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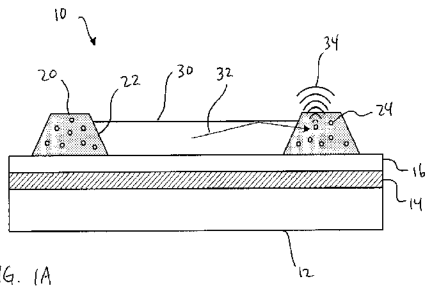

FIG. 1A

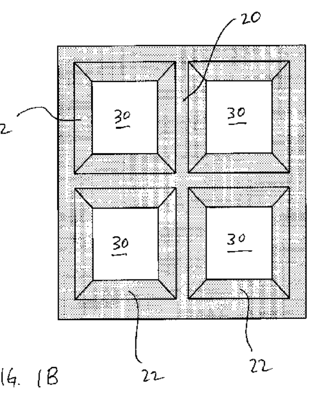

FIG. 1B

(57) Abstract: Organic light emitting devices (OLEDs) having improved outcoupling efficiency by the use of topographical features that scatter light. The OLEDs comprise a substrate with an active element disposed over the substrate. The topographical features are disposed at a position where they are in the path of waveguided light emitted from the active element. In certain embodiments, the topographical features have scattering centers that scatter waveguided light emitted from the active element. The scattering centers may be microparticles. In certain embodiments, the topographical features have a reflective surface that reflects waveguided light emitted from the active element. Also described is a method for making an organic light emitting device.

WO 2010/030591 A2

OLEDs Having Light-Scattering Embankments

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/095,784, filed on 10 Sept. 2008, which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

[0002] The present invention relates to organic light emitting devices, and more particularly, to organic light emitting devices having improved outcoupling efficiency.

BACKGROUND

[0003] For many conventional organic light emitting devices (OLEDs), the efficiency of the OLED is limited by their inability to emit all of the light that is generated in the light-emissive region. One of the reasons for this outcoupling inefficiency is due to light being trapped within the OLED structure by internal reflection at interfaces within the OLED, resulting in the waveguiding of light. For example, at a glass-air interface, light that is incident upon the inner surface of the glass-air interface at an angle larger than a critical angle may not cross the interface, and instead, may be reflected internally and become trapped within the device. This waveguided light propagates laterally in the layered structure of the device and may not be emitted effectively, lowering the external quantum efficiency of the device. Therefore, there is a need for techniques to improve the outcoupling efficiency of OLEDs.

SUMMARY

[0004] In one aspect, the present invention provides an organic light emitting device comprising: a substrate; an active element disposed over the substrate; and a topographical feature disposed at a position in the path of waveguided light emitted from the active element, wherein the topographical feature has scattering centers that scatter waveguided light emitted from the active element. The scattering centers may be located within the topographical feature or may be located at a boundary of the topographical feature. The organic light emitting device may be used in a lighting apparatus for illumination.

[0005] In another aspect, the present invention provides an top-emitting organic light emitting device comprising: a substrate; an active element disposed over the substrate, wherein the active element includes a top electrode and a bottom electrode; and a topographical feature disposed at a position in the path of waveguided light emitted from the active element, wherein the topographical feature has a reflective surface.

[0006] In another aspect, the present invention provides a method for making an organic light emitting device, comprising: providing a substrate with a bottom electrode disposed over the substrate; disposing a polymer layer over the substrate and the bottom electrode; excavating a first portion of the polymer layer that lies over the bottom electrode to create a topographical feature positioned laterally to the bottom electrode; disposing a reflective layer over the bottom electrode and the topographical feature; and removing a portion of the reflective layer that lies over the bottom electrode.

[0007] In another aspect, the present invention provides a bottom-emitting organic light emitting device comprising: (1) a substrate; (2) an active element disposed over the substrate, wherein the active element includes an anode, a cathode, and one or more organic layers between the anode and the cathode; and (3) a topographical feature disposed at a position in the path of waveguided light from both the active element and the substrate, wherein the topographical feature has: (a) scattering centers that scatter waveguided light; (b) a reflective surface; or (c) both.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIGS. 1A and 1B show portions of an organic light emitting device according to an embodiment of the present invention. FIG. 1 shows a cross-section side view of the organic light emitting device. FIG. 1B shows a top view of the organic light emitting device.

[0009] FIG. 2 shows a portion of an organic light emitting device according to another embodiment of the present invention.

[0010] FIG. 3 shows a portion of an organic light emitting device according to another embodiment of the present invention.

[0011] FIG. 4 shows a portion of an organic light emitting device according to another embodiment of the present invention.

[0012] FIGS. 5A-5E show various steps in a method for making an organic light emitting device according to another embodiment of the present invention.

[0013] FIG. 6 shows a portion of a bottom-emitting OLED according to another embodiment.

[0014] FIG. 7 shows an OLED used in a lighting apparatus according to another embodiment.

DETAILED DESCRIPTION

[0015] The present invention provides organic light emitting devices (OLEDs) having improved outcoupling efficiency by the use of one or more topographical features that scatter light. The OLEDs comprise a substrate with an active element disposed over the substrate. As used herein, the term "active element" refers to the basic light-producing unit of the organic light emitting device, comprising at least two electrodes with a light emitting organic material disposed between the two electrodes. The active element can also include other structures, such as charge transport layers, charge injection layers, and/or charge blocking layers. As such, the active element may have any suitable architecture known for making OLEDs, including those having a stack of organic layers between two electrodes. Light generated in the active element may be waveguided in various parts of the structure, including the electrodes, the organic layers, and/or the substrate (if it is transparent). This waveguided light may be absorbed within the structure of the active element or may be coupled out of the edges of the structure.

[0016] The topographical feature is disposed at a position where it is in the path of waveguided light emitted from the active element. The position of the topographical feature will depend upon various considerations, such as the structure, geometry, or position of the active element, the propagation path of the waveguided light, and whether the device is a top-emitting device or a bottom-emitting device. For example, in many cases, the topographical feature will be positioned lateral to the active element. The term "lateral," when referring to the position of a topographical feature, refers to the position of the topographical feature relative to the active element on the x-y plane only (defined by the plane of the substrate). The term "lateral" does not limit the relative position of the topographical feature on the z-axis (i.e., the elevation or depression of the topographical feature relative to the active element). For example, where waveguided light is emitted out of the sides of the active element, the topographical feature can be positioned directly lateral to the active element. Where the waveguided light is emitted out of a structure above the active element (e.g., a protective layer), the topographical feature can be positioned laterally at an elevation above the active element. Positioning of the topographical features laterally to the active element has the benefit of avoiding or reducing disruption to the emission of non-waveguided light.

[0017] The topographical feature is any structure defined by an elevation or depression on a surface that exists during the fabrication of the organic light emitting device. For example, the topographical feature may be formed from elevations on a surface, such as ridges, embankments, mesas, plateaus, islands, steps, etc. Alternatively, the topographical feature may be formed from depressions on a surface, such as pits, basins, channels, valleys, etc. The topographical feature may have various dimensions and geometries, depending upon various considerations, such as the size of the active element, the depth of the active element, the position of the active element, etc. The topographical features may or may not have angled sidewalls.

[0018] The material used to make the topographical feature may depend upon whether the light-scattering function of the topographical feature operates by light entering through the topographical feature. In embodiments where waveguided light is transmitted through the topographical feature, the topographical feature can be made using any suitable material having a relatively low index of refraction as compared to the waveguiding structures in the active element. In some cases, the material used to form the topographical feature has a refractive index in the range of 1.0 to 3.0; and in some cases, in the range of 1.0 to 1.5. Materials that can be used for making the topographical feature include polymeric materials (e.g., polyacrylate) or inorganic materials such as silicon nitrates or silicon oxides. In some cases, the topographical feature is transparent to light, and as such, can be formed of any suitable transparent material. The topographical feature may be formed by any suitable microfabrication technique, including micro-embossing, lithography, printing, micro-machining, etc.

[0019] In one aspect of the present invention, the topographical feature has scattering centers that scatter waveguided light emitted from the active element. The scattering centers may be located within the topographical feature or may be located at a boundary of the topographical feature (e.g., on an inner or outer aspect on a surface of the topographical feature). As used herein, the term "scattering centers" refers to discrete, nano- or micro-scaled non-uniformities (in structure, composition, or both) dispersed within the topographical feature or at a boundary of the topographical feature. Scattering is intended to include any type of physical or optical process that causes light to deviate from a straight trajectory in a diffuse manner. As such, scattering may involve the processes of refraction, re-radiation, diffuse reflection, and/or interference.

[0020] In certain embodiments, the topographical features contain the scattering centers. In such embodiments, the scattering centers are discrete, nano- or micro-scaled non-uniformities dispersed within the medium of the topographical features which serve to scatter light passing through the topographical features. Also, in such embodiments, the topographical features are formed of a transparent material such as transparent polymeric materials (e.g., polyacrylate) or transparent inorganic materials (e.g., silicon nitrates or silicon oxides). Further, the refractive index of the scattering centers is different (either higher or lower) from the refractive index of the composition medium of the topographical feature (i.e., the refractive indexes are mismatched). In some cases, the difference in the refractive indices may be 0.1 or greater. In some embodiments, to avoid or reduce disruption to the emission of non-waveguided light, the scattering centers may be present only in the topographical features and there are no scattering centers in the active element.

[0021] Various types of non-uniformities may serve as scattering centers in the topographical feature, including microparticles, microbubbles, or microdroplets. The size of the scattering centers can be selected according to various considerations, such as the wavelength of light that is emitted by the active element and transmitted through the topographical feature. In some cases, the scattering centers have an average size in the range of 0.1 μm to 10 μm. In some cases, the scattering centers have a size that is similar to or less than the wavelength of light that is emitted by the active element and transmitted through the topographical feature. In such cases, the scattering centers have an average size in the range of 0.1 μm to 1 μm; and in some cases, in the range of 0.1 μm to 0.5 μm.

[0022] In embodiments where the scattering centers are microparticles, the microparticles may be formed of any suitable material having a refractive index that is different (either lower or higher) from the refractive index of the composition medium of the topographical feature. Such suitable materials include alumina, silica, metal oxides (e.g., titanium oxide or zinc oxide), ceramics such as glass, metal-coated spheres, etc. The microparticles may be formed using more than one material (e.g., metal-coated glass particles). In embodiments where the scattering centers are microbubbles, the microbubbles may be gas bubbles dispersed within the medium of the topographical feature.

[0023] Referring to the example embodiment shown in FIGS. 1A and 1B, an organic light emitting device 10 comprises a drive circuit layer 14 (e.g., made using thin-film transistors) formed on a substrate 12. Drive circuit layer 14 is coated with a passivation layer 16. Mounted on passivation layer 16 is an active element 30 comprising a stack of organic layers between two electrodes. Positioned directly lateral to active element 30 are optically transparent embankments 20 (i.e., topographical features) that have angled sidewalls 22. Angled sidewalls 22 may have an angle in the range of 30° – 60° relative to the substrate.

[0024] Embankments 20 are made of an optically transparent material having a refractive index of 1.5. Randomly dispersed within embankments 20 are microparticles 24 having a size in the range of 0.1 μm to 0.5 μm. Thus, the microparticles have a size similar to or smaller than the wavelength of light that is emitted by active element 30 as transmitted through embankments 20.

[0025] In operation, some of the light 32 generated by active element 30 is internally reflected and waveguided out of the side of active element 30. Embankments 20 are positioned at a location where they are in the path of waveguided light that exits from the side of active element 30. As such, the waveguided light is incident upon embankment 20 and is transmitted therethrough. The waveguided light becomes scattered upon striking microparticles 24, causing the trajectory of the waveguided light to change to an outward direction (as diffused light 34), thereby increasing the effective efficiency of device 10.

[0026] FIG. 1B shows a top view of a portion of organic light emitting device 10. As seen in this view, embankments 20 surrounding active elements 30 define a matrix of pixels units within the basin-like areas created by embankments 20. In this embodiment, in addition to defining pixel units, embankments 20 may also serve other functions, such as passivation or electrical insulation. An organic light emitting device. An organic light emitting device comprising a matrix of pixel units can be used in a lighting apparatus (e.g., for interior/exterior illumination), as will be further described below.

[0027] In certain embodiments, the scattering centers are located at a boundary of the topographical features. In such embodiments, the scattering centers are discrete, nano- or micro-scaled structural non-uniformities at the boundary of the topographical features. The structural non-uniformities function to increase the topographical features's interaction with incident light, thereby scattering the incident light. For example, the scattering centers may form one of the various types of light-scattering textured surfaces that are known in the art. Examples of such light-scattering textured surfaces include surfaces having gratings, grids, corrugations, bumps, grooves, ridges, pores, roughness, or other features that provide for a non-smooth surface at the nano- or micro-scale level. The textured surface may have a pattern that is random or non-random (e.g., repeating or uniform). The structural non-uniformities can be formed by any suitable technique, including deposition techniques or lithographic techniques. For example, a textured surface can be formed on the topographical feature by lithographic patterning or by depositing the above-described microparticles onto a surface of the topographical feature.

[0028] Referring to the example embodiment shown in FIG. 2, an organic light emitting device 40 comprises a drive circuit layer 14 formed on a substrate 12. Drive circuit layer 14 is coated with a passivation layer 16. Mounted on passivation layer 16 is an active element 30 comprising a stack of organic layers between two electrodes. An embankment 50 is positioned directly lateral to active element 30. On the side facing active element 30, embankment 50 has a rough, light-scattering surface 52.

[0029] In operation, some of the light 32 generated by active element 30 is internally reflected and then waveguided out of the side of active element 30. The waveguided light is incident upon rough surface 52, where it becomes scattered to create diffused light 34. In this embodiment, the light-scattering function of embankments 50 do not rely on the waveguided light entering through embankment 50. As such, it is not necessary for embankments 50 to be transparent or be formed of a low-index material. For example, embankments 50 may be formed of polyimide.

[0030] Referring to the example embodiment shown in FIG. 3, an organic light emitting device 60 comprises a drive circuit layer 14 formed on a substrate 12. Drive circuit layer 14 is coated with a passivation layer 16. A portion of the surface of passivation layer 16 is patterned to form a corrugated surface 64 on passivation layer 16. Mounted on passivation layer 16 is an active element 30 comprising a stack of organic layers between two electrodes. Over corrugated surface 64, an optically transparent embankment 62 is positioned directly lateral to active element 30. As such, the bottom boundary of embankment 62 against corrugated surface 64 has a rough texture.

[0031] In operation, some of the light 32 generated by active element 30 is internally reflected and then waveguided out of the side of active element 30. The waveguided light is incident upon embankment 62 and is transmitted therethrough. Within embankment 62, the waveguided light strikes the bottom boundary of embankment 62 against corrugated surface 64, where it becomes scattered to create diffused light 34.

[0032] In another aspect of the present invention, at least a portion of the topographical feature has a reflective surface that reflects waveguided light emitted from the active element. The reflective surface may be formed of any of various materials that are capable of reflecting light. Examples of such materials include metals such as aluminum, silver, or gold.

[0033] In certain embodiments, the reflective surface is designed to reduce the possibility of electrical shorting between the top electrode and the bottom electrode of the active element. This may be achieved by electrically isolating the reflective surface from the bottom electrode, the top electrode, or both. For example, there may be a gap or an insulating material between the reflective surface and one or more of the electrodes of the active element (e.g., the bottom electrode, the top electrode, or both). This may also be achieved by using a dielectric material for making the reflective surface. For example, the reflective surface may be a dielectric mirror formed of multiple thin layers of dielectric materials having different refractive indices between neighboring layers. Common materials for making dielectric mirrors include magnesium fluoride, silicon dioxide, tantalum pentoxide, zinc sulfide ($n = 2.32$), and titanium dioxide ($n = 2.4$).

[0034] Referring to the example embodiment shown in FIG. 4, a top-emitting organic light emitting device 70 comprises a drive circuit layer 14 formed on a substrate 12. Drive circuit layer 14 is coated with a passivation layer 16. Mounted on passivation layer 16 is an active element 30 comprising a stack of organic layers between a cathode electrode (not shown) and an anode electrode 38. Anode electrode 38 is in electrical contact with drive circuit layer 14 via a contact 18. An embankment 72 is positioned directly lateral to active element 30.

[0035] On its sidewalls, embankment 72 has reflective surfaces 74. To reduce the possibility of electrical shorting between the cathode electrode and anode electrode 38 via reflective surface 74, a gap 76 is provided between reflective surface 74 and anode electrode 38. In operation, some of the light 32 generated by active element 30 is internally reflected and then waveguided out of the side of active element 30. The waveguided light strikes reflective surface 74 and reflected in an outward direction.

[0036] Devices having topographical feature with a reflective surface can be fabricated using any suitable technique. One such fabrication process involves providing a substrate having a bottom electrode (e.g., the anode) of the active element disposed over the substrate. A polymer layer is disposed over the bottom electrode and the substrate. The polymeric material used in the polymer layer may be any of the above-described polymeric materials used for making the topographical features. An excavation process will be used to pattern the polymer layer to create the topographical features. As such, in some cases, the polymer layer may serve as a photoresist layer (either positive or negative) to be patterned in a photolithography process.

[0037] The polymer layer may be formed by depositing a polymer precursor at the site and then polymerizing the polymer precursor. For example, UV-crosslinkable acrylate monomers may be deposited onto the bottom electrode and over the substrate, and then crosslinked by UV exposure to form the polymer layer.

[0038] Topographical features are formed by excavating portions of the polymer layer, including those portions that lie over the bottom electrode. The excavation may be performed using any of various techniques that remove material in a controlled manner, such as lithographic or etching processes, direct-write etching using energetic beams (e.g., laser, ion, or electron), micromachining, or microdrilling. A reflective layer is then disposed over the bottom electrode and the topographical features. Depending upon the particular needs (e.g., electrical isolation), portions of the reflective layer are then removed. The remainder of the active element structures (e.g., the organic layers and the top electrode) are then disposed over the bottom electrode.

[0039] FIGS. 5A-5E illustrate an example method for fabricating an organic light emitting device having topographical features with reflective surfaces. As shown in FIG. 5A, a substrate 12 having a drive circuit layer 14 and a passivation layer 16 is provided. A bottom electrode 82 (e.g., the anode) for an active element is then disposed on passivation layer 16. UV-crosslinkable acrylate monomers are then deposited onto passivation layer 16 and bottom electrode 82 by spin-coating. The acrylate monomers are then crosslinked by UV-light exposure to create a photoresist layer 80. The thickness of photoresist layer 80 can be controlled by adjusting the viscosity of the coating solution or adjusting the spinning rotation speed.

[0040] Referring to FIG. 5B, using a photomask, portions 86 of photoresist layer 80 are etched away by photolithography to create embankments 84 that define a basin area 88. At basin area 88, a portion 89 of photoresist layer 80 remains (which, as will be seen in FIG. 5E, allows for the creation of gaps 94 between reflective layer 90 and bottom electrode 82). Referring to FIG. 5C, a reflective metallic material is then deposited over the entire basin area 88 and embankments 84 to create a reflective layer 90 (providing a reflective surface).

[0041] Referring to FIG. 5D, to create electrically isolated sections of reflective layer 90, portions of reflective layer 90 over bottom electrode 82 and the top surfaces of embankments 84, along with remaining portion 89 of photoresist layer 80, are etched away. Referring to FIG. 5E, an active element 92 is then constructed in basin area 88 by deposition of the organic layers and the top electrode over bottom electrode 82. By this fabrication method, gaps 94 are created between bottom electrode 82 and reflective layer 90, which can prevent electrical shorting between bottom electrode 82 and the top electrode (not shown) of active element 92.

[0042] The OLEDs described herein may be top-emitting OLEDs or bottom-emitting OLEDs. As explained in U.S. Patent No. 7,012,363 (Weaver et al.), which is incorporated by reference herein, a top-emitting OLED is configured to transmit light in a direction away (upward) from the substrate, whereas a bottom-emitting OLED is configured to transmit light through the substrate. An OLED of the present invention may be both top-emitting and bottom-emitting. Further, the OLEDs described herein may be passive matrix or active matrix OLEDs. The organic light emitting devices of the present invention may be used in a variety of electronic devices, including flat panel displays, computer monitors, televisions, billboards, lights for interior or exterior illumination and/or signaling, heads up displays, fully transparent displays, flexible displays, laser printers, telephones, cell phones, personal digital assistants (PDAs), laptop computers, digital cameras, camcorders, viewfinders, micro-displays, vehicles, a large area wall, theater or stadium screen, or a sign.

[0043] In certain embodiments, an OLED of the present invention may be configured as a bottom-emitting OLED. In a bottom-emitting OLED, in addition to the waveguiding of light within the organic layer(s) of the active element (organic waveguide mode), there may also be waveguiding within the substrate due to internal reflection at the substrate-air interface (substrate waveguide mode). At the substrate-air interface, any light with an incident angle larger than the critical angle (with respect to the normal of the surface) will be internally reflected. In such cases, the topographical feature may be configured and/or positioned to receive waveguided light from both the active element and the substrate. The topographical feature may be configured in any of the ways described herein.

[0044] For example, FIG. 6 shows a bottom-emitting OLED having a transparent substrate 102 and an active element 104 which includes a cathode electrode 106 (anode electrode not shown). The OLED has an embankment 120 that is positioned lateral to the active element 104 to receive light in the organic waveguide mode 110. Embankment 120 is also in the path of light in the substrate waveguide mode 112. In this particular example, via its bottom face 126, embankment 120 is in direct physical contact with substrate 102.

[0045] Embankments 120 are made of an optically transparent material and have randomly dispersed microparticles 122 dispersed therein. Waveguided light that is incident upon embankment 120 is transmitted through and becomes scattered upon striking microparticles 122, causing the trajectory of the waveguided light to change to an outward direction 116. In an alternate embodiment, embankments 120 have a reflective surface (as described above) for reflecting waveguided light in an outward direction. This embodiment may or may not be used in combination with the scattering centers.

[0046] As mentioned above, an organic light emitting device described herein may be used in a lighting apparatus (e.g., for interior/exterior illumination). The lighting apparatus may use an OLED in any suitable configuration, e.g., bottom-emitting (with a transparent substrate) and/or in an inverted configuration. OLEDs in the inverted configuration are described in U.S. Patent No. 7,012,363 (Weaver et al.), which is incorporated by reference herein. In such cases, the cathode is disposed between the anode and the substrate. For example, the device may comprise, in order, a substrate, a cathode, an active element, and an anode.

[0047] In some cases, the lighting apparatus may use an OLED having two or more topographical features and having multiple active elements. For example, as explained above (see FIG. 1B), the topographical features may define a matrix of pixel units, each containing an active element. FIG. 7 shows an example embodiment of a lighting apparatus which includes a panel having multiple pixel units. The lighting panel comprises an OLED 130 having a series of embankments 134 arranged in a grid that divides the OLED panel 130 into a matrix of pixel units 132, each containing an active element. The embankments 120 may be designed according to various considerations, including one or more of the following: (1) the thickness of the OLED, (2) the patterning resolution in constructing the embankments, (3) the density of the scattering centers in the embankment, (4) minimizing the number of reflections encountered by waveguided light, and (5) maximizing the active light emitting area. Taking such factors into consideration, in some cases, embankments 134 may have a width of 10 μm (micrometers) or less, but other dimensions are also possible. In some cases, the distance "D" between opposing embankments 134 (as measured from the centerlines of embankments 134) of a pixel unit 132 is in the range of 1 to 100 μm, but other distances are also possible.

[0048] The organic light emitting devices described herein may be made using any suitable manufacturing technique, including techniques involving roll-to-roll processing, stamping, and/or batch processing. Stamping processes are described in U.S. Patent No. 6,294,398 (Kim et al.), U.S. Patent No. 6,468,819 (Kim et al.), and U.S. Patent Application Publication No. 2005/0170621 (Kim et al.), which are all incorporated by reference herein.

[0049] As used herein, wherein referring to parts of an OLED, "top" means furthest away from the substrate, while "bottom" means closest to the substrate. For example, for a device having two electrodes, the bottom electrode is the electrode closest to the substrate, and is generally the first electrode fabricated. Where one (first) part of a device is denoted to be disposed "over" another (second) part, it is meant that the first part is disposed further away from the substrate than the second part, but necessarily directly on the second part.

[0050] The foregoing description and examples have been set forth merely to illustrate the invention and are not intended to be limiting. Each of the disclosed aspects and embodiments of the present invention may be considered individually or in combination with other aspects, embodiments, and variations of the invention. In addition, unless otherwise specified, none of the steps of the methods of the present invention are confined to any particular order of performance. Modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art and such modifications are within the scope of the present invention.

CLAIMS

What is claimed is:

1. An organic light emitting device comprising:

a substrate;

an active element disposed over the substrate, wherein the active element includes an anode, a cathode, and one or more organic layers between the anode and the cathode; and

a topographical feature disposed at a position in the path of waveguided light emitted from the active element, wherein the topographical feature has scattering centers that scatter waveguided light emitted from the active element.

2. The device of claim 1, wherein the scattering centers are dispersed within the topographical feature.

3. The device of claim 2, wherein the scattering centers are microparticles.

4. The device of claim 3, wherein the microparticles have a size in the range of 0.1 μm to 10 μm.

5. The device of claim 4, wherein the microparticles have a size in the range of 0.1 μm to 0.5 μm.

6. The device of claim 2, wherein the topographical feature is formed of a material having a refractive index in the range of 1.0 – 3.0.

7. The device of claim 6, wherein the scattering centers are formed of a material having a refractive index that differs by 0.1 or greater from the refractive index of the material used in forming the topographical feature.

8. The device of claim 7, wherein the scattering centers are formed of a material having a refractive index greater than the refractive index of the material used in forming the topographical feature.

9. The device of claim 6, wherein the topographical feature is optically transparent.

10. The device of claim 1, wherein the topographical feature is positioned lateral to the active element.

11. The device of claim 1, wherein the scattering centers are located at a boundary of the topographical feature.

12. The device of claim 11, wherein the scattering centers form a textured surface on the topographical feature.

13. The device of claim 12, wherein the textured surface is a rough surface.

14. The device of claim 12, wherein the topographical feature has a sidewall facing the active element, and wherein the sidewall has the textured surface.

15. The device of claim 12, wherein the textured surface is located at a bottom boundary of the topographical feature.

16. The device of claim 15, wherein the topographical feature is formed of a material having a refractive index in the range of 1.0 – 3.0.

17. The device of claim 1, wherein the topographical feature is an embankment having an angled sidewall.

18. A lighting apparatus for illumination comprising the organic light emitting device of claim 1.

19. The lighting apparatus of claim 18, wherein the organic light emitting device is bottom-emitting.

20. The lighting apparatus of claim 18, wherein the organic light emitting device comprises two or more topographical features and a plurality of active elements.

21. The lighting apparatus of claim 18, wherein the two or more topographical features form a matrix of pixel units, each pixel unit comprising an active element.

22. The lighting apparatus of claim 21, wherein the distance between two opposing topographical features of a pixel unit is in the range of 1 – 100 μm.

23. The lighting apparatus of claim 21, wherein at least one topographical feature is continuous alongside at least two adjacent pixel units.

24. The lighting apparatus of claim 21, wherein the scattering centers are microparticles dispersed within the topographical features.

25. A bottom-emitting organic light emitting device comprising:

a substrate;

an active element disposed over the substrate, wherein the active element includes an anode, a cathode, and one or more organic layers between the anode and the cathode; and

a topographical feature disposed at a position in the path of waveguided light from both the active element and the substrate, wherein the topographical feature has: (a) scattering centers that scatter waveguided light; (b) a reflective surface; or (c) both.

26. The device of claim 25, wherein the topographical feature is an embankment positioned lateral to the active element.

27. The device of claim 26, wherein the embankment is in physical contact with the substrate.

28. The device of claim 27, wherein embankment has scattering centers, the scattering centers being microparticles dispersed within the embankment.

29. A top-emitting organic light emitting device comprising:

a substrate;

an active element disposed over the substrate, wherein the active element includes a top electrode and a bottom electrode; and

a topographical feature disposed at a position in the path of waveguided light emitted from the active element, wherein the topographical feature has a reflective surface; and

wherein the reflective surface: (a) is electrically isolated from both the top electrode and the bottom electrode, or (b) comprises a dielectric material.

30. The device of claim 29, wherein the reflective surface is electrically isolated from both the top electrode and the bottom electrode.

31. The device of claim 30, wherein gaps exist between the reflective surface and the top electrode and between the reflective surface and the bottom electrode.

32. The device of claim 29, wherein the reflective surface comprises a dielectric material.

33. The device of claim 32, wherein the reflective surface is a dielectric mirror.

34. The device of claim 29, wherein the topographical feature is an embankment having an angled sidewall.

35. A method for making an organic light emitting device, comprising:

providing a substrate with a bottom electrode disposed over the substrate;

disposing a polymer layer over the substrate and the bottom electrode;

excavating a first portion of the polymer layer that lies over the bottom electrode to create a topographical feature positioned laterally to the bottom electrode;

disposing a reflective layer over the bottom electrode and the topographical feature; and

removing a portion of the reflective layer that lies over the bottom electrode.

36. The method of claim 35, wherein the polymer layer is a photoresist layer.

37. The method of claim 35, wherein the polymer layer is created by depositing a polymer precursor over the substrate and the bottom electrode, and polymerizing the polymer precursor to form the polymer layer.

38. The method of claim 35, wherein the excavating is performed by photolithography.

39. The method of claim 35, wherein a second portion of the polymer layer remains over the bottom electrode after the step of excavating the first portion of the polymer layer.

40. The method of claim 35, further comprising disposing a plurality of organic layers and a top electrode over the bottom electrode.

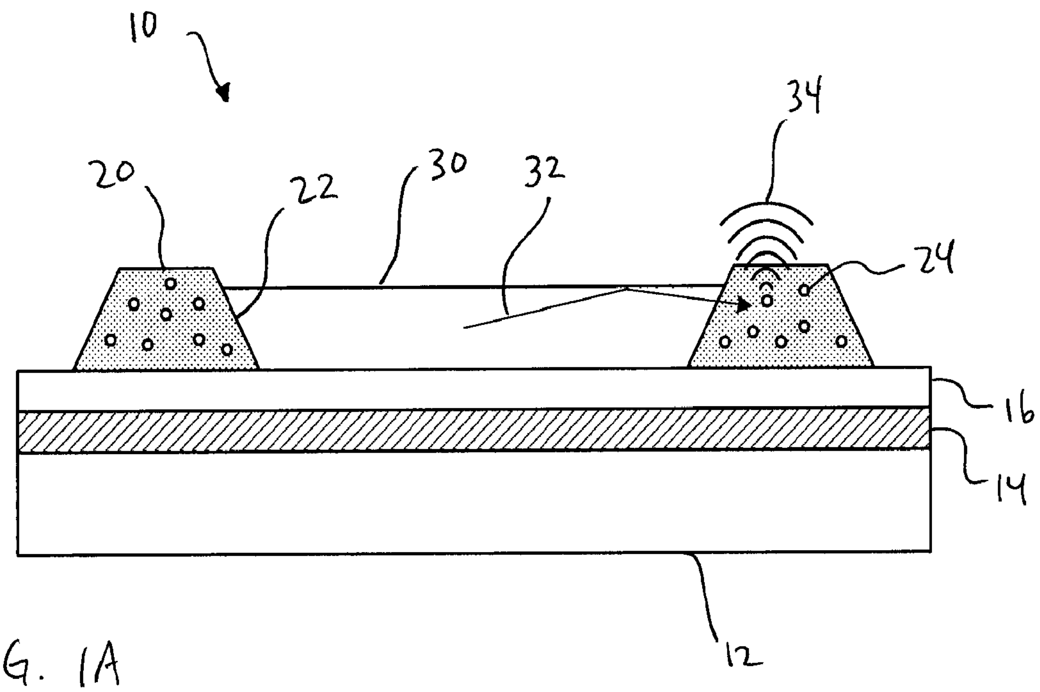

FIG. 1A

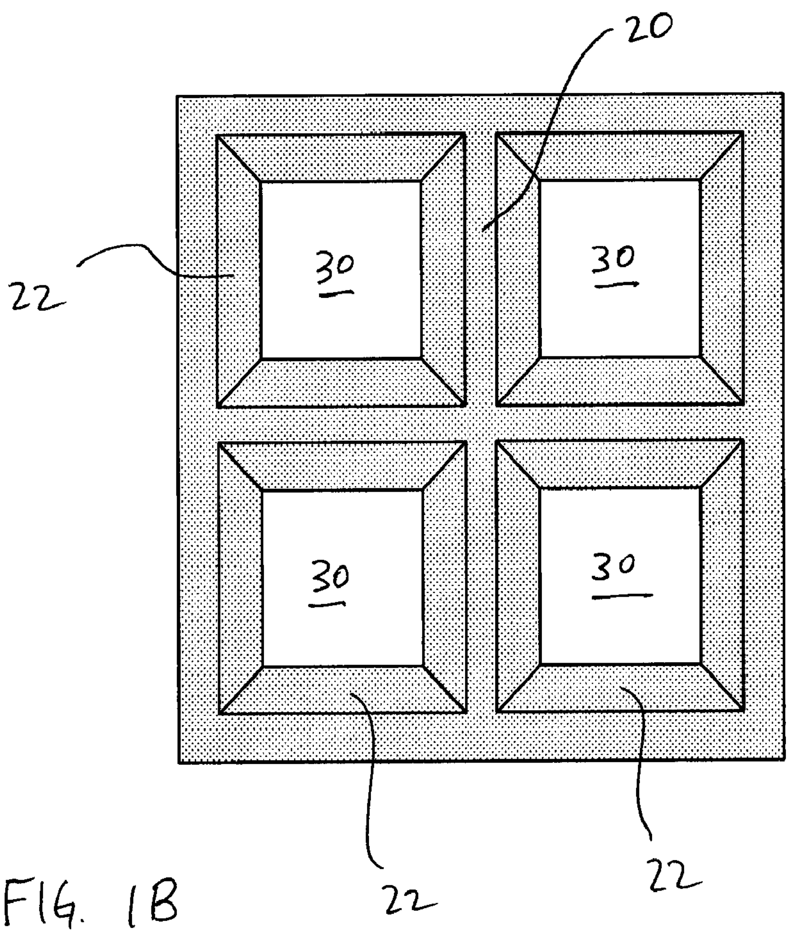

FIG. 1B

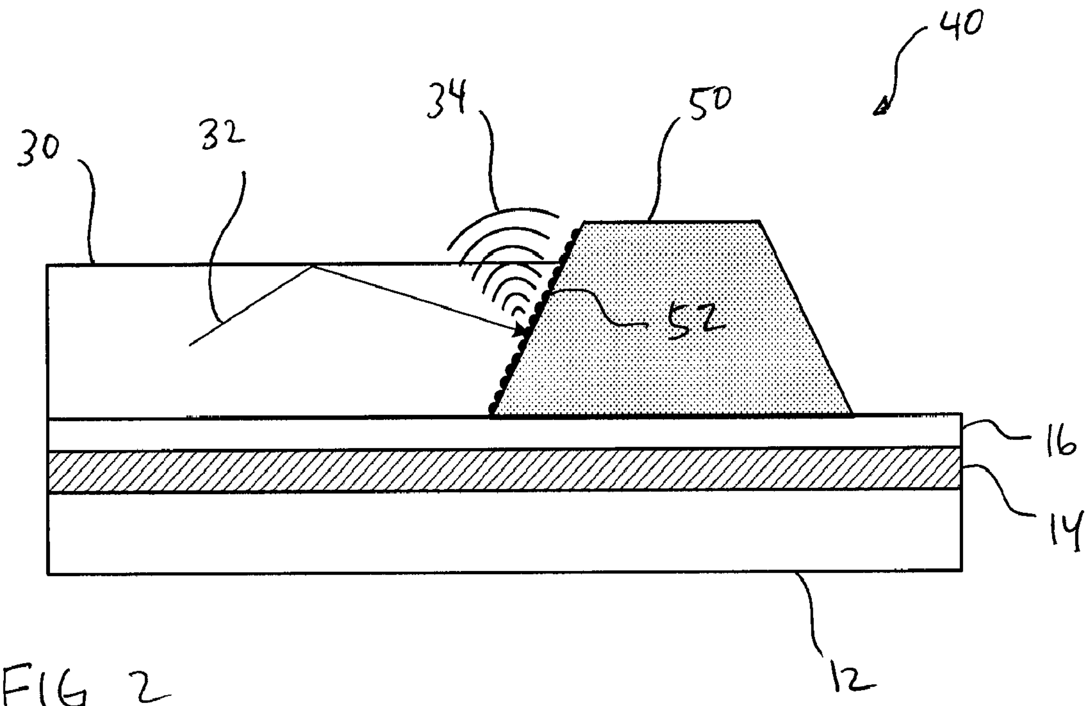

FIG. 2

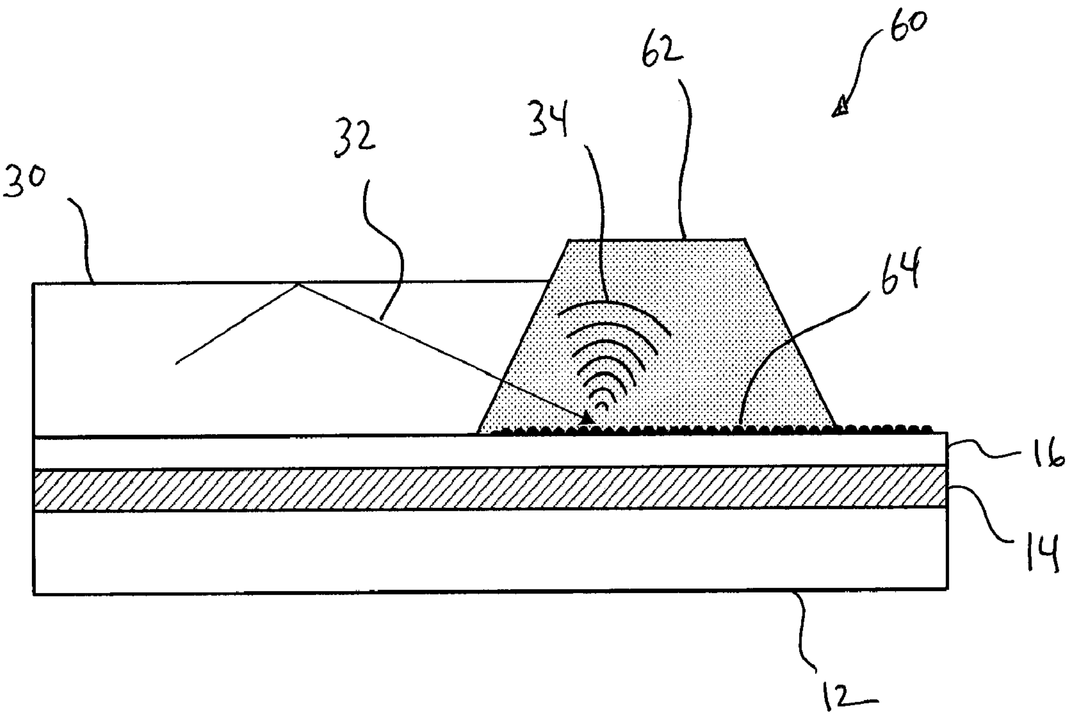

FIG. 3

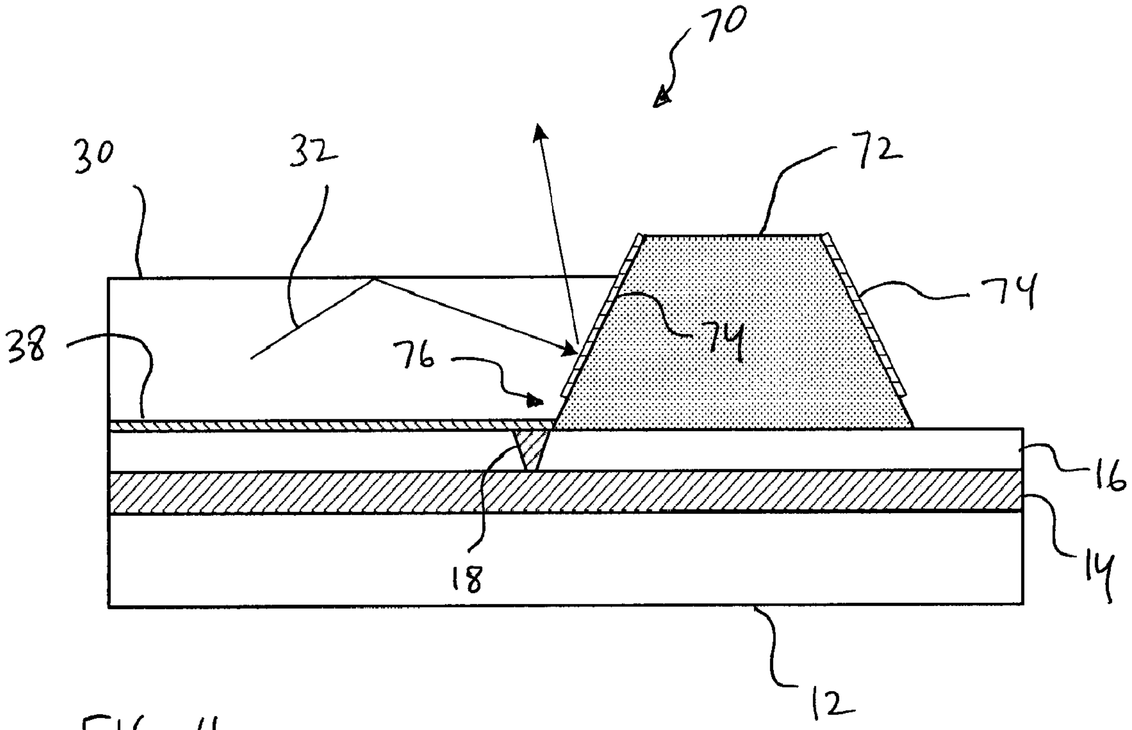

FIG. 4

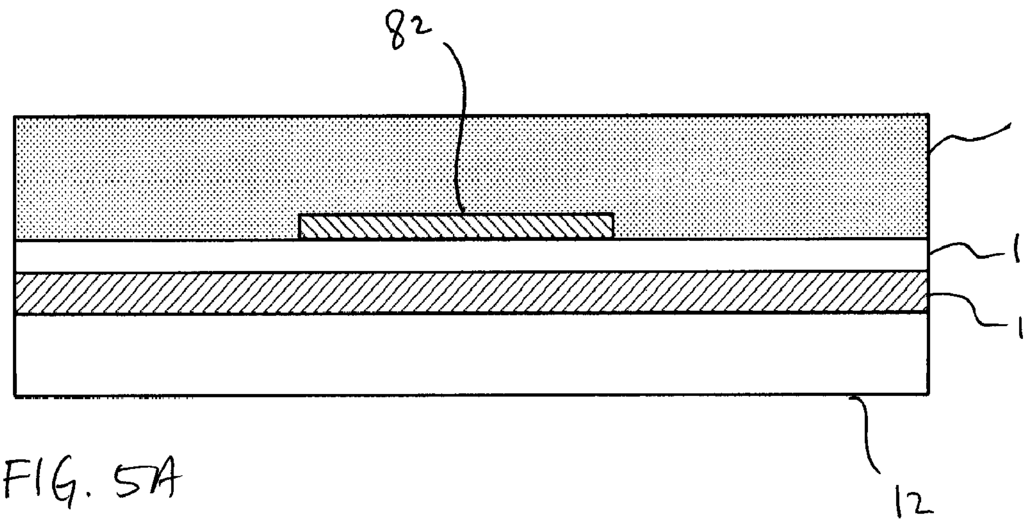

FIG. 5A

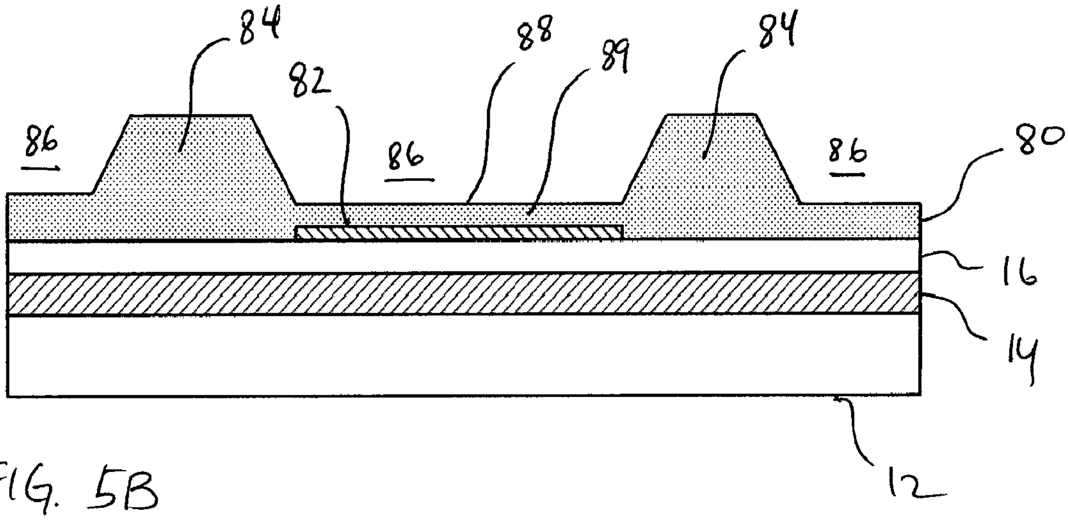

FIG. 5B

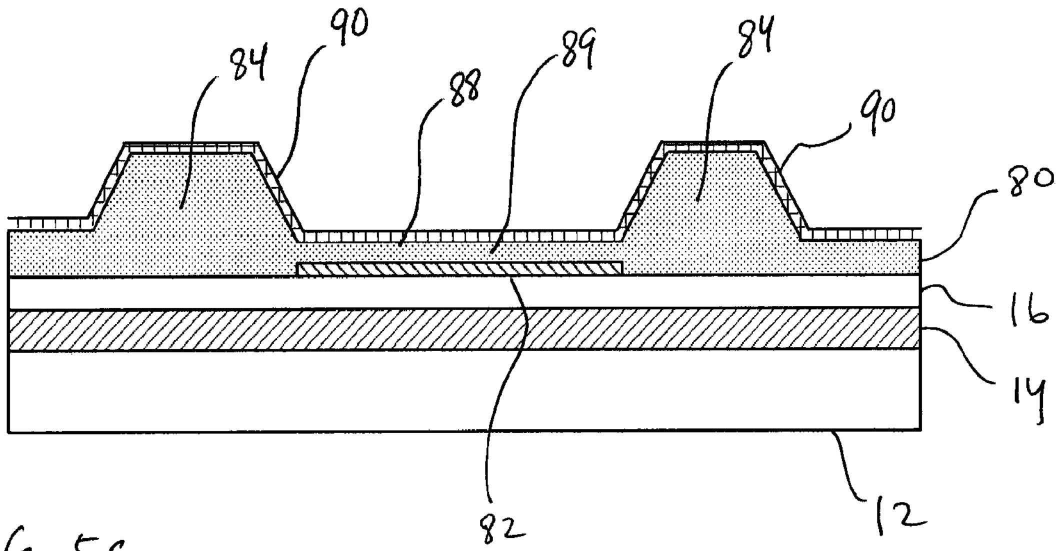

FIG. 5C

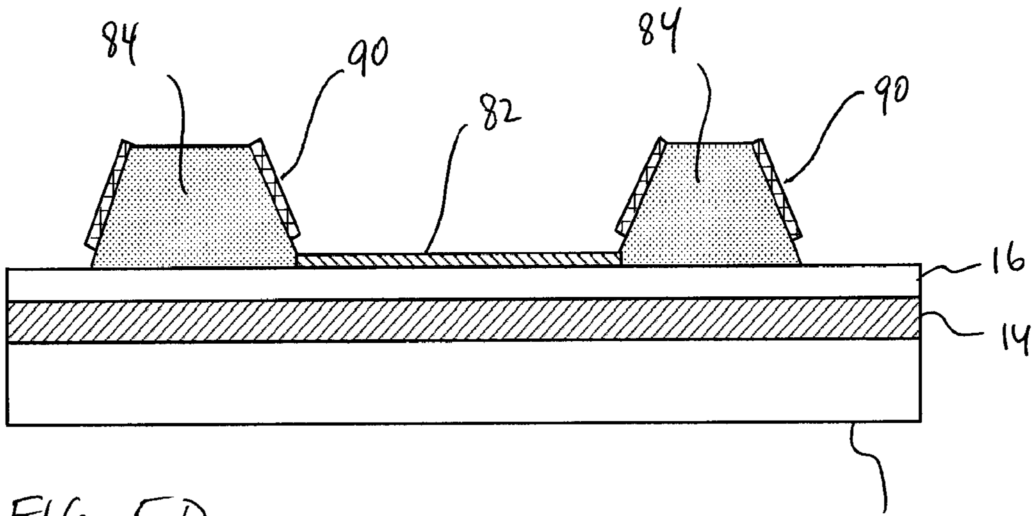

FIG. 5D

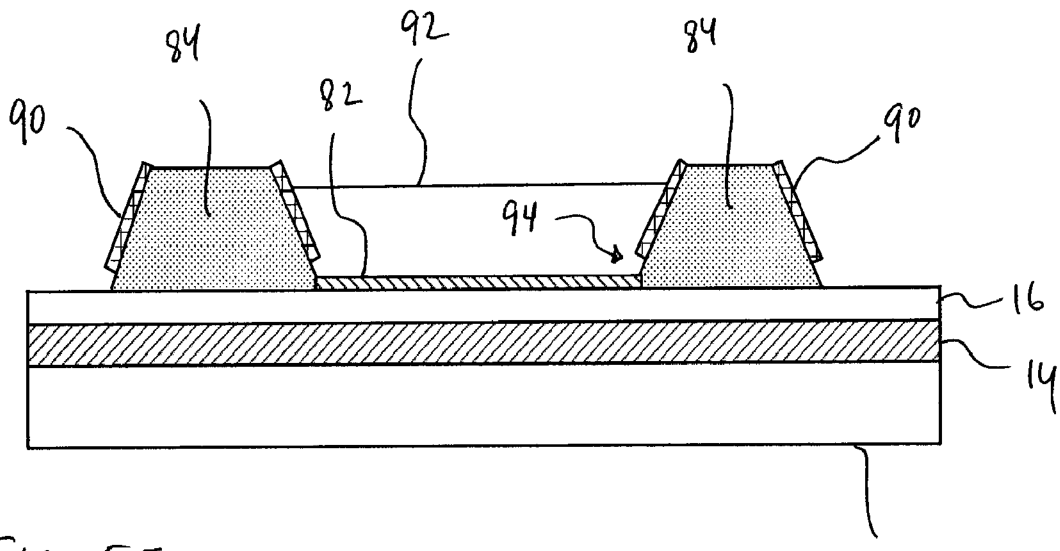

FIG. 5E

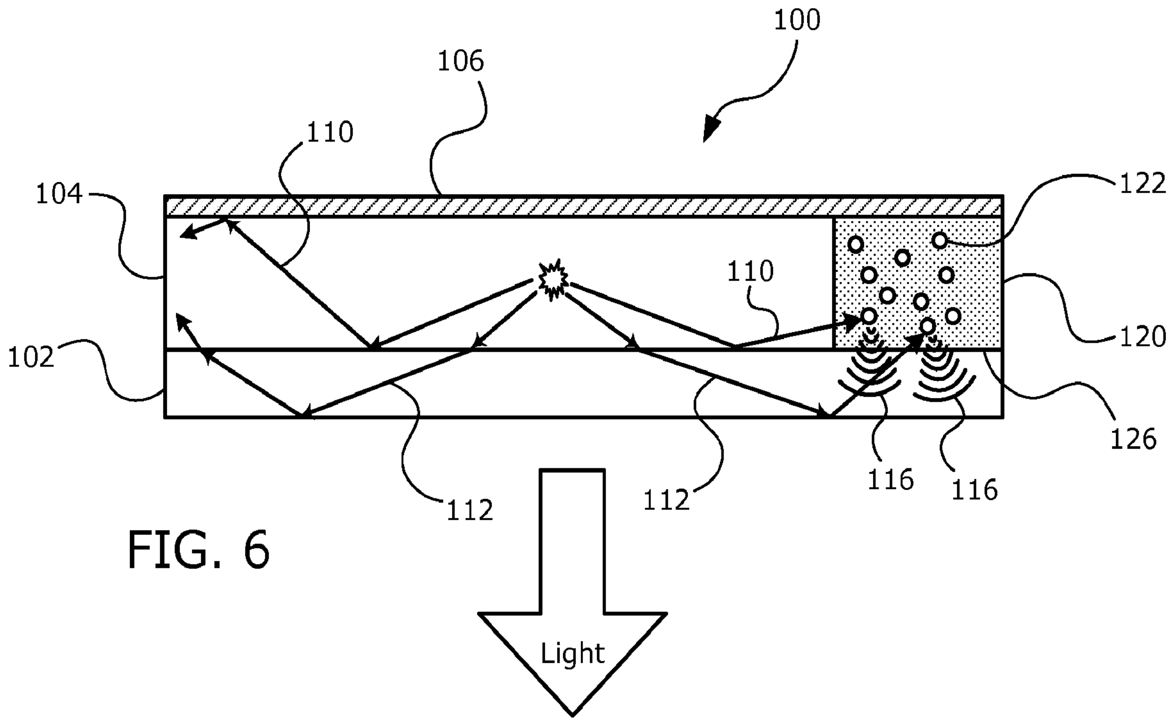
100
106
110
104
122
110
120
102
126
116
116
112
112
Light

FIG. 6

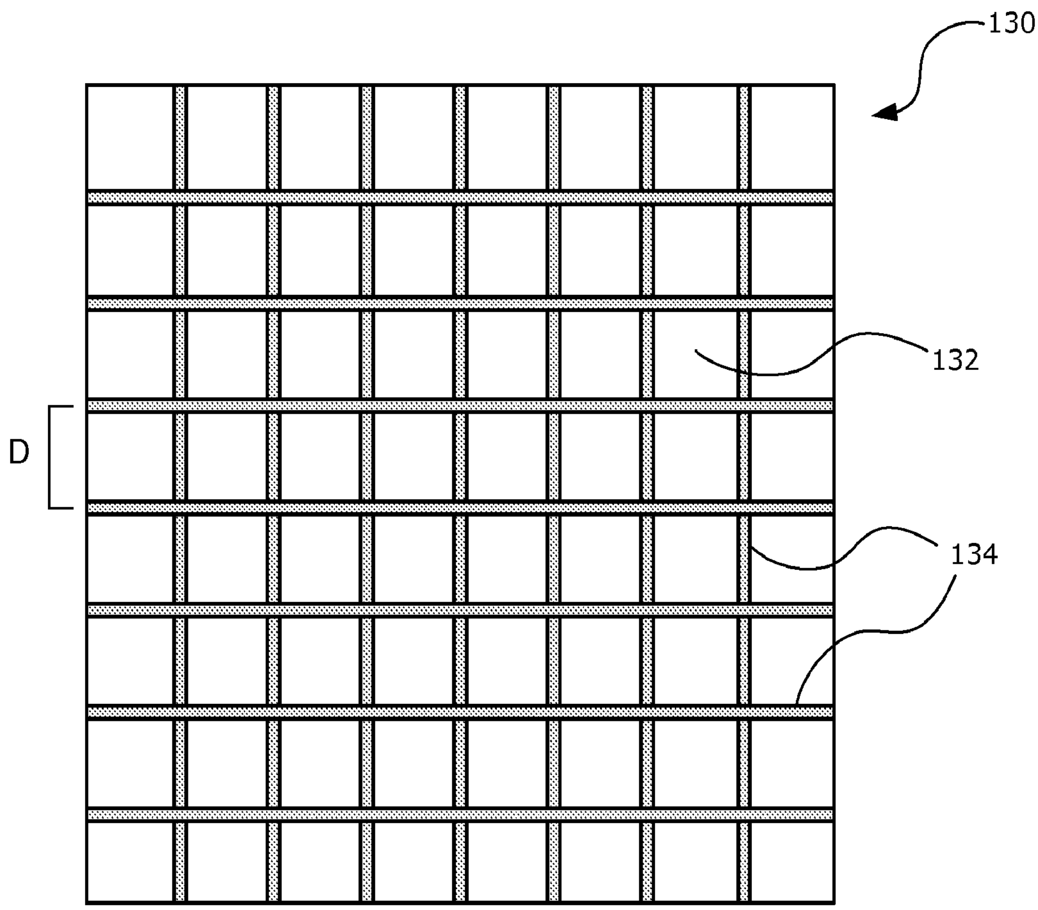
130
132
D
134

FIG. 7