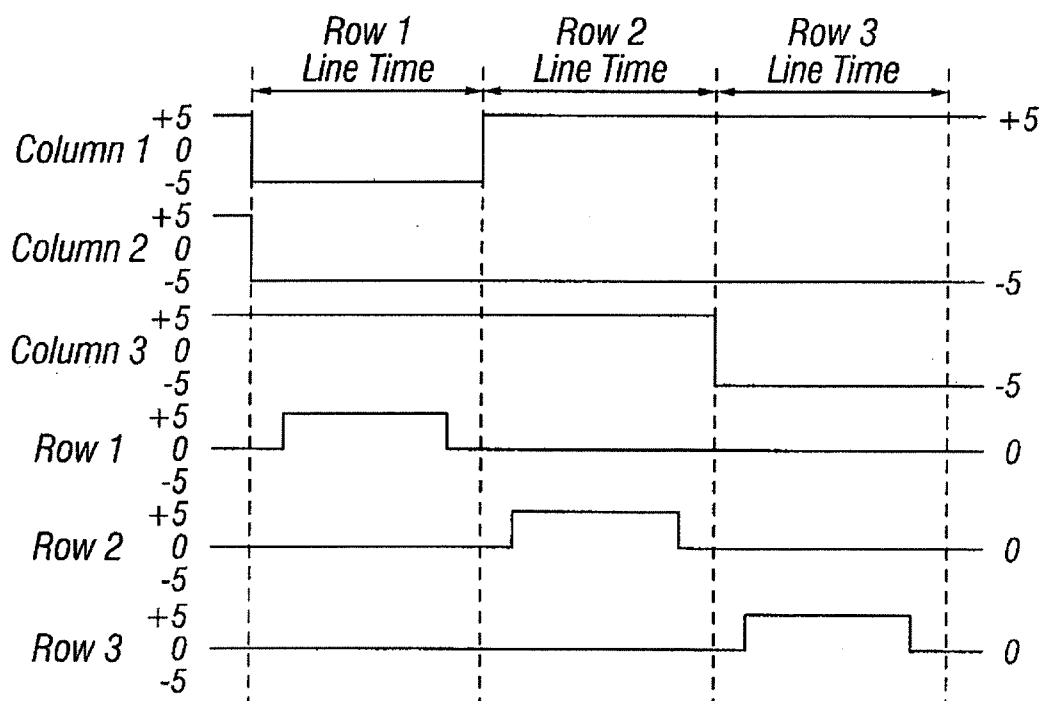


FIG. 5B

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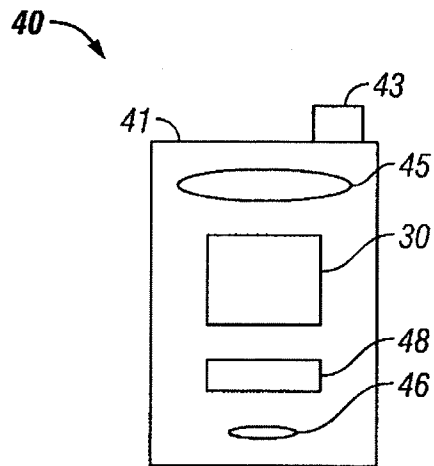


FIG. 6A

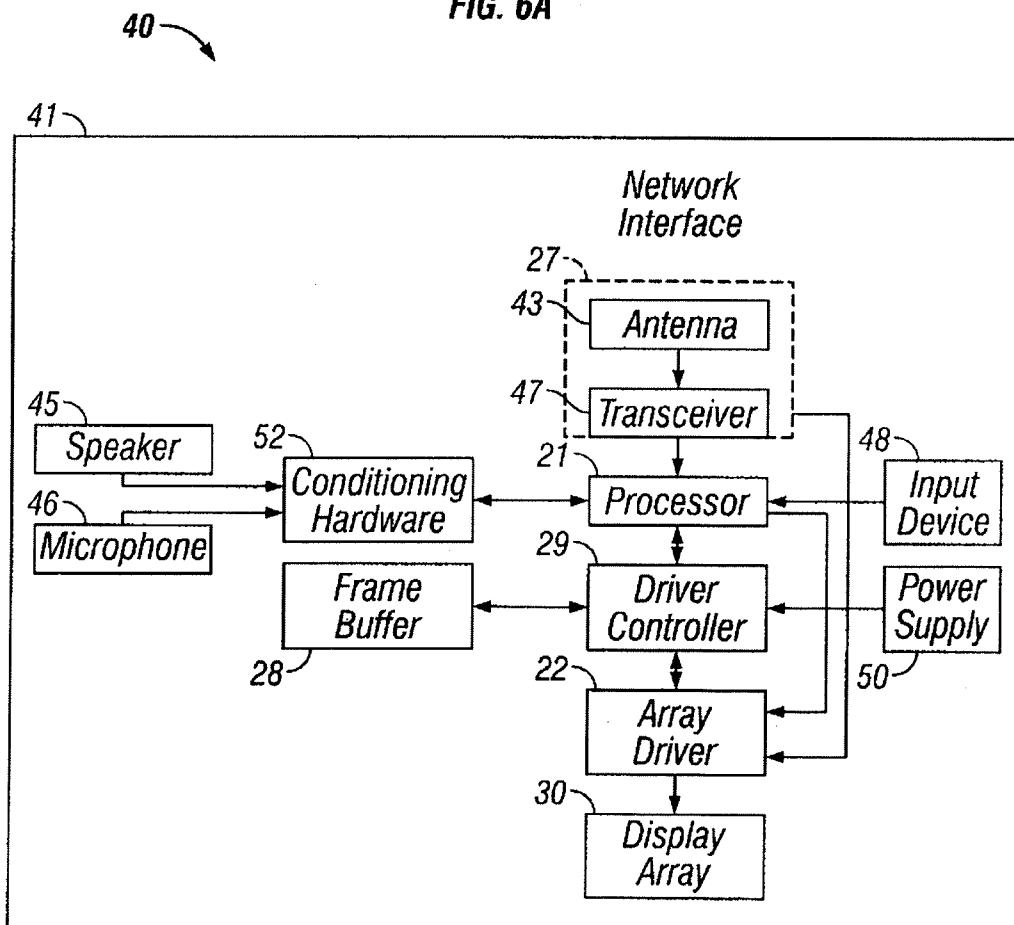


FIG. 6B

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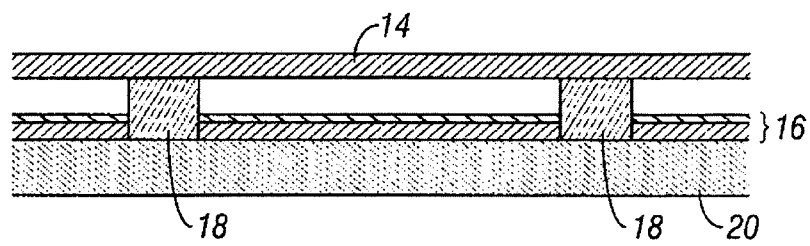


FIG. 7A

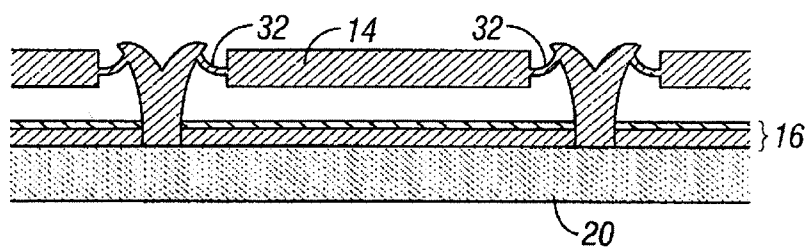


FIG. 7B

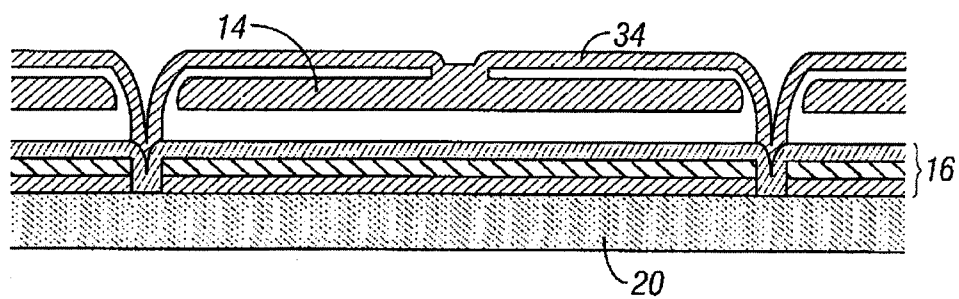


FIG. 7C

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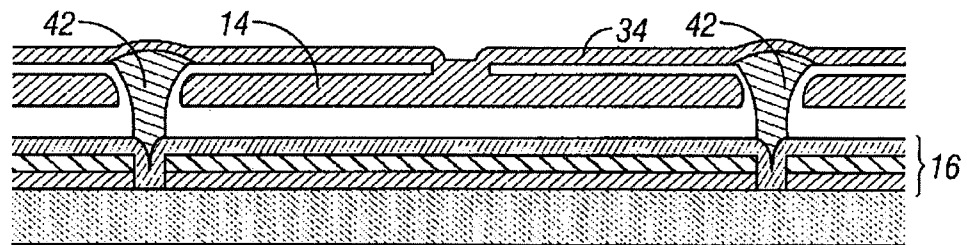


FIG. 7D

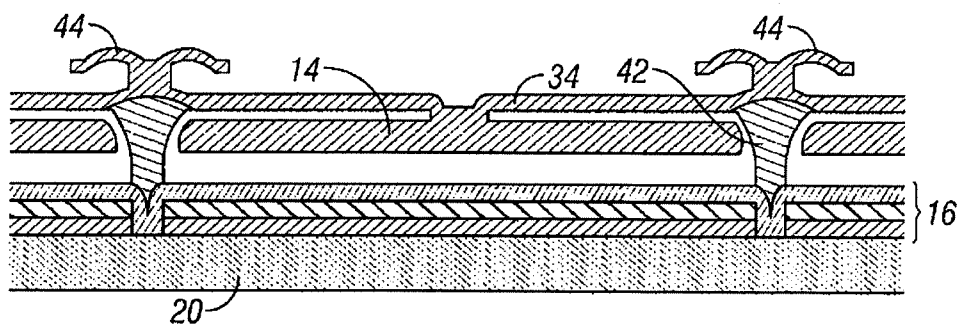


FIG. 7E

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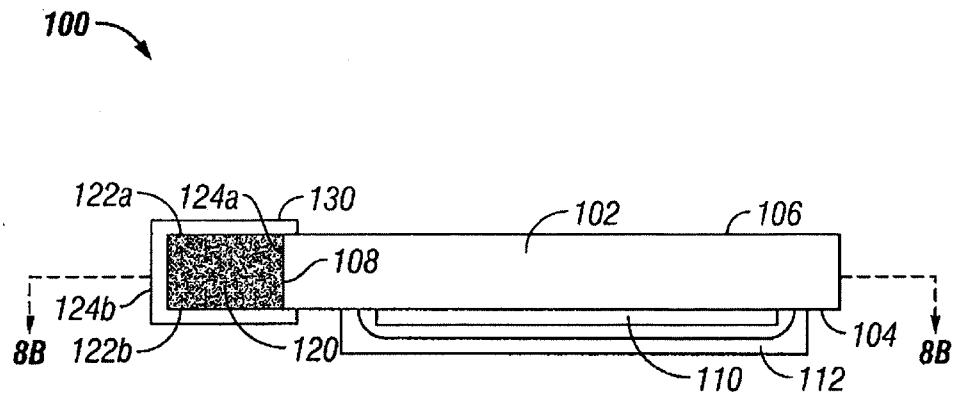


FIG. 8A

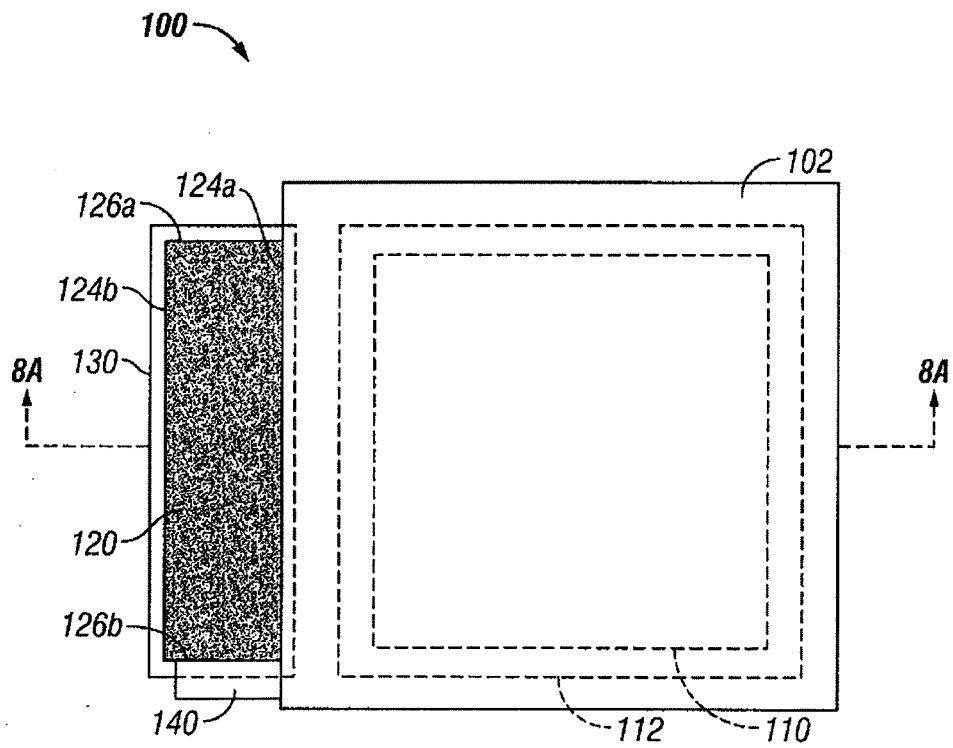


FIG. 8B

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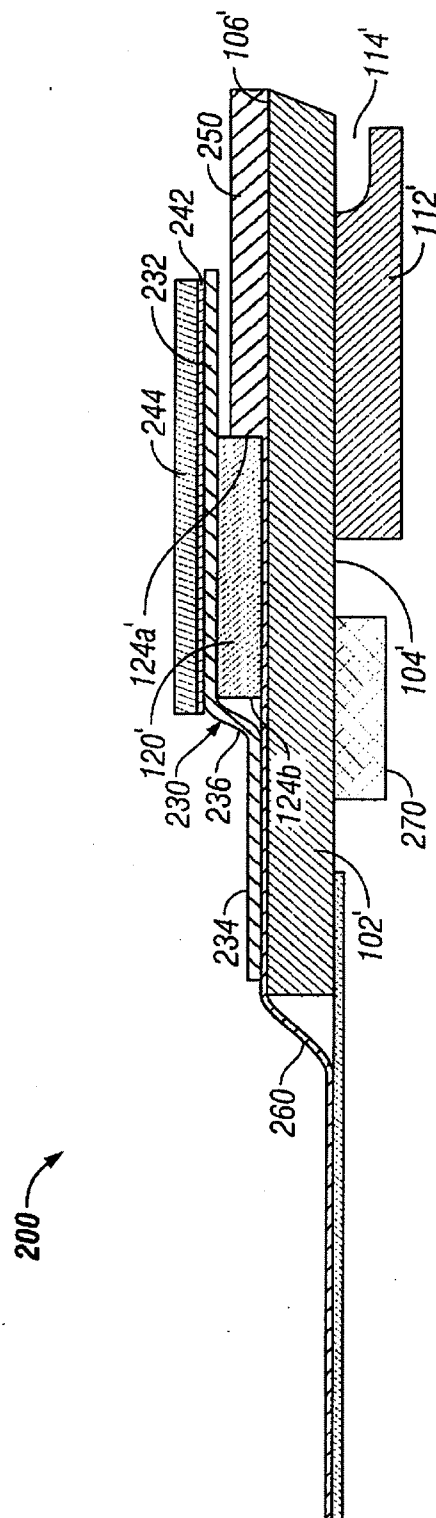


FIG. 9

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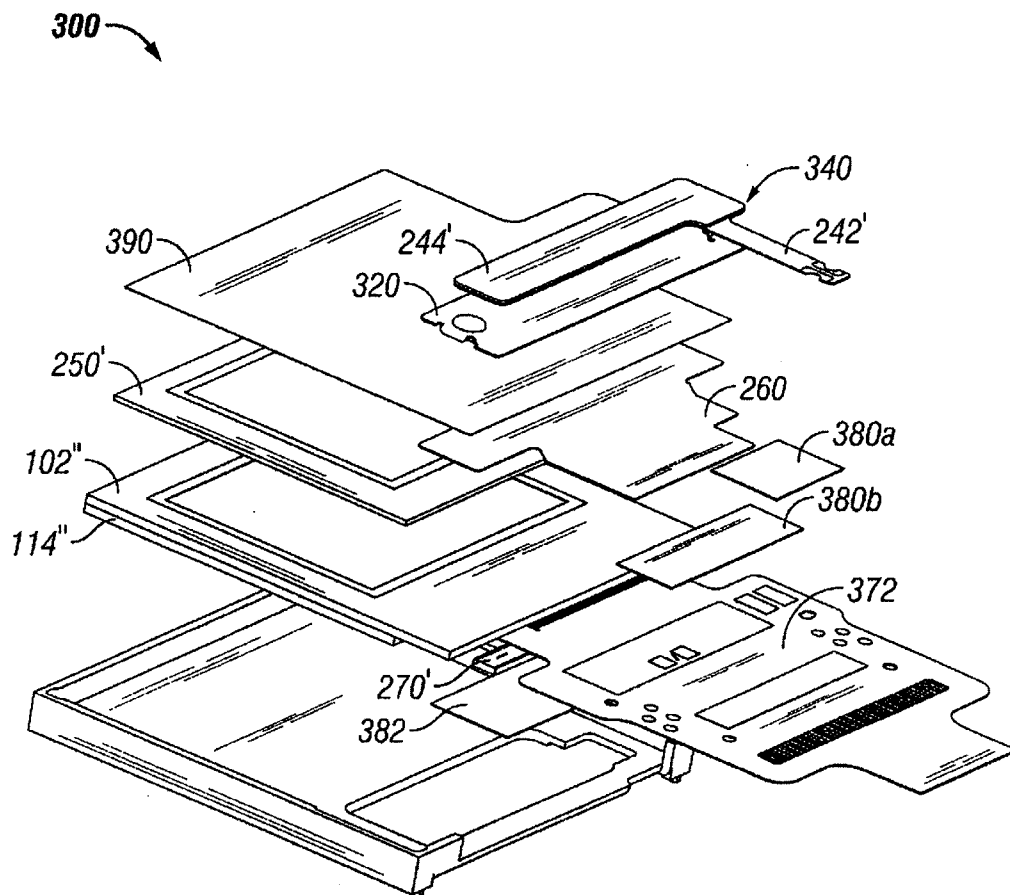


FIG. 10

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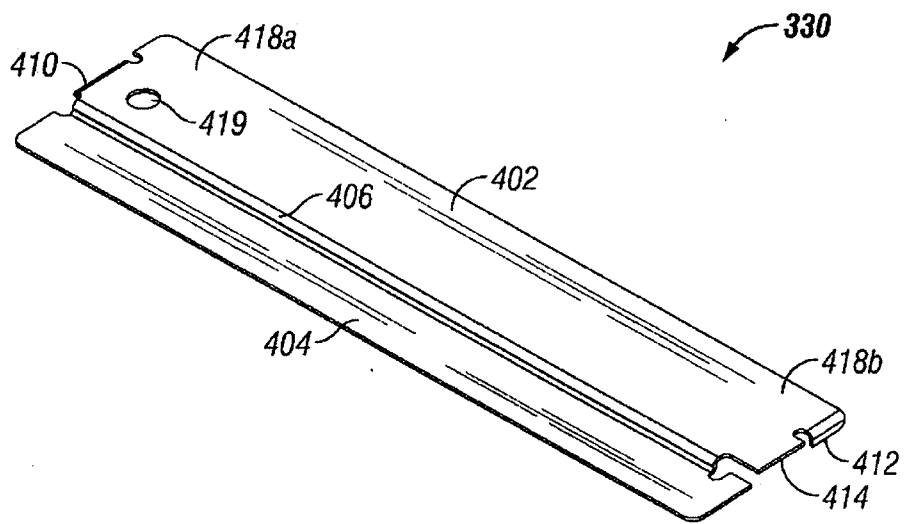


FIG. 11A

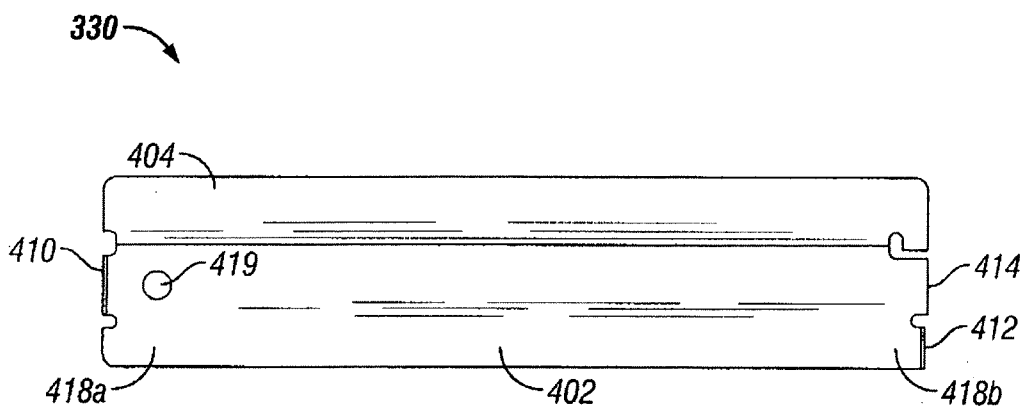


FIG. 11B

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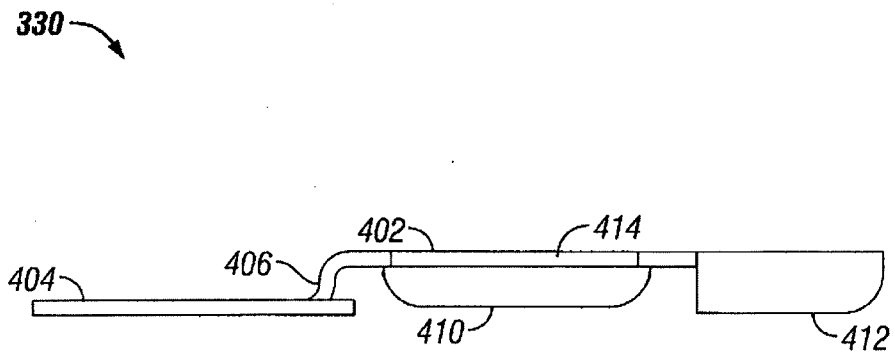


FIG. 11C

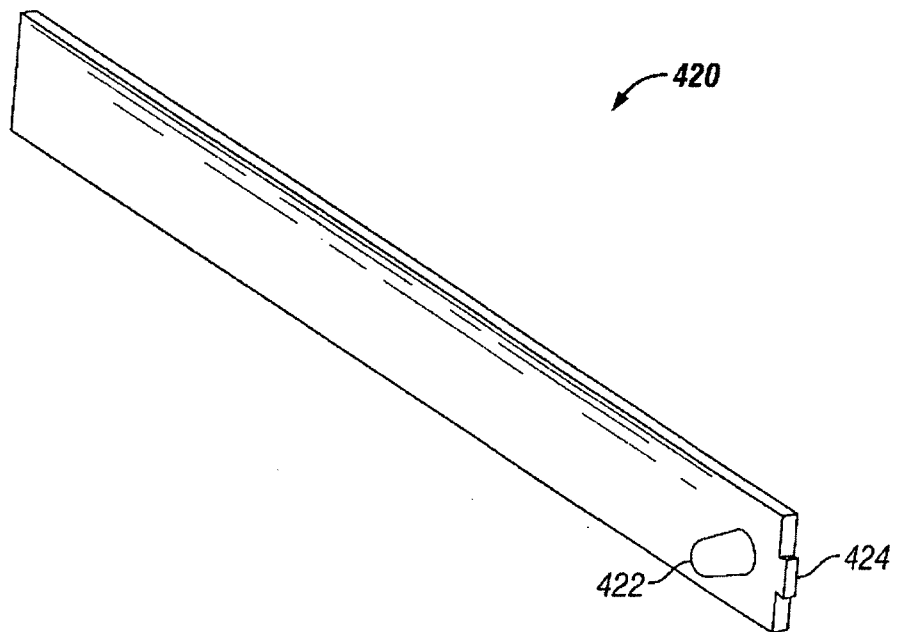


FIG. 12

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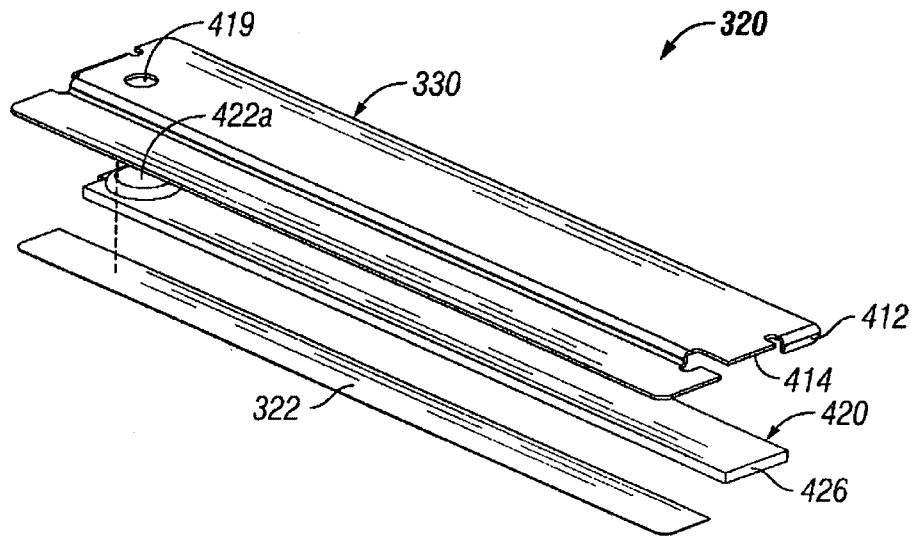


FIG. 13A

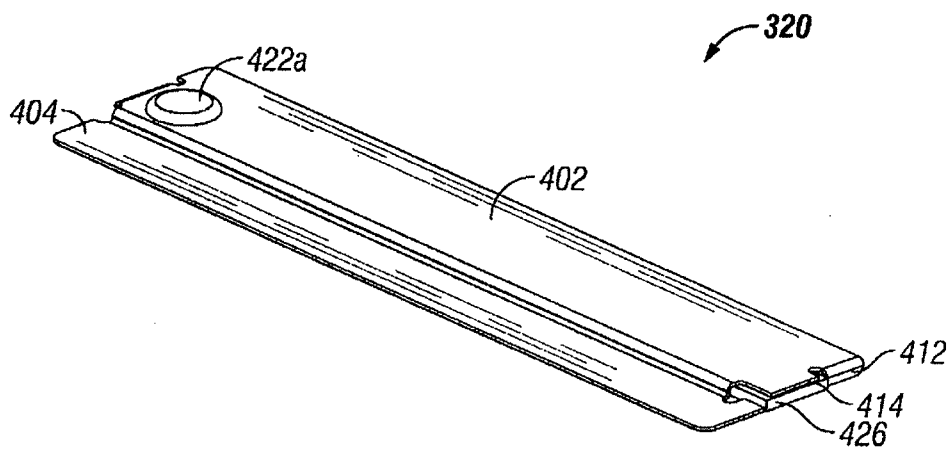


FIG. 13B

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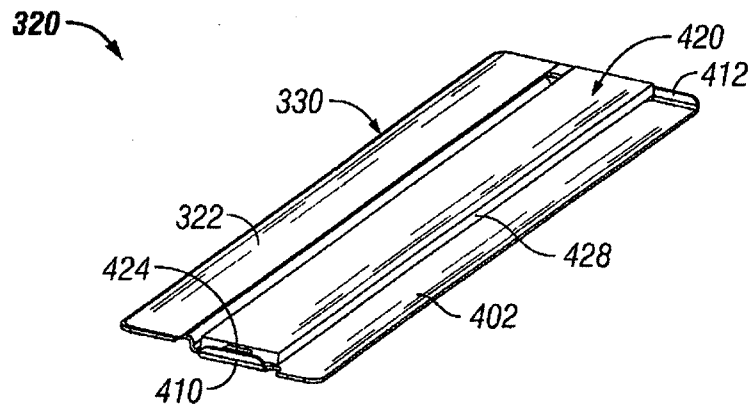


FIG. 13C

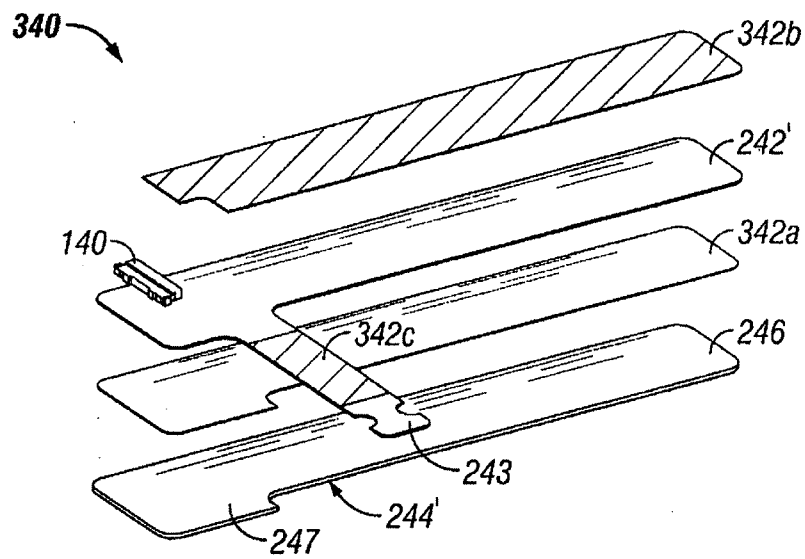


FIG. 14A

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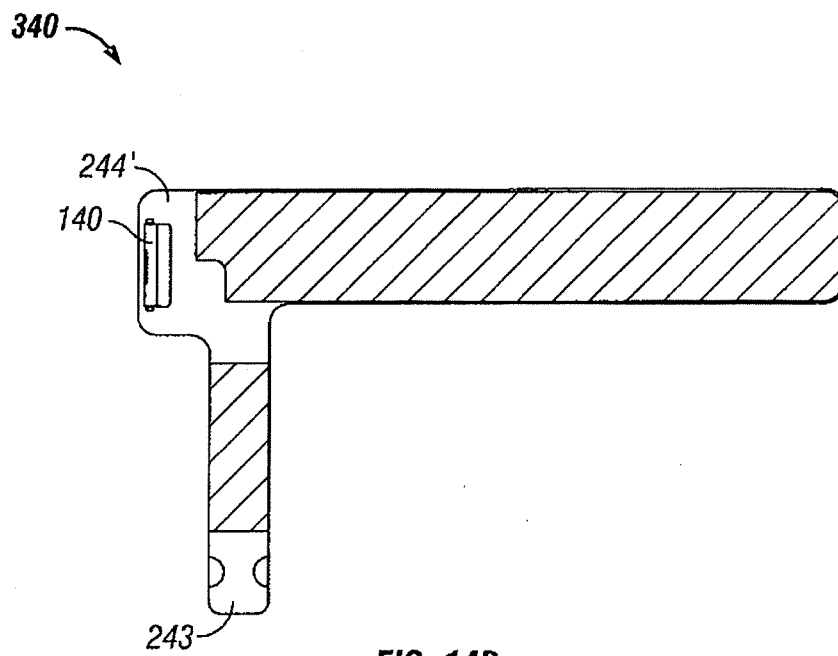


FIG. 14B

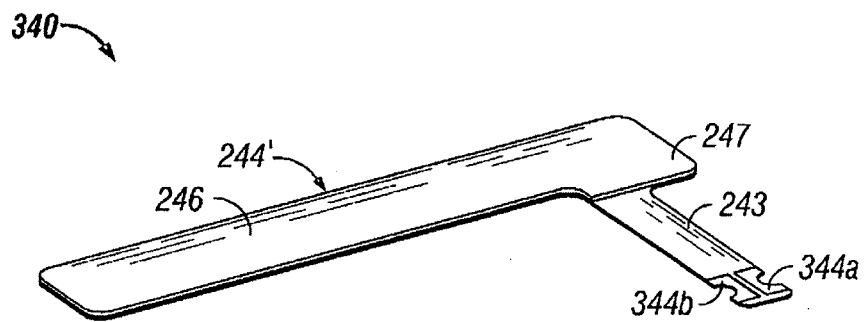


FIG. 14C

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2010/021678

A. CLASSIFICATION OF SUBJECT MATTER

INV. G02B6/00 G02B26/00 G02F1/13357
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/109686 A1 (SUGIURA TAKURO [JP]) 25 May 2006 (2006-05-25)	1-13, 21-28
Y	paragraphs [0019] - [0033]; figures 2,8 -----	14-20
A	US 6 431 716 B1 (KUSAKABE KIYOSHI [JP]) 13 August 2002 (2002-08-13) column 6, line 35 - column 7, line 35; figure 2 -----	1-28
Y	US 2008/084602 A1 (XU GANG [US] ET AL) 10 April 2008 (2008-04-10) paragraphs [0060] - [0064] -----	14-20
X	US 2005/213346 A1 (KAO KO-CHIA [TW] ET AL) 29 September 2005 (2005-09-29) paragraphs [0006], [0007]; figure 1 ----- -/--	1



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

15 April 2010

Date of mailing of the international search report

21/04/2010

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2010/021678

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	EP 0 895 274 A1 (SHARP KK [JP]; IDEMITSU KOSAN CO [JP]) 3 February 1999 (1999-02-03) paragraphs [0051] - [0053] -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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