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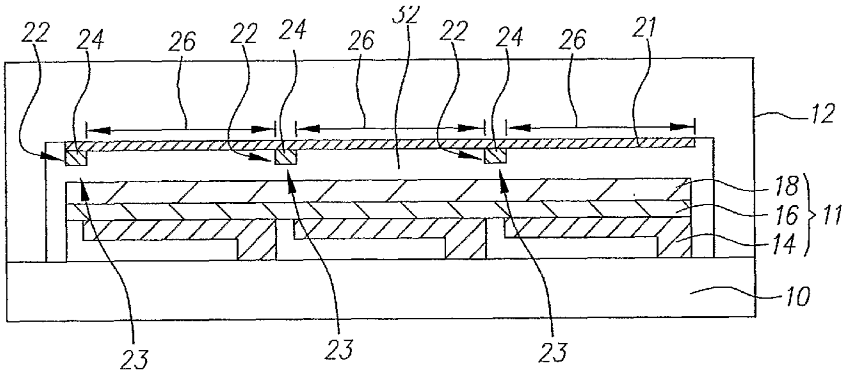

(57) Abstract: An organic light -emit ting diode (OLED) device, comprising: a substrate (10) ; one or more OLEDs (11) formed on the substrate (10) comprising a first electrode (14) formed over the substrate (10), one or more layers of organic material (16), one of which emits light, formed over the first electrode (14), and a second electrode (18) formed over the one or more layers of organic material (16) ; a cover (12) provided over the OLBDs (11) and spaced apart from the OLEDs (11) to form a gap (32) ; and one or more color filter elements (21) located in the gap (32) to filter the light; wherein at least portions of one color filter element (21) or layered combinations of two or more color filter elements (21) form spacer elements (24) having a thickness greater than the thickness of at least another portion of a color filter element (21) located in the gap (32).

WO 2007/002097 A1

OLED DEVICE HAVING SPACERS

FIELD OF THE INVENTION

The present invention relates to organic light-emitting diode (OLED) devices, and more particularly, to OLED device structures for improving light output, improving robustness, and reducing manufacturing costs.

BACKGROUND OF THE INVENTION

Organic light-emitting diodes (OLEDs) are a promising technology for flat-panel displays and area illumination lamps. The technology relies upon thin-film layers of materials coated upon a substrate and employing an encapsulating cover affixed to the substrate around the periphery of the OLED device. The thin-film layers of materials can include, for example, organic materials, electrodes, conductors, and silicon electronic components as are known and taught in the OLED art. The cover includes a cavity to avoid contacting the cover to the thin-film layers of materials when the cover is affixed to the substrate.

OLED devices generally can have two formats known as small molecule devices such as disclosed in U.S. Patent No. 4,476,292 and polymer OLED devices such as disclosed in U.S. Patent No. 5,247,190. Either type of OLED device may include, in sequence, an anode, an organic electroluminescent (EL) element, and a cathode. The organic EL element disposed between the anode and the cathode commonly includes a plurality of organic layers such as an organic hole-transporting layer (HTL), an emissive layer (EML) and an organic electron-transporting layer (ETL). Holes and electrons recombine and emit light in the EML layer. Tang et al. (Appl. Phys. Lett., 51, 913 (1987), Journal of Applied Physics, 65, 3610 (1989), and U.S. Patent No. 4,769,292) demonstrated highly efficient OLEDs using such a layer structure. Since then, numerous OLEDs with alternative layer structures, including polymeric materials, have been disclosed and device performance has been improved.

Light is generated in an OLED device when electrons and holes that are injected from the cathode and anode, respectively, flow through the electron transport layer and the hole transport layer and recombine in the emissive layer. Many factors determine the efficiency of this light generating process. For example, the selection of anode and cathode materials can determine how efficiently the electrons and holes are injected into the device; the selection of ETL and HTL can determine how efficiently the electrons and holes are transported in the device, and the selection of EML materials can determine how efficiently the electrons and holes be recombined and result in the emission of light, etc. It has been found, however, that one of the key factors that limits the efficiency of OLED devices is the inefficiency in extracting the photons generated by the electron-hole recombination out of the OLED devices. Due to the high optical indices of the organic materials used, most of the photons generated by the recombination process are actually trapped in the devices due to total internal reflection. These trapped photons never leave the OLED devices and make no contribution to the light output from these devices.

A typical OLED device uses a glass substrate, a transparent conducting anode such as indium-tin-oxide (ITO), a stack of organic layers, and a reflective cathode layer. Light generated from the device is emitted through the glass substrate. This is commonly referred to as a bottom-emitting device. Alternatively, a device can include a substrate, a reflective anode, a stack of organic layers, and a top transparent cathode layer. Light generated from the device is emitted through the top transparent electrode. This is commonly referred to as a top-emitting device. In these typical devices, the refractive index of the ITO layer, the organic layers, and the glass is about 1.9, 1.7, and 1.5 respectively. It has been estimated that nearly 60% of the generated light is trapped by internal reflection in the ITO/organic EL element, 20% is trapped in the glass substrate, and only 20% of the generated light is actually emitted from the device and performs useful functions.

OLED devices can employ a variety of light-emitting organic materials patterned over a substrate that emit light of a variety of different frequencies, for example red, green, and blue, to create a full-color display. Alternatively, it is known to employ an unpatterned broad-band emitter, for example white, together with patterned color filters, for example red, green, and blue, to create a full-color display. The color filters may be located on the substrate, for a bottom-emitter, or on the cover, for a top-emitter. For example, U.S. Patent 6,392,340 entitled "Color Display Apparatus having Electroluminescence Elements" issued May 21, 2002 illustrates such a device.

Referring to Fig. 2, an OLED device as taught in the prior art includes a substrate **10** on which are formed thin-film electronic components **20**, for example conductors, thin-film transistors, and capacitors in an active-matrix device or conductors in a passive-matrix device. Color filters **28R**, **28G**, and **28B** are patterned on the substrate **10**. Over the color filters **28R**, **28G**, and **28B** are formed first electrode(s) **14**. One or more layers of unpatterned organic materials **16** are formed over the first electrode(s) **14**, including at least one emission layer, for emitting broad-band light. One or more second electrode(s) **18** are formed over the layers of organic materials **16**. An encapsulating cover **12** with a cavity forming a gap **32** to avoid contacting the thin-film layers **(14, 16, 18, 20)** is affixed to the substrate **10**. In some designs, it is proposed to fill the gap **32** with a curable polymer or resin material to provide additional rigidity, or a desiccant to provide protection against moisture. The second electrode(s) **18** may be continuous over the plurality of emitting elements. Upon the application of a voltage across the first and second electrodes **14** and **18** provided by the thin-film electronic components **20**, a current can flow through the organic material layers **16** to cause one of the organic layers to emit light **50a** through the substrate. The arrangement used in Fig. 2 typically has a thick, highly conductive, reflective electrode **18** and suffers from a reduced light-emitting area **26** due to the presence of thin-film electronic components **20** which block light emission. Referring to Fig. 3, a top-emitter configuration employing patterned emissive materials **26R**, **26G**, **26B** for emitting different colors of light **50b** can locate a first electrode **14** partially over the thin-film electronic components **20** thereby increasing the amount of light-emitting area **26**. Since, in this top-emitter case, the first electrode **14** does not transmit light, it can be thick, opaque, and highly conductive. However, the second electrode **18** must then be at least partially transparent. It is also known to employ such a top emitter structure using a white emitter with color filters and a gap between the color filters and the OLED (see Fig. 2 of above-referenced U.S. Patent 6,392,340 and Fig. 2 of JP2003-257622).

In commercial practice, the substrate and cover have comprised 0.7 mm thick glass, for example as employed in a bottom-emitter configuration in the Eastman Kodak Company LS633 digital camera. For relatively small devices, for example as found in cell phones or digital cameras, the use of a cavity in an encapsulating cover **12** is an effective means of providing relatively rigid protection to the thin-film layers of materials **16**. However, for very large devices, the substrate **10** or cover **12**, even when composed of rigid materials like glass and employing materials in the gap **32**, can bend slightly and cause the inside of the encapsulating cover **12** or gap materials to contact or press upon the thin-film layers of materials **16**, possibly damaging them and reducing the utility of the OLED device.

It is known to employ spacer elements to separate thin sheets of materials. For example, US6259204 B1 entitled "Organic electroluminescent device" describes the use of spacers to control the height of a sealing sheet above a substrate. Such an application does not, however, provide protection to thin-film layers of materials in an OLED device. US20040027327 A1 entitled "Components and methods for use in electro-optic displays" published 20040212 describes the use of spacer beads introduced between a backplane and a front plane laminate to prevent extrusion of a sealing material when laminating the backplane to the front plane of a flexible display. However, in this design, any thin-film layers of materials are not protected when the cover is stressed. Moreover, the sealing material will reduce the transparency of the device and requires additional manufacturing steps.

US6821828 B2 entitled "Method of manufacturing a semiconductor device" describes an organic resin film such as an acrylic resin film patterned to form columnar spacers in desired positions in order to keep two substrates apart. The gap between the substrates is filled with liquid crystal materials. The columnar spacers may be replaced by spherical spacers sprayed onto the entire surface of the substrate. However, columnar spacers are formed lithographically and require complex processing steps and expensive materials. Moreover, this design is applied to liquid crystal devices and does not provide protection to thin-film structures deposited on a substrate. U.S. Patent 6,559,594 entitled “Light Emitting Device” issued May 6, 2003 describes resin separators formed on a cover glass of an electroluminescent device to form spacers. Such spacers may require photolithographic processing and additional expenses in manufacture of OLED devices. Similarly, US6559594 entitled “Light Emitting Device” describes the use of a resin spacer formed on the inside of the cover of an EL device. However, such a resin spacer may de-gas and requires expensive photolithographic processing and may interfere with the employment of color filters.

US6551440 B2 entitled “Method of manufacturing color electroluminescent display apparatus and method of bonding light-transmitting substrates” granted 20030422. In this invention, a spacer of a predetermined grain diameter is interposed between substrates to maintain a predetermined distance between the substrates. When a sealing resin deposited between the substrates spreads, surface tension draws the substrates together. The substrates are prevented from being in absolute contact by interposing the spacer between the substrates, so that the resin can smoothly be spread between the substrates. This design does not provide protection to thin-film structures deposited on a substrate.

The use of cured resins is also optically problematic for top-emitting OLED devices. As is well known, a significant portion of the light emitted by an OLED may be trapped in the OLED layers, substrate, or cover. By filling the gap with a resin or polymer material, this problem may be exacerbated.

There is a need therefore for an improved OLED device structure that improves both the mechanical robustness and light output of an OLED device and reduces manufacturing costs.

SUMMARY OF THE INVENTION

In accordance with one embodiment, the invention is directed towards an organic light-emitting diode (OLED) device, comprising: a substrate; one or more OLEDs formed on the substrate comprising a first electrode formed over the substrate, one or more layers of organic material, one of which emits light, formed over the first electrode, and a second electrode formed over the one or more layers of organic material; a cover provided over the OLEDs and spaced apart from the OLEDs to form a gap; and one or more color filter elements located in the gap to filter the light; wherein at least portions of one color filter element or layered combinations of two or more color filter elements form spacer elements having a thickness greater than the thickness of at least another portion of a color filter element located in the gap.

ADVANTAGES

The present invention has the advantage that it improves the robustness and performance of an OLED device and reduces manufacturing costs.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross section of a top-emitter OLED device having spacer elements according to one embodiment of the present invention;

Fig. 2 is a cross section of a prior-art OLED device;

Fig. 3 is a cross section of an alternative prior-art OLED device;

Fig. 4 is a cross section of a top-emitter OLED device having spacer elements according to an alternative embodiment of the present invention;

Fig. 5 is a cross section of a top-emitter OLED device having spacer elements and an end cap according to yet another embodiment of the present invention;

Fig. 6 is a top view of an OLED device having spacer elements distributed between light-emitting areas according to another embodiment of the present invention;

Figs. 7a-7c are cross sections of color filters and spacer elements according to various embodiments of the present invention; and

Fig. 8 is a more detailed cross section of a top-emitter OLED device having spacer elements as shown in Fig. 1 according to one embodiment of the present invention.

It will be understood that the figures are not to scale since the individual layers are too thin and the thickness differences of various layers too great to permit depiction to scale.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 1, in accordance with one embodiment of the present invention, an organic light-emitting diode (OLED) device comprises a substrate **10**; one or more OLEDs **11** formed on the substrate **10** comprising a first electrode **14** formed over the substrate, one or more layers of organic material **16**, one of which is light emitting, formed over the first electrode **14**, and a second electrode **18** formed over the one or more layers of organic material **16**; a cover **12** provided over the OLED **11** and spaced apart from the OLED **11** to form a gap **32**; and one or more color filter elements **21, 24** located in the gap to filter the light. A layered combination of a portion of filter element **21** and filter element **24** forms spacer elements **22** having a thickness greater than the thickness of another portion of filter element **21** located in the gap **32**. In the embodiment of Fig. 1, a gap **23** separates the filter element **24** from the OLED **11**. The OLED **11** may further comprise one or more protective and/or optical layers formed over the second electrode **18**. For example, a protective layer of aluminum oxide followed by a layer of parylene as described in U.S. Patent applications 2001/0052752 and 2002/0003403 may be employed.

The present invention may be employed together with a scattering layer located between the cover **12** and substrate **10** to scatter light that would otherwise be trapped in the OLED device, in conjunction with a transparent low-index element having a refractive index lower than that of the OLED and of the encapsulating cover, as taught in co-pending, commonly assigned USSN

11/065,082 filed February 24, 2005. Materials of a light scattering layer can include organic materials (for example polymers or electrically conductive polymers) or inorganic materials. The organic materials may include, e.g., one or more of polythiophene, PEDOT, PET, or PEN. The inorganic materials may include, e.g., one or more of SiO_x (x>1), SiN_x (x>1), Si_3N_4, TiO_2, MgO, ZnO, Al_2O_3, SnO_2, In_2O_3, MgF_2, and CaF_2. In order to effectively space the OLED **11** from the cover **12** and provide a useful optical structure when employing a scattering layer as discussed in such co-pending application, the spacer elements **22** preferably have a thickness of one micron or more but preferably less than one millimeter. The spacer elements **22** may be formed from carbon, carbon black, pigmented inks, dyes, or barium oxide, titanium, titanium dioxide, silicon, silicon oxides, or metal oxides, or be formed from a variety of polymers such as photolithographically patternable polymers, for example SU-8 resists commercially available from Microchem Corp. The spacer elements **22** may be a patterned thick film. The spacer elements **22** may be black or form a black matrix or may be color filters employed to filter the broadband light emitted by the OLED and create a color OLED device. Additionally, the spacer elements **22** may further comprise a desiccant. The gap **32** may be filled with a low-index material having a refractive index lower than that of the OLED and of the encapsulating cover, including, e.g., an inert gas, air, nitrogen, or argon.

Referring to Fig. 8, a more detailed cross-section of one light emitting element of an OLED device having active-matrix driving circuitry according to one embodiment of the present invention is shown. Over the substrate **10**, a semiconducting layer **80** is formed and patterned. Preferred materials for the semiconducting layer include polysilicon. A gate-insulating layer **86** is formed over the semiconductor layer. Over the gate-insulating layer, a gate conductor layer **82** is formed. Typical materials used to form the gate-insulating layer **86** are silicon dioxide or silicon nitride. The semiconductor layer **80** is then doped to form source and drain regions on either sides of the gate (not shown). A first interlayer insulator layer **84** is formed over the gate conductor layer **82**. Typical materials used to form the first interlayer insulator layer **84** are silicon dioxide or silicon nitride. Over the first interlayer insulator layer **84**, a second conductor layer is deposited and patterned forming the power lines **88** and the data lines **70.** A second interlayer insulator layer **72** is formed over the second conductor layers. The second interlayer insulator layer **72** preferably is leveled or of a planarizing type material which smooth the device topography. These portions of the semiconductor layer and gate conductor together function as a thin-film transistor. This thin-film transistor as well as the power and data lines make up a portion of the active-matrix circuitry. Additional active-matrix circuitry components such as select lines, additional transistors, and capacitors which are not shown may also be employed to drive the OLED as is known in the art. Over the second interlayer insulator layer **72**, the first electrode **14** is formed. Each first electrode is patterned so as to be isolated from other first electrodes of other neighboring OLEDs. For a top-emitting device, the first electrode **14** is typically formed of a material which is both conductive and reflective, such as for example, aluminum (Al), silver (Ag), or molybdenum (Mo), gold (Au), or platinum (Pt). Around the edges of the first electrodes, an inter-pixel insulating film **54** is formed to reduce shorts between the electrodes **14** and **18**. Use of such insulating films over the first electrode is disclosed in US6246179. While use of an inter-pixel insulating film is preferred, it is not required for successful implementation of the invention.

Over the first electrode, the organic EL layers **16** are deposited. There are numerous organic EL layer structures known in the art wherein the present invention can be employed. A common configuration of the organic EL layers is employed in the preferred embodiment consisting of a hole-injecting layer **66**, a hole-transporting layer **64**, an emitting layer **62**, and an electron-transporting layer **60**. Disposed over the organic EL layers is the second electrode **18**. In a top-emitter configuration the second electrode **18** should be transparent and conductive. Preferred materials used for the second electrode **18** include indium tin oxide (ITO), indium zinc oxide (IZO), or a thin metal layer such as Al, Mg, or Ag which is preferably between 5 nm and 25 nm in thickness. While one layer is shown for the second electrode, multiple sub-layers can be combined to achieve the desired level of conductance and transparency such as an ITO layer and an Al layer. The second electrode may be common to all pixels and does not necessarily require precision alignment and patterning.

Spacer element **22** is disposed above the second electrode **18** between active emitting areas of the pixels as shown. Spacer element **22** is used to space cover **12** from the organic EL element. Color filter **21** is disposed between the cover **12** and the second electrode **18**. The thickness (T1) of spacer element **22** is greater than the thickness (T2) of the color filter element **21** as shown. The color filter is shown as being formed on the cover. However, the color filter may also be formed over the second electrode **18**. The spacer element may be formed on either the cover or above the second electrode **18**. When these elements are formed over the second electrode **18**, it is desirable that a thin film protection layer (not shown), such as a layer of aluminum oxide, be employed.

The color filters may be deposited, for example by screen printing, on the OLED **11** or protective layers described above (for example on the electrode **18** or on any protective or optical layers formed on the electrode **18**) or on the inside of the cover **12** to form locally colored areas that filter the light emitted from the OLEDs. In one embodiment, each OLED may include one or more light emitting layers arranged to produce broad-band light emission, and an array of two or more different colored color filter elements may be located in the gap to filter the light, wherein each of the differently colored color filter elements filters the broad-band light to transmit a different colored light, e.g., so as to form full-color pixels.

The spacer elements **22** may be formed from portions of the color filters **21** positioned over light-emitting areas of the OLEDs themselves, for example by employing a black, light-absorbing color filter in combination with a color selective filer, or by employing a combination of different color filters. Additionally, the spacer elements **22** may include other materials, for example desiccating materials and may be black in color. As disclosed in the present invention, the spacer elements **22** must be thicker than the color filters **21**. Referring to Fig. 7a, this may be achieved by coating an additional color filter layer **24** over a color filter **21**, by overlapping one color filter **21** with another to form an additional layer **24** as shown in Fig. 7b, or by forming a separate color filter spacer element **22** thicker than the other color filters as shown in Fig. 7c. Preferably, the spacer element is more than 500 nm thicker than the other individual color filters, and more preferably one micron thicker or more.

The spacer elements **22** may be randomly located over the OLEDs, regularly distributed over the OLEDs, or may be located between adjacent light-emitting portions **26** of the OLEDs. By positioning the spacer elements **22** between light-emitting portions **26** of the OLED, the spacer elements **22** will not interfere with the light emitted from the OLED and may be employed to absorb ambient light, thereby improving the device contrast. If the spacer elements **22** are located in light-emitting portions of the OLED, the spacer elements **22** are preferably of the same color as the color filter employed for the remainder of the light-emitting area of the OLED. The spacer elements **22** formed from color filter materials may be rigid and incompressible or flexible and compressible, depending on the materials chosen.

The color filters **21** including spacer elements **22** may be applied to either the cover **12** or over the OLED **11** before the cover **12** is disposed on the OLED **11** and after the OLED **11** is formed on the substrate **10**. Once the cover **12** is formed and the OLED **11** with all of its layers deposited on the substrate, together with any electronic components, the color filters **21** including spacer elements **22** may be deposited on the OLED and the cover **12** brought into alignment with the OLED **11**. Alternatively, the color filters and spacer elements **22** may be distributed over the inside of the cover **12** and then the spacer elements **22** and the cover **12** brought into alignment with the OLED **11** and substrate **10**. The spacer elements **22** bay be in contact with the cover **12** and the OLED **11** at the same time as shown in Fig. 4. Alternatively, as shown in Fig. 1, the spacer elements **22** may not be in contact with both of the cover **12** and the OLED **11** unless the substrate **10** or cover **12** are stressed, for example by bending.

Referring to Fig. 4, in one embodiment of the present invention, the spacer elements **22** may be patterned over the surface of the OLED **11** or encapsulating cover **12**. In this embodiment, the spacer elements **22** may be located between the light emitting areas **26** of the OLED device and in contact with both the color filters **21** and the OLED **11** so that any light emitted by the OLED will not encounter the spacer elements **22** and thereby experience any undesired optical effect. In this case, the spacer elements **22** may be black and light absorbing, since no light is emitted from the areas in which the spacer elements **22** are deposited and a black spacer element can then absorb stray emitted or ambient light, thereby increasing the sharpness and ambient contrast of the OLED device. The spacer elements **22** may be located either around every light emitting area **26** or in areas between some of the light-emitting areas **26**, for example in rows **42** or columns **40** between pixel groups as is shown in Fig. 6. The spacer elements may be in the form of a continuous grid, a continuous bar in either the row or column direction, or discrete islands.

In a preferred embodiment, the spacer elements are located around the periphery of any light-emitting areas. In these locations, any pressure applied by the deformation of the encapsulating cover **12** or substrate **10** is transmitted to the spacer elements **22** at the periphery of the light-emitting areas, thereby reducing the stress on the light-emitting materials. Although light-emitting materials may be coated over the entire OLED device, stressing or damaging them (without creating an electrical short) may not have a deleterious effect on the OLED device. If, for example, the top electrode **18** is damaged, there may not be any change in light emission from the light-emitting areas **26**. Moreover, the periphery of the OLED light-emitting areas may be taken up by thin-film silicon materials, for example thin-film transistors, or metal bus wiring that are more resistant to stress.

The encapsulating cover **12** may or may not have a cavity forming the gap **32**. If the encapsulating cover does have a cavity, the cavity may be deep enough to contain the spacer elements **22** so that the periphery of the encapsulating cover **12** may be affixed to the substrate, as shown in Fig. 1. The spacer elements **22** may be in contact with only the inside of the encapsulating cover **12** (if applied to the cover) or be in contact with only the OLED **11** (if applied to the OLED), or to both the OLED **11** and the inside of the encapsulating cover **12**. If the spacer elements **22** are in contact with both the OLED **11** and the inside of the encapsulating cover **12** and the encapsulating cover **12** is affixed to the substrate **10**, the cavity in the encapsulating cover **12** should have a depth approximately equal to the thickness of the spacer elements **22**. Alternatively, referring to Fig. 5, the encapsulating cover may not have a cavity. In this case, a sealant **30** should be employed to defeat the ingress of moisture into the OLED device. An additional end-cap **29** may be affixed to the edges of the encapsulating cover **12** and substrate **10** to further defeat the ingress of moisture or other environmental contaminants into the OLED device.

According to the present invention, an OLED device employing spacer elements **22** formed from filter elements **21, 24** located between an encapsulating cover **12** and an OLED **11** in a gap **32**, is more robust in the presence of stress between the cover **12** and the substrate **10**. In a typical situation, the cover is deformed either by bending the entire OLED device or by separately deforming the cover or substrate, for example by pushing on the cover or substrate with a finger or hand or by striking the cover or substrate with an implement such as a ball. When this occurs, the substrate or cover will deform slightly putting pressure on the spacer elements. The spacer elements will preferably absorb the pressure, preventing the cover **12** from pressing upon the OLED **11** and thereby maintaining the gap **32**.

In order to maintain a robust and tight seal around the periphery of the substrate and cover, and to avoid possible motion of the cover **12** with respect to the substrate **10** and possibly damaging the electrodes and organic materials of the OLED, it is possible to adhere the cover to the substrate in an environment that has a pressure of less than one atmosphere. If the gap is filled with a relatively lower-pressure gas (for example air, nitrogen, or argon), this will provide pressure between the cover and substrate to help prevent motion between the cover and substrate, thereby creating a more robust component.

An additional protective layer may be applied to the top electrode **18** to provide environmental and mechanical protection, or to provide useful optical effects. For example, layers of Al_2O_3 may be coated over the electrode **18** to provide a hermetic seal and may also provide useful optical properties to the electrode **18**.

The spacer elements may have a total thickness of between 10 nm and 100 microns, more preferably between 100 nm and 10 microns. It is not essential that all of the spacer elements have the same shape or size. The color filter element portions between spacer elements have a thickness less than that of the spacer elements, and preferably have a thickness between 1 and 2 microns.

Conventional lithographic means can be used to pattern color filter elements to create the spacer elements using, for example, photo-resist, mask exposures, and etching as known in the art. Alternatively, coating may be employed in which a liquid, for example polymer having a dispersion of titanium dioxide, may form the spacer elements **22**. The spacer elements may be sprayed on or deposited using inkjet techniques.

Most OLED devices are sensitive to moisture or oxygen, or both, so they are commonly sealed in an inert atmosphere such as nitrogen or argon, along with a moisture-absorbing desiccant such as alumina, bauxite, calcium sulfate, clays, silica gel, zeolites, barium oxide, alkaline metal oxides, alkaline earth metal oxides, sulfates, or metal halides and perchlorates. The spacer elements **22** may have desiccating properties and may include one or more of the desiccant materials. Methods for encapsulation and desiccation include, but are not limited to, those described in U.S. Patent No. 6,226,890 issued May 8, 2001 to Boroson et al. In addition, barrier layers such as SiO_x ($x>1$), Teflon, and alternating inorganic/polymeric layers are known in the art for encapsulation.

OLED devices of this invention can employ various well-known optical effects in order to enhance their properties if desired. This includes optimizing layer thicknesses to yield maximum light transmission, providing dielectric mirror structures, replacing reflective electrodes with light-absorbing electrodes, providing anti-glare or anti-reflection coatings over the display, providing a polarizing medium over the display, or providing colored, neutral density, or color conversion filters over the display. Filters, polarizers, and anti-glare or anti-reflection coatings may be specifically provided over the cover or as part of the cover.

The present invention may also be practiced with either active- or passive-matrix OLED devices. It may also be employed in display devices or in area illumination devices. In a preferred embodiment, the present invention is employed in a flat-panel OLED device composed of small molecule or polymeric OLEDs as disclosed in but not limited to U.S. Patent No. 4,769,292, issued September 6, 1988 to Tang et al., and U.S. Patent No. 5,061,569, issued October 29, 1991 to VanSlyke et al. Many combinations and variations of organic light-emitting displays can be used to fabricate such a device, including both active- and passive-matrix OLED displays having either a top- or bottom-emitter architecture.

PARTS LIST

10	substrate
11	OLED
12	cover
14	electrode
16	organic layers
18	electrode
20	thin-film electronic components
21	color filter(s)
22	spacer element
23	gap
24	additional layer
26	light-emitting area
26R, 26G, 26B	red, green, and blue light-emitting elements
28R, 28G, 28B	red, green, and blue filters
29	end cap
30	sealant
32	gap
40	columns between light-emitting areas
42	rows between light-emitting areas
50a, 50b	light
54	inter-pixel insulating film
60	electron-transporting layer
62	emitting layer
64	hole-transporting layer
66	hole-injecting layer
70	data lines
72	second interlayer insulator layer
80	semiconducting layer
82	gate conductor layer
84	interlayer insulator layer
86	gate-insulating layer
88	power lines
T1	thickness
T2	thickness

CLAIMS:

1. An organic light-emitting diode (OLED) device, comprising:

a substrate;

one or more OLEDs formed on the substrate comprising a first electrode formed over the substrate, one or more layers of organic material, one of which emits light, formed over the first electrode, and a second electrode formed over the one or more layers of organic material;

a cover provided over the OLEDs and spaced apart from the OLEDs to form a gap; and

one or more color filter elements located in the gap to filter the light;

wherein at least portions of one color filter element or layered combinations of two or more color filter elements form spacer elements having a thickness greater than the thickness of at least another portion of a color filter element located in the gap.

2. The OLED device of claim 1, comprising a plurality of OLEDs and wherein the spacer elements are black or form a black matrix.

3. The OLED device of claim 1, comprising a plurality of OLEDs and wherein the spacer elements are positioned between light-emitting areas of adjacent OLEDs.

4. The OLED device of claim 1, wherein the spacer elements comprise two or more overlapping color filters.

5. The OLED device of claim 4, comprising a plurality of OLEDs and wherein the spacer elements comprise two or more different colored color filters that overlap in the area between the light emitting areas of adjacent OLEDs.

6. The OLED device of claim 4, wherein the spacer elements comprise two or more same colored color filters that overlap in the light emitting area over one of the OLEDs.

7. The OLED device of claim 1, wherein the spacer elements comprise separate color filter elements thicker than other color filters located in the gap.

8. The OLED device of claim 1, wherein the color filter elements comprise screen-printed or photolithographically patterned thick films.

9. The OLED device of claim 1, wherein the spacer elements are in contact with one of the cover and an OLED and are not in contact with the other of the cover and the OLED unless the substrate or cover are stressed.

10. The OLED device of claim 1, wherein the spacer elements are irregularly distributed over the one or more OLEDs.

11. The OLED device of claim 1, wherein the spacer elements are regularly distributed over the one or more OLEDs.

12. The OLED device of claim 1, wherein the spacer elements comprise titanium dioxide, polymer, metal oxide, carbon, carbon black, pigmented inks, dyes, or barium oxide.

13. The OLED device of claim 1, further comprising an encapsulating end-cap affixed to both the cover and the substrate.

14. The OLED device of claim 1, wherein the gap is filled with a low-index material having a refractive index lower than that of the OLEDs and of the encapsulating cover.

15. The OLED device of claim 14, wherein the gap is filled with an inert gas, air, nitrogen, or argon.

16. The OLED device of claim 1, wherein the spacer elements have a thickness equal to or greater than 1 micron.

17. The OLED device of claim 1, further comprising a light scattering layer located between the substrate and cover for scattering light emitted by the OLEDs.

18. The OLED device of claim 1, wherein the gap is maintained at a pressure of less than one atmosphere.

19. The OLED device of claim 1, comprising a plurality of OLEDs each including a broad-band light emitting layer, and an array of two or more different colored color filter elements located in the gap to filter the light, wherein each of the differently colored color filter elements filters the broad-band light to transmit a different colored light.

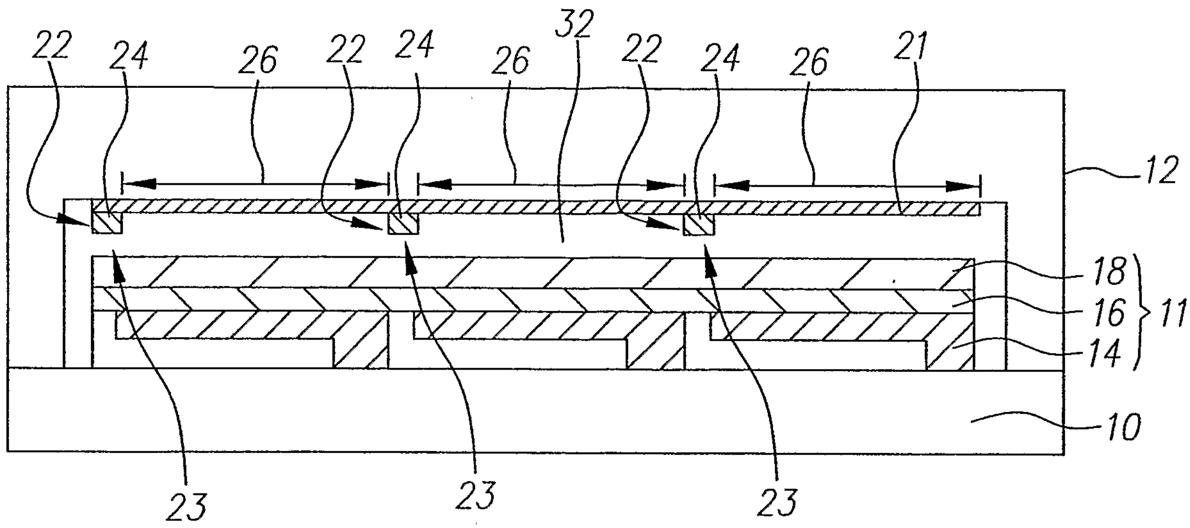

FIG. 1

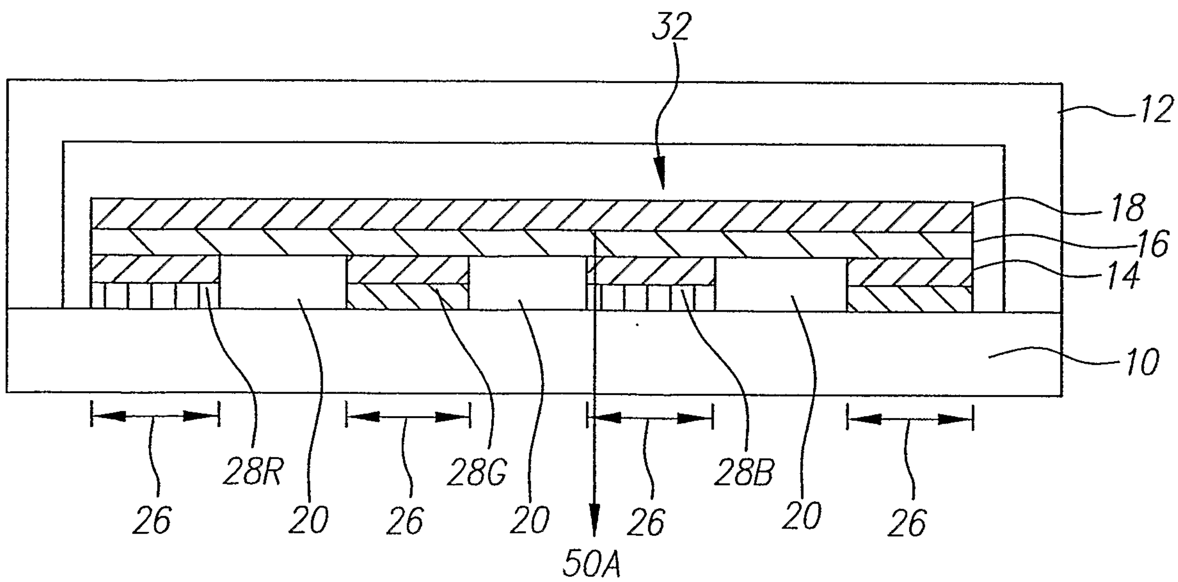

FIG. 2
(Prior Art)

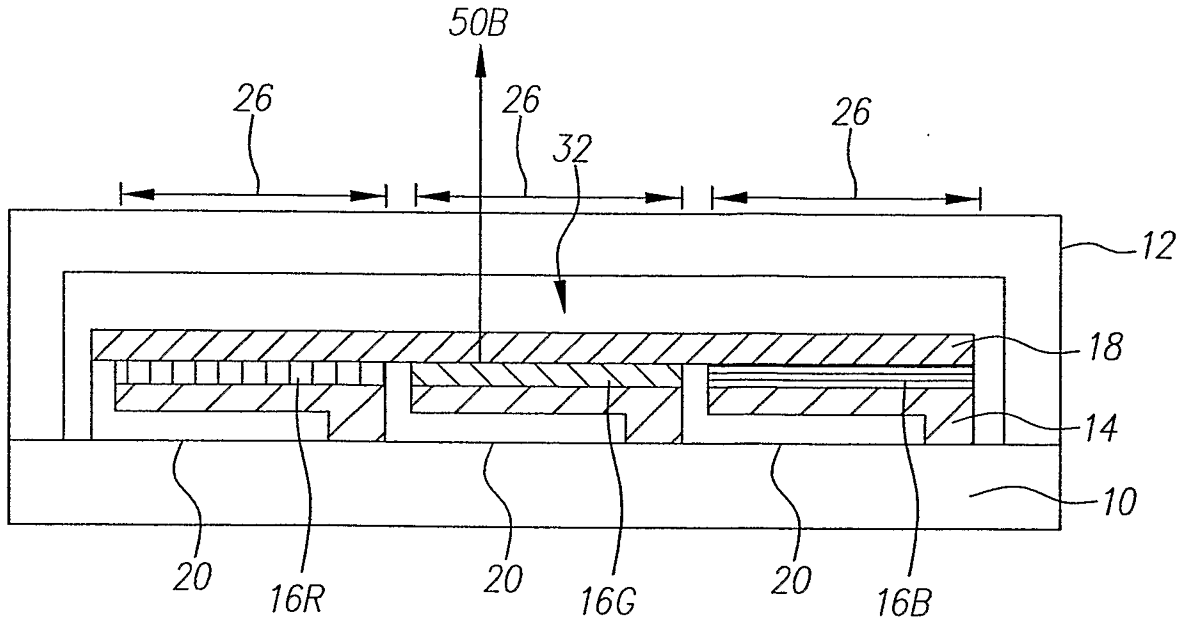

FIG. 3
(Prior Art)

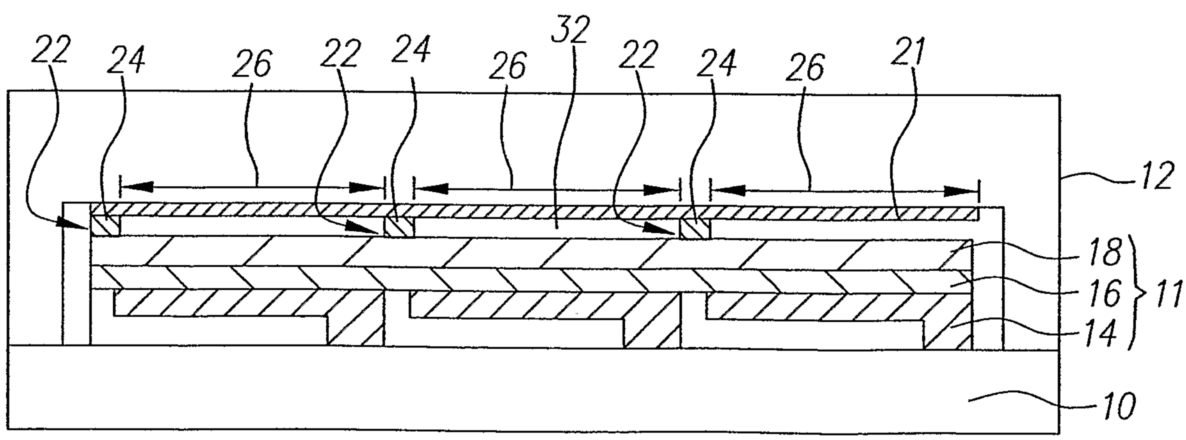

FIG. 4

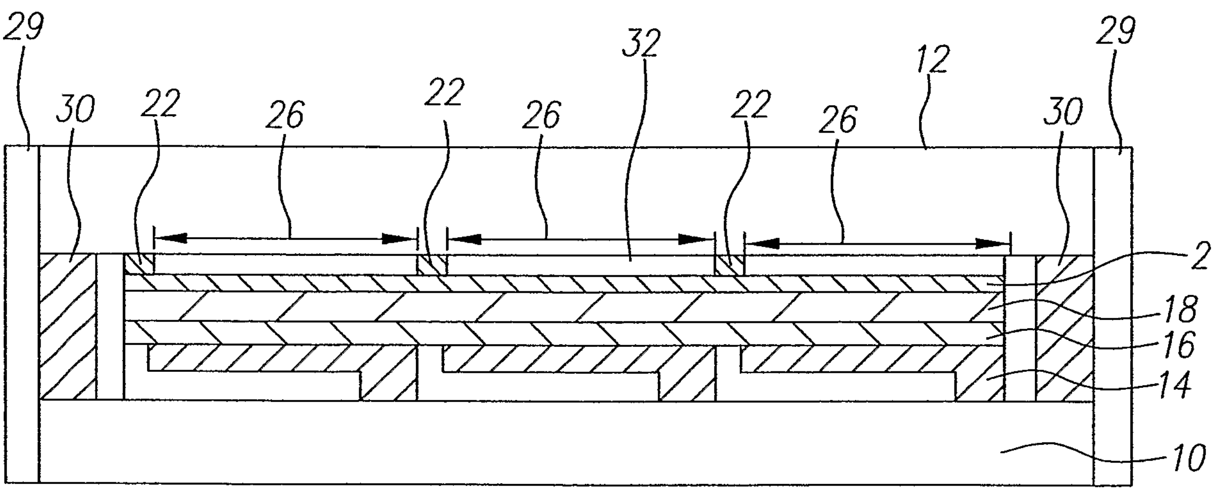

FIG. 5

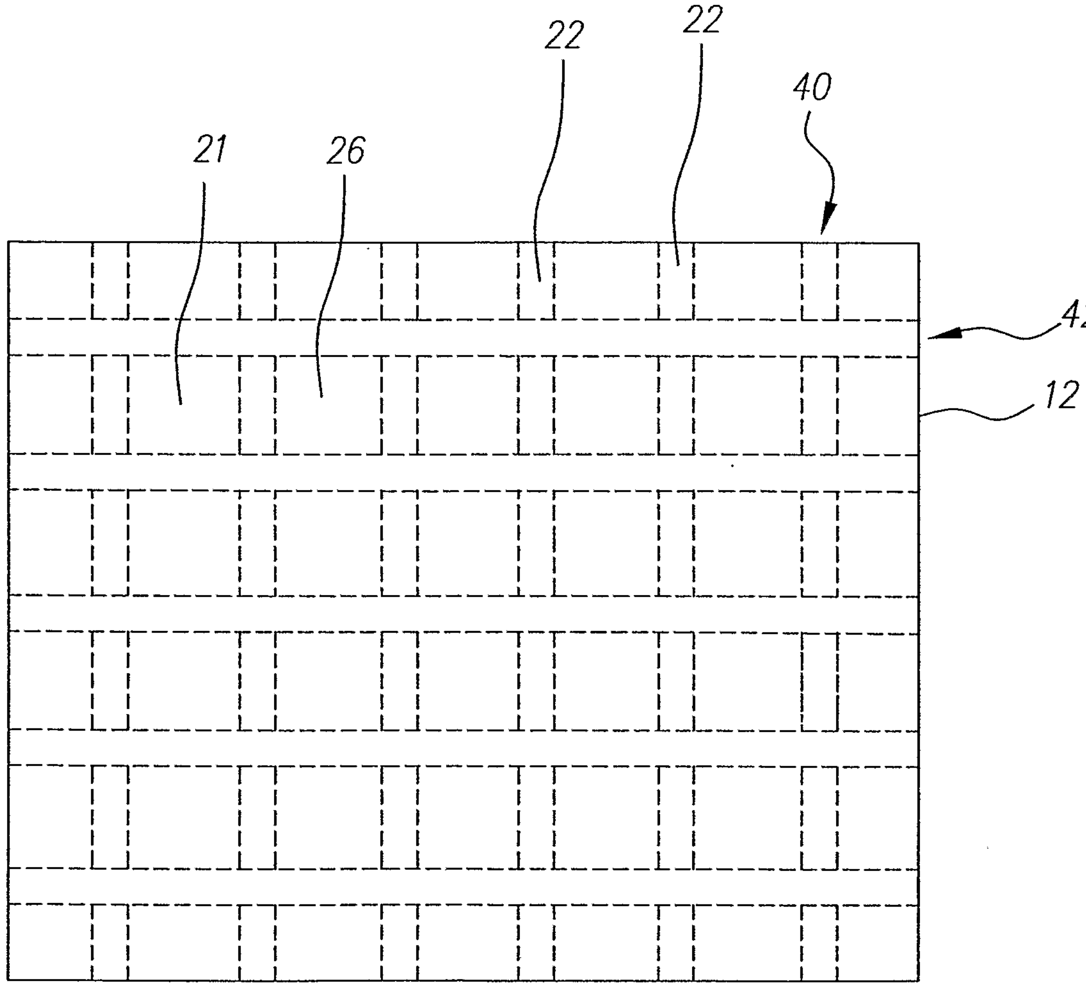

FIG. 6

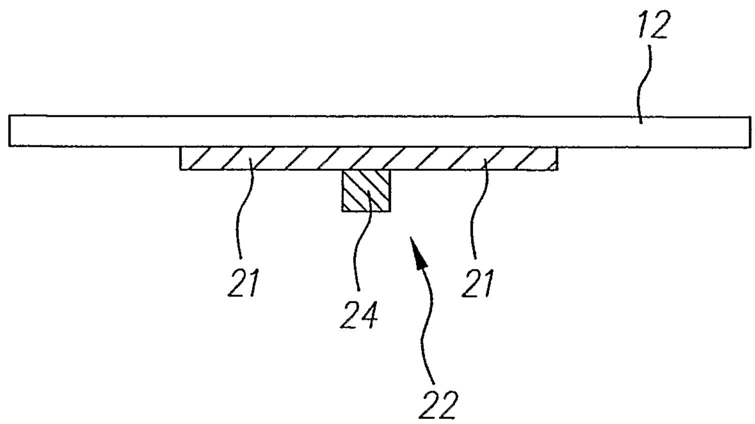

FIG. 7A

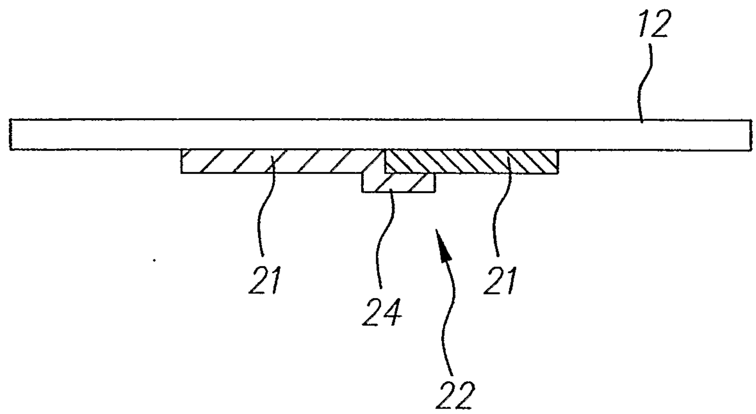

FIG. 7B

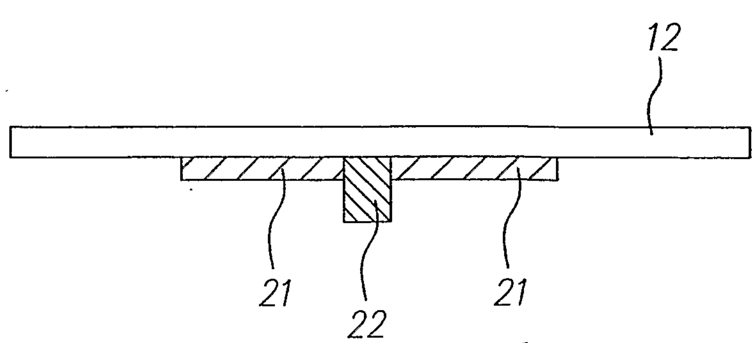

FIG. 7C

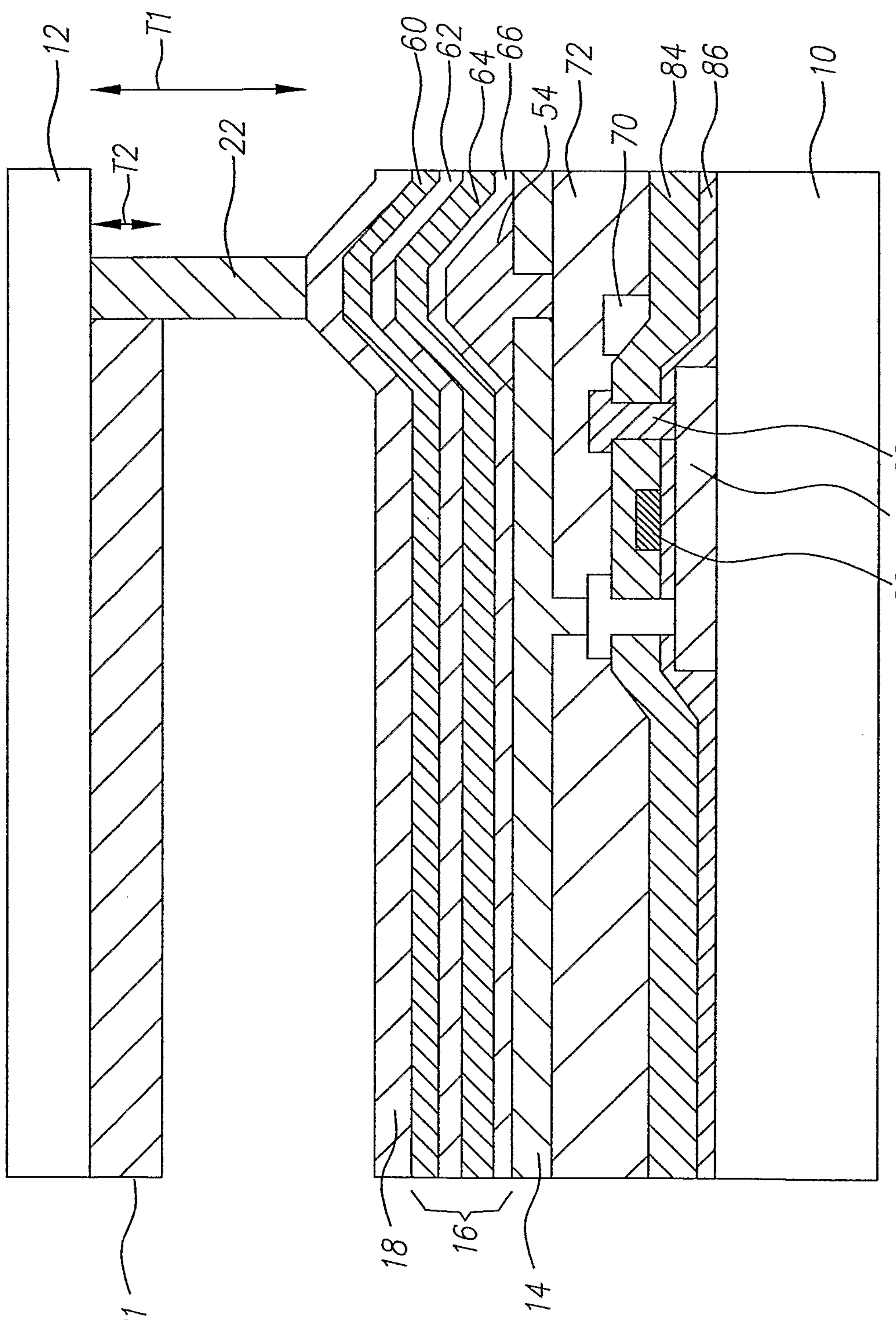

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/023994

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L27/32 H01L51/52

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)
H01L 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	JP 2004 335224 A (SHIN STI TECHNOLOGY KK) 25 November 2004 (2004-11-25)	1,3-9, 11,12, 16,17
Y	abstract paragraphs [0012], [0013], [0019] - [0026], [0032] - [0034], [0043], [0046] - [0051], [0059] - [0063], [0093] - [0103]; figures 4-6 -----	13-15
X	US 2003/107314 A1 (URABE TETSUO [JP] ET AL) 12 June 2003 (2003-06-12) paragraphs [0032], [0033], [0037], [0045], [0049], [0050]; figure 1 -----	1-5,8,9, 11,12,19
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 October 2006	27/10/2006

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 833 668 B1 (YAMADA TSUTOMU [JP] ET AL) 21 December 2004 (2004-12-21) column 8, line 22 - column 11, line 11; figures 4,6	13-15
A	US 5 239 228 A (TANIGUCHI KOUJI [JP] ET AL) 24 August 1993 (1993-08-24) column 4, line 48 - column 5, line 21; figure 3	1-5,8,9, 11-15, 18,19
A	EP 0 731 373 A (IBM [US]) 11 September 1996 (1996-09-11) column 6, line 21 - line 30 column 7, line 26 - line 42; figure 8	1,3-8, 11-14

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Information on patent family members

International application No
PCT/US2006/023994

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