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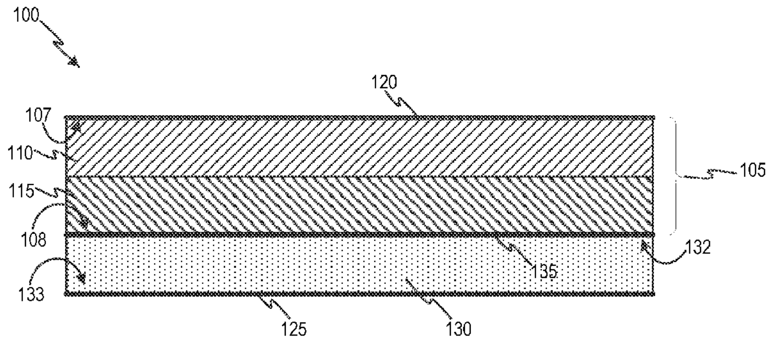

FIG. 1

(57) Abstract: Systems and methods for storing energy are disclosed. An apparatus may include a display substrate having a first surface and a second surface. In some embodiments, the first surface may include a first anode. In some embodiments, the display substrate may have a plurality of reverse biased organic light emitting diodes. The apparatus may further include an energy storage device having a first surface and a second surface. The energy storage device may also include a dielectric material and a second anode disposed on the second surface. The apparatus may also include a cathode disposed between and in contact with the second surface of the display substrate and the first surface of the energy storage device.

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DISPLAY INTEGRATED ENERGY STORAGE APPARATUS

BACKGROUND

[0001] Electronic devices, particularly mobile devices and the like have become more common in everyday society. One drawback of these electronic devices is their inability to hold an electrical charge for a desirably long period of time. As a result, users are limited by the time they can use an electronic device before charging it, thereby limiting its use as a mobile device.

[0002] Current attempts to alleviate this issue have revolved primarily around increasing battery storage capacity. However, these attempts have fallen short because the increase in battery storage capacity has also increased the size and weight of the electronic device, which also diminishes its use as a mobile device.

SUMMARY

[0003] In an embodiment, an apparatus for storing energy in a display may include a display substrate having a first surface and a second surface. In some embodiments, the first surface may include a first anode. The apparatus may further include an energy storage device having a first surface and a second surface. The energy storage device may also include a dielectric material and a second anode disposed on the second surface. The apparatus may also include a cathode disposed between and in contact with the second surface of the display substrate and the first surface of the energy storage device.

[0004] In an embodiment, an article of manufacture may include an electronic display. The electronic display may include a display substrate having a first surface and a second surface. The first surface of the display substrate may include a first anode. The electronic display may further include an energy storage device having a first surface and a second surface. The energy storage device may also include a dielectric material and a second anode disposed on the second surface. The electronic display may include a cathode disposed between and in contact with the second surface of the display substrate and the first surface of the energy storage device

[0005] In an embodiment, a method of constructing an apparatus for storing energy in a display may include providing a display substrate having a first surface and a second surface, depositing one or more first anodes upon the first surface of the display substrate, depositing one or more cathodes upon the second surface of the display substrate, depositing an energy storage device upon the one or more cathodes, and depositing one or more second anodes upon the energy storage device. The energy storage device may include a dielectric material and may share the one or more cathodes with the display substrate.

[0006] In an embodiment, an organic light emitting diode display apparatus may include a plurality of organic light emitting diodes. Each organic light emitting diode may include a cathode, an anode, and a dielectric material. Each organic light emitting diode may be configured to store a charge when being reverse biased.

[0007] In an embodiment, an apparatus for storing energy in a display may include a display substrate having a first surface and a second surface and an energy storage device having a first surface and a second surface. The energy storage device may also have a dielectric material and a first anode disposed on the second surface. The apparatus may further include a combination layer having a first surface and a second surface. The first surface of the combination layer may include a first cathode disposed on the first surface. The apparatus may further include a second cathode disposed between and in contact with the second surface of the display substrate and the first surface of the energy storage device and a second anode disposed between and in contact with the first surface of the display substrate and the second surface of the combination layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 depicts a cross-sectional schematic view of a display integrated energy storage device according to an embodiment.

[0009] FIG. 2 depicts a cross-sectional schematic view of an alternative display integrated energy storage device according to an embodiment.

[0010] FIG. 3 depicts a cross-sectional schematic view of another display integrated energy storage apparatus according to an embodiment.

[0011] FIG. 4 depicts a single organic light emitting diode according to an embodiment.

[0012] FIG. 5 depicts a flow diagram of a method of constructing an apparatus for storing energy in a display according to an embodiment.

DETAILED DESCRIPTION

[0013] This disclosure is not limited to the particular systems, devices, and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

[0014] As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

[0015] The following terms shall have, for the purposes of this application, the respective meanings set forth below.

[0016] An "electronic display" refers to a device that is capable of displaying text, images, video, and/or the like in response to receiving electronic signals. The electronic display can be configured to be integrated as a component of another device or as a standalone device. The display technology used in the electronic display is not limited by this disclosure, and may include, for example, thin film transistors, liquid crystals, light emitting diodes, organic light emitting diodes, active matrix organic light emitting diodes, color super-twist nematics, plasma, electroluminescent components, laser-based components, and the like.

[0017] An "electronic device" refers to a device that generally contains at least an electronic display and requires energy to power the electronic display. In some embodiments, the electronic device includes a processor and a tangible, non-transitory, computer-readable memory. The memory may contain programming instructions that, when executed by the processor, cause the computing device to perform one or more operations according to the programming instructions. Examples of electronic devices are not limited by this disclosure, and may include, for example, a television, a computer monitor, a display monitor, a billboard advertisement, a cellular phone, a feature phone, a smartphone, a pager, a personal digital assistant (PDA), a camera, a tablet, a phone-tablet hybrid (for example, a "phablet"), a laptop computer, a netbook, an ultrabook, a global positioning satellite (GPS) navigation device, an in-dash automotive component, a media player, a watch, a handheld imaging device, a personal medical device, an electronic photo frame, a security device, a keypad, and the like.

[0018] The present disclosure relates generally to an electronic display that includes a display integrated energy storage apparatus. The display integrated energy storage apparatus is capable of displaying text, videos, images, and/or the like, as well as storing energy because of the use of a common electrode configured to work multiple ways. This presents an advantage over other display integrated devices known in the art because of the ability to store energy rather than merely generating energy or obtaining energy from a separate energy storage device, as well as its ability to integrate several components in a much smaller and compact form factor, which increases its usability across a wide variety of electronic devices. In addition, the use of larger display substrates allows for increased energy storage, as described in greater detail herein.

[0019] FIG. 1 depicts a cross-sectional schematic view of a display integrated energy storage apparatus, generally designated **100,** according to an embodiment. The apparatus **100** may at least include, for example, a display substrate **105** and an energy storage device **130.** The apparatus **100** may generally be configured to substantially simultaneously display text, images, video, and/or the like on the display substrate **105** and store energy in the energy storage device **130.** The energy stored in the energy storage device **130** may be used, for example, to provide energy to the display substrate **105,** to provide energy to other components that may be in operable communication with the apparatus **100** and/or the like. In some embodiments, the energy storage device **130** may be positioned underneath the display substrate **105.** In other embodiments, the energy storage device **130** may be positioned on top of the display substrate **105.** In these embodiments, the energy storage device **130** may be substantially transparent so as to allow visible light to pass from the display substrate **105** through the energy storage device **130** to be viewed. In other embodiments, the energy storage device **130** may be integrated within the display substrate, as will be discussed in greater detail with respect to FIG. 4 herein. In some embodiments, the energy storage device **130** may be positioned substantially parallel to the display substrate **105.** In other embodiments, the energy storage device **130** may be positioned substantially perpendicular to the display substrate **105.** In these embodiments, the perpendicularly positioned energy storage device may additionally function as, for example, a polarizer and/or a screen protector.

[0020] In some embodiments, the display substrate **105** may be any substrate now known or later developed that can display text, images, video, and/or the like. In some embodiments, the display substrate **105** may be transparent and/or flexible. In some embodiments, the display substrate **105** may include a plurality of diodes and/or other components that may at least be capable of emitting light. Examples of a display substrate may include, for example, a thin film transistor display, a liquid crystal display, a light emitting diode display, an organic light emitting diode display, an active matrix organic light emitting diode display, a color super-twist nematic display, a liquid crystal monitor display, a plasma display, an electroluminescent display, and/or the like.

[0021] In some embodiments, the display substrate **105** may include an emissive layer **110.** The emissive layer **110** may include an organic material capable of emitting light when a current is passed between a first anode **107** and a cathode **135,** as described in greater detail herein. In some embodiments, the emissive layer **110** may contain a phosphorescent emissive material. The phosphorescent materials may have higher luminescent efficiencies associated with such materials than other emissive materials. Examples of phosphorescent emissive materials may include, but are not limited to, iridium tris(2-phenylpyidine), Tris(2,2'-bipyridine) ruthenium(II), Tris(1,10-phenanthroline)ruthenium(Il), ***fac-txis(2-*** phenylpyridinato-¥,$C^{2'}$)iridium(III), iridium(Iii) bis(2-phenyl quinolyl-*N*,$C^{2'}$) aceiylacetonate, and/or the like. In other embodiments, the emissive layer **110** may contain a fluorescent emissive material. Examples of fluorescent emissive materials may include, but are not limited to, 4,4-bis 9-ethyl-3-carbazovinylene-l,l-biphenyl and 5,12-dihydro-5,12-dimethylquino[2,3-&]acridine-7,14-dione (DMQA). In some embodiments, the emissive layer **110** may also include a host material which may be capable of transporting electrons and/or holes, doped with an emissive material that may trap electrons, holes, and/or excitons, such that excitons relax from the emissive material via a photoemissive mechanism. Examples of host materials may include, for example, tris(8-hydroxyquinolinato)aluminium (Alq_3), 4,4'-bis(*N*-carbazolyl)biphenyl (CBP) and *N,N*'-dicarbazolyl-3,5-benzene (mCP). In some embodiments, the emissive layer **110** may include a single material that combines transport and emissive properties. In some embodiments, the emissive layer **110** may include other materials, such as dopants that tune the emission of the emissive material, regardless of whether the emissive material is a dopant or a major constituent. In some embodiments, the emissive layer **110** may include a plurality of emissive materials capable of, in combination, emitting a desired spectrum of light. Examples of emissive materials may include, for example, platinum octaethylporphine (PtOEP), Tris(2,2'-bipyridine) ruthenium(II), Tris(1,10-phenanthroline)ruthenium(II), /ac-tris(2-pheny1pyridinato-*N*,$C^{2'}$)iridiura(ni), iridium(IH) bis(2-phenyl quino!yl-*N*,$C^{2'}$} acetylacetonate, transition metal complexes such as $[Cr(NH_3)_5SCN]^{2+}$, Rubidium(II) (phenanthroline), Palladium(II) α,α'-diimine, transition metal complex dendrimers such as platinum porphyrin based phosphorescent dendrimers (Pt-8C«-TPP), and/or the like. An example of a host material may be, for example, a compound with the formula of Y—$[X(Ar^1)(Ar^2)(Ar^3)]_n$, where each X is independently selected from Si, Ge, Sn, Pb, Se, Ti, Zr, and Hf; Y is selected from phenyl, alkyl, cycloalkyl, and a group of the formula Ar'-A-Ar", where each Ar' and Ar" are independently selected from an aromatic group; A is alkyl, cycloalkyl, —O—, or Si(R')(R"), where R' and R" are independently selected from phenyl or alkyl; each Ar^1, Ar^2, and Ar^3 are independently selected from alkyl or an aromatic group; each Ar^1, Ar^2, and Ar^3 may be independently substituted with one or more of alkyl, alkenyl, alkoxy, phenyl, aralkyl, halogen, NH_2, NHR, NR_2, $S1R_3$ and CN, and additionally or alternatively, one or more of adjacent Ar^1, Ar^2, Ar^3 may be linked together by a linking group selected from a covalent bond, —O—, —CH_2—, —CHR—, —CR_2—, —

NH— and —NR—; each R is selected from alkyl, alkenyl, aryl, and aralkyl; n is an integer from 2 to the maximum number of sites on Y that can accept a substituent; and where the host material has an energy gap of at least 3.2 eV and a triplet energy of at least about 3.0 eV.

[0022] In some embodiments, the emissive material may be included in the emissive layer **110** in any number of ways. For example, an emissive small molecule may be incorporated into a polymer. This may be accomplished in one or more ways, such as by doping the small molecule into the polymer either as a separate and distinct molecular species, by incorporating the small molecule into the backbone of the polymer, to form a co-polymer, or by bonding the small molecule as a pendant group on the polymer. In some embodiments, other emissive layer materials and structures may be used. For example, a small molecule emissive material may be present as the core of a dendrimer. In some embodiments, the emissive materials may include one or more ligands bound to a metal center. A ligand may be referred to as "photoactive" if it contributes directly to the photoactive properties of an organometallic emissive material. A "photoactive" ligand may provide, in conjunction with a metal, the energy levels from which and to which an electron moves when a photon is emitted. Other ligands may be referred to as "ancillary." Ancillary ligands may modify the photoactive properties of the molecule, such as, for example, by shifting the energy levels of a photoactive ligand, but ancillary ligands do not directly provide the energy levels involved in light emission. A ligand that is photoactive in one molecule may be ancillary in another.

[0023] In some embodiments, the display substrate may contain a conductive layer **115.** The conductive layer **115** may be, for example, an electron transport layer. The conductive layer may include one or more electron transport materials such as, for example, metal chelated oxinoid compounds, such as bis(2-methyl-8- quinolinolato)(para-phenyl-phenolato)aluminum(lll) (BAIQ), tris(8-hydroxyquinolato)aluminum (Alq_3), and tetrakis(5-

hydroxyquinolato)- aluminum (ZrQ); azole compounds, such as 2-(4-biphenylyl)-5-(4-t-butylphenyl)-l,3,4-oxadiazole (PBD), 3-(4-biphenylyl)-4-phenyl-5-(4-t-butylphenyl)-l,2,4-triazole (TAZ), and l,3,5-tri(phenyl-2-benzimidazole)benzene (TPBI); quinoxaline derivatives such as 2,3-bis(4-fluorophenyl)quinoxaline; phenanthroline derivatives such as 9,10-diphenylphenanthroline (DPA) and 2,9-dimethyl-4,7- diphenyl-l,10-phenanthroline (DDPA); and combinations thereof. In certain embodiments, an electron transport material may be selected from the group consisting of BAIQ, Alq_3, ZrQ, and combinations thereof.

[0024] The display substrate **105** described herein is not limited in size. In some embodiments, the display substrate **105** may have a surface size of about 1 square millimeter to about 2500 square meters. In some embodiments, the surface area of a display substrate may be about 1 square millimeter, about 1 square centimeter, about 10 square centimeters, about 100 square centimeters, about 1000 square centimeters, about 5000 square centimeters, about 1 square meter, about 5 square meters, about 10 square meters, about 25 square meters, about 50 square meters, about 100 square meters, about 1000 square meters, about 2500 square meters, and ranges between any two of these values. In some embodiments, the display substrate **105** may have a plurality of pixels and/or subpixels. The display substrate **105** may have a pixel density of about 100 pixels per inch to about 10,000 pixels per inch. In some embodiments, the display substrate pixel density may be about 100 pixels per inch, about 500 pixels per inch, about 1000 pixels per inch, about 2500 pixels per inch, about 5000 pixels per inch, about 10,000 pixels per inch, and ranges between any two of these values.

[0025] In some embodiments, the display substrate **105** may have a first surface **107** and a second surface **108.** The first surface **107** may generally be a surface that is used for viewing the text, images, video, and/or the like of the display. In some embodiments, the first surface **107** may be affixed to another substrate such as, for example, a protective glass substrate, a protective polymer substrate, and/or the like. In some embodiments, the first surface 107 may include the first anode 120. The first anode 120 may be affixed to the first surface 107 and/or may be integrated as a portion of the first surface. In some embodiments, the second surface 108 may be in contact with a cathode 135, as described in greater detail herein. As a result, an electrical current may be passed from the cathode 135 to the first anode 120 through the display substrate 105 to cause excitation of the diodes and/or other objects to allow visible light to be emitted from the display substrate 105, as described in greater detail herein.

[0026] In various embodiments, the energy storage device 130 may include a dielectric material. Examples of dielectric materials may include, for example, silicone polymers, epoxies, polyimide, polyethylene, polypropylene, polyphenylene oxide, polysulphone, solge! materials, ceramers, silicon dioxide, aluminum oxide, zirconium oxide, and other metal oxide insulators. In some embodiments, the dielectric material may be a portion of a laminate structure, such as, for example, structures having at least a laminate dielectric thin film, one or more layers of dielectric material, and/or the like. In some embodiments, the dielectric material may be configured to provide uniform backlighting for the display substrate 105. In those embodiments, the dielectric material may further include, for example, a photon waveguide, a dispersion agent, and/or the like. The photon waveguide may generally be a device used to evenly disperse photons. The dispersion agent may include, for example, polyethylene glycol, polypyrrole (PPy), dodecyl octaethylene glycol ether (CnEOs), and polyaniline (PAn). In some embodiments, the dielectric material may be a high dielectric material that is configured to provide increased heat transfer, rigidity, and low thermal conductivity. Examples of a high dielectric material may include, for example, a ferroelectric material, a paraelectric material, tantalum oxide, and barium strontium titanate.

[0027] In various embodiments, the energy storage device 130 may be optimized for heat transfer. In some embodiments, the energy storage device 130 may incorporate one or more heat pipes and/or one or more other advanced heat dissipation properties. In some embodiments, use of heat pipes and/or other advanced heat dissipation properties may improve performance of the apparatus 100. In other embodiments, the energy storage device 130 may contain one or more ceramic components. Ceramic components may be selected for their chemical stability, thermal stability, and low coefficient of thermal expansion.

[0028] In various embodiments, the energy storage device 130 may have a first surface 132 and a second surface 133. In some embodiments, a second anode 125 may be disposed on the second surface 133 of the energy storage device 130. In some embodiments, the second surface 133 may be modified to increase its surface area to increase the total energy storage for a given potential. In some embodiments, the energy storage device 130 may incorporate and/or work in conjunction with one or more of a capacitor, a parallel plate capacitor, a pseudocapacitor, an ultracapacitor, an electric double layer capacitor, a battery, and the like. In other embodiments, the energy storage device 130 may act as a capacitor, a parallel plate capacitor, a pseudocapacitor, an ultracapacitor, an electric double layer capacitor, a battery, and/or the like.

[0029] In various embodiments, the apparatus 100 may also include the cathode 135 disposed between and in contact with the second surface 108 of the display substrate 105 and the first surface 107 of the energy storage device 130. In some embodiments, the cathode 135 may be configured to attach to one or more external energy sources, such as through an interface and/or the like. In some embodiments, the cathode 135 may be a common electrode that is used by both the display substrate 105 and the energy storage device 130. In some embodiments, the positioning of the first anode 120 on the first surface 107 of the display substrate 105, the cathode 135 between the display substrate 105 and the energy storage device 130, and the second anode 125 on the second surface 133 of the energy storage device 130 may ensure the flow of electrical current flows from the cathode 135 to both of the anodes **120, 125.** As a result, in some embodiments, the positioning of the first anode **120,** the second anode **125,** and the cathode **135** may provide an array addressable electric field. The array addressable electric field may generally be an electric field that has a strength and a shape that can be manipulated by adjusting the applied voltage and/or the position of the electrodes **120, 125, 135.** The electric field may be selectively tuned to affect all or part of the display through the placement of the electrodes **120, 125, 135** near the display substrate **105** and the amount of voltage supplied. In other embodiments, the positioning of the first anode **120,** the second anode **125,** and the cathode **135** may provide an array addressable current flow. In some embodiments, the cathode **135** may further be coupled with one or more complementary electrodes, which may improve energy density.

[0030] In some embodiments, any of the first anode **120,** the second anode **125,** and the cathode **135** may include one or more electrically conductive materials. Examples of electrically conductive materials may include, but are not limited to, metals such as copper, aluminum, nickel, gold, and stainless steel. In other embodiments, the energy storage device 130 may include a semiconducting material. Examples of semiconducting materials may include organic and/or inorganic semiconductors. Suitable inorganic semiconductors may include, for example, silicon, silicon carbide, boron nitride, aluminum nitride, nickel oxide, zinc oxide, and zinc sulfide. Suitable organic semiconductors may include, for example, poly-3-hexylthiophene, pentacene, perylene, carbon nanotubes, and C_{60} fullerenes.

[0031] FIG. 2 depicts a cross-sectional schematic view of an alternative display integrated energy storage apparatus, generally designated **200,** according to an embodiment. Similar to the display integrated apparatus **100** of FIG. 1, the alternative apparatus **200** may at least include, for example, a display substrate **205** and an energy storage device **230.** The alternative apparatus **200** may generally be configured to substantially simultaneously display text, images, video, and/or the like on the display substrate **205** and store energy in the energy storage device **230.** The energy stored in the energy storage device **230** may be used, for example, to provide energy to the display substrate **205,** to provide energy to other components that may be in operable communication with the alternative apparatus **200** and/or the like.

[0032] In various embodiments, the display substrate **205** may include an emissive layer **210** and/or a conductive layer **215,** as well as a first surface **207** and a second surface **208.** In some embodiments, a first anode **220** may be disposed upon the first surface **207** of the display substrate **205.**

[0033] In various embodiments, the energy storage device **230** may have a first surface **232** and a second surface **233.** The first surface **235** of the energy storage device **230** may be in contact with a cathode **235,** where the cathode is also in contact with the second surface **208** of the display substrate **205.** A second anode **225** may be disposed upon the second surface **233** of the energy storage device **230.**

[0034] In various embodiments, the energy storage device **230** may be an electrochemical double layer capacitor. In some embodiments, the energy storage device **230** may lack a dielectric material, which may be replaced by an electrolyte. The electrolyte may include, for example, a conductive salt and/or a solvent. Specific examples of the electrolyte may include polymer gel electrolytes such as Poly(vinyl alcohol) (PVA), Poly(vinyl chloride), Poly(ethylene oxide) (PEO), Poly(vinylidene carbonate), and Poly(vinylidene fluoride), polymer gel electrolytes with redox electrochemical active compound additives such as PEO-$L1ClO_4$ with Nal-I_2, PVA-H_2S0_4 with P-benzenediol, PVA-KOH with KI, and PVA-H_2SO_4 with hydroquinone ($C_6H_4(OH)_2$), and Room Temperature Molten Salts (RTMS) such as l-ethyl-3-methylimidazolium (EMI), *N,N*-diethyl-*N*-methyl-*N*-(2-methoxyethyl)ammonium, BF_4, and bis(trifluoromethane)sulfonamide $(CF_3SO_2)_2N$ (TFSI). In some embodiments, the electrolyte may be a liquid with low viscosity, low density, and high conductivity over a range of ambient temperature conditions. In some embodiments, the electrolyte may be commercially inexpensive, chemically and electrochemically stable, and compatible with carbon. In some embodiments, the electrolyte may provide a voltage below 1.8 V. In other embodiments, particularly those containing an electrolyte with an organic aprotic liquid may be less prone to form gas and may be more effective in providing a higher energy density over a wide usable range of temperature and potential. In these embodiments, the electrolyte may permit a voltage greater than 1.8 V, which may result in a higher capacity in the capacitor.

[0035] In some embodiments, the second anode **225** and the cathode **235** may be provided by an oxide or carbon layer formed on metal foil and separated by a porous non-conducting membrane **240.** Examples of the porous non-conducting membrane **240** include, but are not limited to, paper, porous propylene, and/or the like. The liquid electrolyte may provide electrical contact to the second anode **225** and the cathode **235** through the porous non-conducting membrane **240.** This may result in an inherently high resistance, which may be mitigated by rolling a large sheet of electrode material into a roll to give high surface area. In some embodiments, the resistance of the electrolyte may be a significant factor in the total resistance. In some embodiments, temperature may have a major influence on the electrolyte in the performance of the energy storage device **230** since the conductivity of the electrolyte decreases with temperature. The energy storage device **230** may further include one or more electrical interfaces to an external device, such as a power supply, separators, and/or one or more environmental seals.

[0036] FIG. 3 depicts a cross-sectional schematic view of another display integrated energy storage apparatus, generally designated **300,** according to an embodiment. In some embodiments, the apparatus **300** may have at least a display substrate **305,** an energy storage device **330,** and a combination layer **350.**

[0037] In various embodiments, the display substrate **305** may generally be located between the energy storage device **330** and the combination layer **350.** In some embodiments, the display substrate **305** may have a first surface **307** and a second surface **308.** The first surface **307** may be substantially proximate to the combination layer **350,** and the second surface **308** may be substantially proximate to the energy storage device **330.**

[0038] In various embodiments, the energy storage device **330** may have a first surface **332** and a second surface **333.** In some embodiments, the first surface **332** may be substantially proximate to the display substrate **305.** In some embodiments, the energy storage device **330** may have a first anode **360** disposed on the second surface **333.** In some embodiments, a second cathode **365** may be disposed between and in contact with the second surface **308** of the display substrate **305** and the first surface **332** of the energy storage device **330.** In some embodiments, the energy storage device **330** may contain a dielectric material. In other embodiments, the energy storage device **330** may contain an electrolyte.

[0039] In various embodiments, the combination layer **350** may have a first surface **352** and a second surface **353.** In some embodiments, the second surface **353** of the combination layer **350** may be substantially proximate to the display substrate **305.** In some embodiments, a first cathode **355** may be disposed on the first surface **352** of the combination layer **350.** In some embodiments, a second anode **370** may be disposed between and in contact with the first surface **307** of the display substrate **305** and the second surface **353** of the combination layer **350.** In some embodiments, a first cathode **355** may be disposed on the first surface **352** of the combination layer **350.**

[0040] In some embodiments, the combination layer **350** may be used to provide additional energy storage. In these embodiments, the combination layer **350** may have the same elements and properties discussed herein with respect to the various energy storage devices described herein. In some embodiments, the combination layer **350** may provide protection for the display substrate **305** to prevent damage. In some embodiments, the combination layer **350** may act as a polarizer.

[0041] FIG. 4 depicts a single organic light emitting diode (OLED), generally designated **400,** according to an embodiment. A plurality of OLEDs **400** may be present in any of the display substrates previously described herein, as well as any display substrate not particularly described. The OLED **400** may be reverse biased so that the flow of electrical current flows from the anode **410** to the cathode **405,** which is the opposite of the operation previously described herein. This reverse biasing may occur at a voltage of -5 V or greater, but at an amount that is below an LED breakdown voltage. The LED breakdown voltage may be the voltage at which the diode begins to conduct backwards. Reverse breakdown voltage may vary depending on the chip geometry and dopant concentration of the LED, but typical values for a GalnN/GaN multiple quantum well LED may range from about 11 V to about 23 V. By limiting the voltage when in a reverse bias mode, damage to the LED may be avoided. Furthermore, in some embodiments, reverse biasing may cause a depletion layer capacitance to dominate the OLED **400,** which turns the OLED into a capacitor to store energy. The OLED **400** may further be configured to emit light when it discharges the stored energy. When a reverse bias voltage is applied to the OLED **400,** an excess of charge carriers build up in a depletion region. Once the reverse bias voltage is removed, the stored charge carriers may be released from the depletion region and may travel through a circuit. This effect is analogous to the operation of an electrical capacitor. With proper wiring of the circuit containing the OLED **400,** energy released during depletion layer capacitance discharge may be converted into emitted light.

[0042] FIG. 5 depicts a flow diagram of a method of constructing an apparatus for storing energy in a display according to an embodiment. The method described herein may be completed by any individual, group of individuals, machine, group of machines and/or the like. For purposes of clarity, a "system" will be referred to as completing the processes described herein, where the system is any combination of individuals, machines and/or the like. Furthermore, the processes described herein refer generally to "depositing," which can be any appropriate method of application now known or later developed, including, but not limited to, spin coating, dip coating, evaporative deposition, cladding, thermal vapor deposition, E-beam evaporation, coat sputtering, pulsed laser deposition, chemical vapor deposition, and other similar methods

[0043] In various embodiments, the system may provide **505** a display substrate, such as, for example, any of the display substrates described herein with respect to FIGS. 1-3. The display substrate may have at least a first surface and a second surface.

[0044] The system may deposit **510** one or more first anodes upon the second surface of the display substrate, and may also deposit **515** one or more cathodes upon the first surface of the display substrate. The anodes and the cathodes may be any electrodes now known or later developed, including, but not limited to, the cathodes previously described with respect to FIGS. 1-4 herein.

[0045] In various embodiments where a combination layer is used, the system may deposit **520** the combination layer upon the display substrate. In some embodiments, the combination layer may be deposited **520** upon the first anodes attached to the second surface of the display substrate. In some embodiments, the combination layer may include a plurality of third electrodes, where at least one of the third electrodes is an anode shared with the display substrate.

[0046] In various embodiments, the system may deposit **525** an energy storage device upon the one or more cathodes. In some embodiments, the energy storage device may be deposited **525** in such a manner that it shares the one or more cathodes with the display substrate. In some embodiments, the energy storage device may be deposited **525**

substantially parallel to the display substrate, as previously described herein. In other embodiments, the energy storage device may be deposited **525** substantially perpendicular to the display substrate, as previously described herein.

[0047] In some embodiments, the system may deposit **530** one or more second anodes upon the energy storage device. In some embodiments, the one or more second anodes may be deposited **530** upon the second surface of the energy storage device, as previously described herein.

[0048] In various embodiments, the system may deposit **535** additional materials. The additional materials are not limited by this disclosure, and may include, for example, additional substrates, additional layers, additional laminating materials, additional electrodes, connections to other components, and/or the like.

EXAMPLES

Example 1: Display Device with Integrated Electrochemical Double Layer Capacitor

[0049] A semi-flexible electrochemical double layer capacitor (EDLC) with an organic light emitting diode (OLED) display substrate may have a stack that includes a 0.5 mm polycarbonate sheet (20 cm **x** 15cm), a thin film current collector, and an EDLC having a 2 mm **x** 3 mm thick graphene electrodes in l-butyl-3-methyl-imidaxzolium tetraflouroborate (BMIM BF4)/AN electrolyte separated by an ion exchange membrane. The stack may further include a 0.5 mm thick OLED device that includes a common electrode (which serves as a cathode current collector of the EDLC), an OLED bilayer, and a transport anode. The stack may be about 7.5 mm thick. The stack may have a total capacitance of 10800 F (= 20 cm **x** 15cm **x** 0.6 cm **x** 60 F/cm^3) at a working potential of 3.5 V for an energy storage of about 66 kJ (=0.5 **x** 10800 F **x** (3.5 v)^2) or about 18 Wh.

Example 2: PLED Display with Reverse Biased Electrodes

[0050] A standard OLED display may have a stack consisting of (in order): a plurality of cathodes arranged in a cathode layer, an LED stack having a plurality of OLEDs, and a plurality of anodes arranged in an anode layer. The display can be removably attached to an external power supply that charges the display when plugged in. The external power supply is configured to provide about -1.2 V across the stack in a manner that is reverse biased so that the electric charge flows from the anode to the cathode, thereby causing each OLED to act as a capacitor. When the display is removed from the external power supply, the stored charge is used to power the display.

Example 3: Computing Device

[0051] A computing device, particularly a laptop or a tablet, includes a display integrated energy storage apparatus. The display integrated energy storage apparatus has a bilayer OLED display substrate with OLEDs that can be reverse biased. The display substrate shares a cathode with an electrochemical double layer capacitor. The computing device is configured to use the reverse biased OLEDs and the electrochemical double layer capacitor to store charge used to power the display when the computing device is not connected to an AC power outlet. In addition, the display integrated energy storage apparatus can be used to power other components of the computing device. The display is larger than other computing devices to permit additional storage capacity. As a result, the computing device has a very small secondary battery for use in powering its remaining components. This computing device configuration is significantly lighter than other computing devices and can hold a charge for an extended period of time, which allows the computing device to run untethered to an AC power outlet for longer periods of time than other computing devices. In addition, the computing device is less bulky than other computing devices, despite having a larger display.

[0052] In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0053] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

[0054] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0055] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of or "consist of the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example), the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, " a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, " a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[0056] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0057] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera As a nonlimiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0058] Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

CLAIMS

What Is Claimed Is:

1. An apparatus for storing energy in a display, the apparatus comprising:

a display substrate comprising a first surface and a second surface, wherein the first surface comprises a first anode;

an energy storage device comprising a first surface and a second surface, the energy storage device comprising a second anode disposed on the second surface; and

a cathode disposed between and in contact with the second surface of the display substrate and the first surface of the energy storage device.

2. The apparatus of claim 1, wherein the cathode is a common electrode configured to provide an electrical charge to at least a plurality of pixels contained within the display substrate.

3. The apparatus of claim 1, wherein the energy storage device further comprises a dielectric material.

4. The apparatus of claim 3, wherein the dielectric material is a high dielectric material that is configured to provide increased heat transfer, rigidity, and low thermal conductivity.

5. The apparatus of claim 4, wherein the dielectric material is barium strontium titanate.

6. The apparatus of claim 3, wherein the dielectric material comprises a laminate structure.

7. The apparatus of claim 3, wherein the dielectric material is a photon waveguide configured to provide uniform backlighting for the display substrate.

8. The apparatus of claim 3, wherein the dielectric material is a dispersion agent configured to provide uniform backlighting for the display substrate.

9. The apparatus of claim 1, wherein the energy storage device further comprises an electrolyte.

10. The apparatus of claim 1, wherein the energy storage device comprises a capacitor, a parallel plate capacitor, a pseudocapacitor, an ultracapacitor, an electric double layer capacitor, or a battery.

11. The apparatus of claim 1, wherein the energy storage device provides one or more beneficial properties selected from heat transfer, rigidity, and thermal conductivity.

12. The apparatus of claim 1, wherein the energy storage device is positioned substantially parallel to the display substrate.

13. The apparatus of claim 1, wherein the energy storage device is positioned substantially perpendicular to the display substrate.

14. The apparatus of claim 1, wherein the display substrate is a thin film transistor display, a liquid crystal display, a light emitting diode display, an organic light emitting diode display, an active matrix organic light emitting diode display, a color super-twist nematic display, a liquid crystal monitor display, a plasma display, or an electroluminescent display.

15. The apparatus of claim 1, wherein the first anode, the second anode, and the cathode provide an array addressable electric field.

16. The apparatus of claim 1, wherein the first anode, the second anode, and the cathode provide an array addressable current flow.

17. The apparatus of claim 1, wherein the display substrate further comprises at least one of an emissive layer and a conductive layer.

18. An article of manufacture comprising:

an electronic display comprising:

a display substrate comprising a first surface and a second surface, wherein the first surface comprises a first anode;

an energy storage device comprising a first surface and a second surface, the energy storage device comprising a second anode disposed on the second surface; and

a cathode disposed between and in contact with the second surface of the display substrate and the first surface of the energy storage device.

19. The article of manufacture of claim 18, wherein the cathode is a common electrode configured to provide an electrical charge to at least a plurality of pixels contained within the display substrate.

20. The article of manufacture of claim 18, wherein the energy storage device further comprises a dielectric material.

21. The article of manufacture of claim 20, wherein the dielectric material is a high dielectric material that is configured to provide increased heat transfer, rigidity, and low thermal conductivity.

22. The article of manufacture of claim 20, wherein the dielectric material comprises barium strontium titanate.

23. The article of manufacture of claim 20, wherein the dielectric material comprises a laminate structure.

24. The article of manufacture of claim 20, wherein the dielectric material is a photon waveguide configured to provide uniform backlighting for the display substrate.

25. The article of manufacture of claim 20, wherein the dielectric material is a dispersion agent configured to provide uniform backlighting for the display substrate.

26. The article of manufacture of claim 18, wherein the energy storage device further comprises an electrolyte.

27. The article of manufacture of claim 18, wherein the energy storage device comprises a capacitor, a parallel plate capacitor, a pseudocapacitor, an ultracapacitor, an electric double layer capacitor, or a battery.

28. The article of manufacture of claim 18, wherein the energy storage device provides one or more beneficial properties selected from heat transfer, rigidity, and thermal conductivity.

29. The article of manufacture of claim 18, wherein the energy storage device is positioned substantially parallel to the display substrate.

30. The article of manufacture of claim 18, wherein the energy storage device is positioned substantially perpendicular to the display substrate.

31. The article of manufacture of claim 18, wherein the display is a thin film transistor display, a liquid crystal display, a light emitting diode display, an organic light emitting diode display, an active matrix organic light emitting diode display, a color super-twist nematic display, a liquid crystal monitor display, a plasma display, or an electroluminescent display.

32. The article of manufacture of claim 18, wherein the first anode, the second anode, and the cathode provide an array addressable electric field.

33. The article of manufacture of claim 18, wherein the first anode, the second anode, and the cathode provide an array addressable current flow.

34. The article of manufacture of claim 18, wherein the display substrate further comprises at least one of an emissive layer and a conductive layer.

35. The article of manufacture of claim 18, wherein the article is a television, a computer monitor, a display monitor, a billboard advertisement, a cellular phone, a feature phone, a smartphone, a pager, a personal digital assistant, a camera, a tablet, a phone-tablet hybrid, a laptop computer, a netbook, an ultrabook, a global positioning satellite navigation device, an in-dash automotive component, a media player, a watch, a handheld imaging device, a personal medical device, an electronic photo frame, a security device, or a keypad display.

36. A method of constructing an apparatus for storing energy in a display, the method comprising:

providing a display substrate comprising a first surface and a second surface;

depositing one or more first anodes upon the first surface of the display substrate;

depositing one or more cathodes upon the second surface of the display substrate;

depositing an energy storage device upon the one or more cathodes, wherein the energy storage device shares the one or more cathodes with the display substrate; and

depositing one or more second anodes upon the energy storage device.

37. The method of claim 36, further comprising:

depositing a combination layer upon the first anodes attached to the second surface of the display substrate, wherein the combination layer comprises:

a plurality of third electrodes, wherein at least one of the third electrodes is an anode shared with the display substrate; and

a dielectric material.

38. The method of claim 36, wherein depositing the energy storage device comprises depositing the energy storage device substantially parallel to the display substrate.

39. The method of claim 36, wherein depositing the energy storage device comprises depositing the energy storage device substantially perpendicular to the display substrate.

40. An organic light emitting diode display apparatus, the apparatus comprising:

a plurality of organic light emitting diodes,

wherein each organic light emitting diode comprises a cathode, an anode, and a dielectric material, and

wherein each organic light emitting diode is configured to store a charge when being reverse biased.

41. The organic light emitting diode display apparatus of claim 40, wherein each light emitting diode is configured to store a charge when being reverse biased by -5 Volts.

42. An apparatus for storing energy in a display, the apparatus comprising:

a display substrate comprising a first surface and a second surface;

an energy storage device comprising a first surface and a second surface, the energy storage device comprising a first anode disposed on the second surface;

a combination layer comprising a first surface and a second surface, wherein the first surface comprises a first cathode disposed on the first surface;

a second cathode disposed between and in contact with the second surface of the display substrate and the first surface of the energy storage device;

a second anode disposed between and in contact with the first surface of the display substrate and the second surface of the combination layer.

43. The apparatus of claim 42, wherein at least one of the combination layer and the energy storage device comprises a dielectric material.

44. The apparatus of claim 42, wherein the combination provides a protective covering for the display substrate.

45. The apparatus of claim 42, wherein the second cathode is a common electrode configured to provide an electrical charge to at least a plurality of pixels contained within the display substrate.

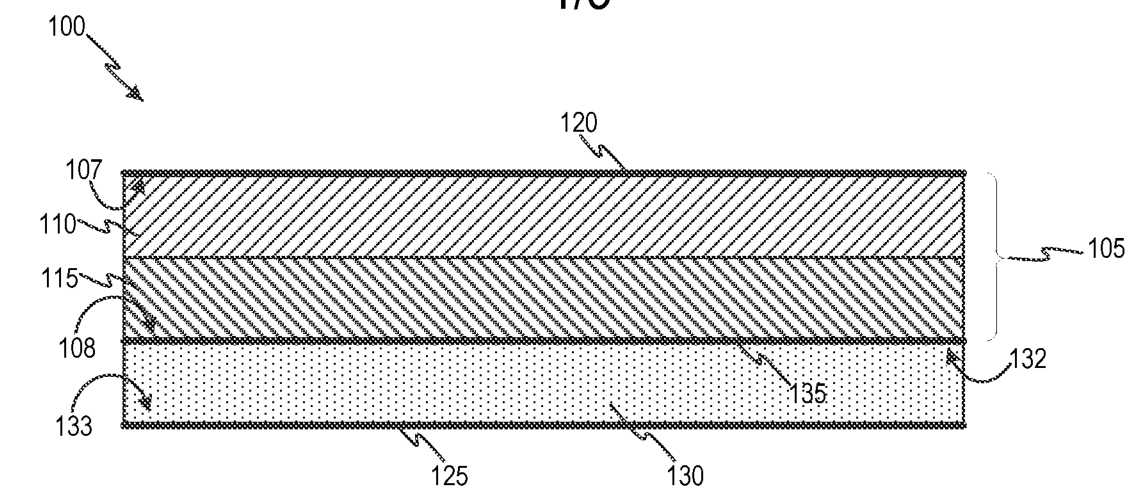
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FIG. 1

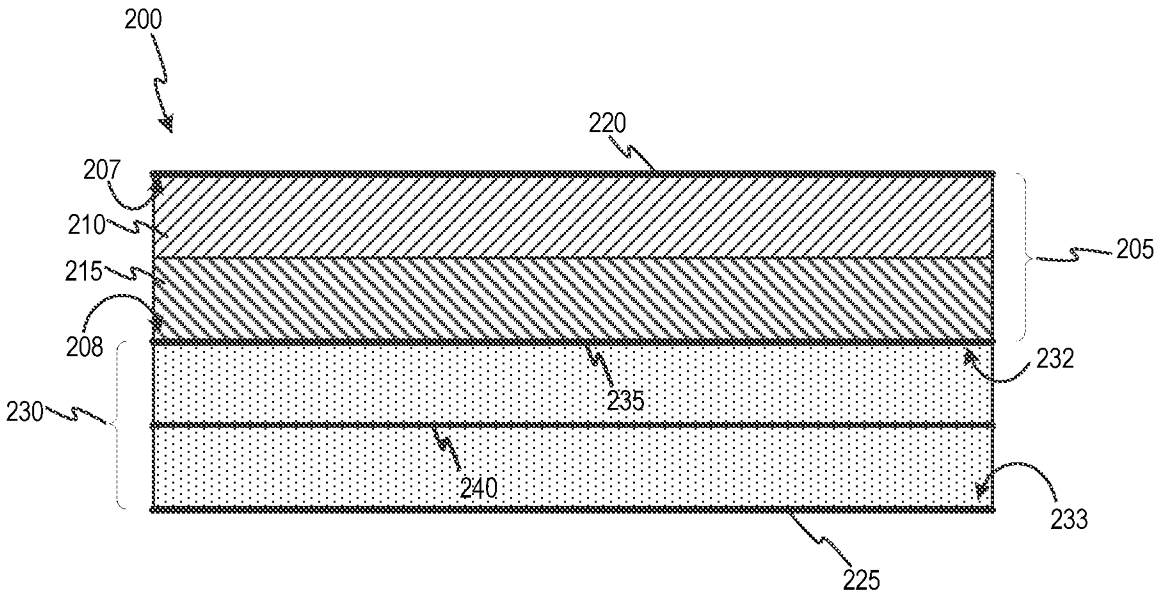
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FIG. 2

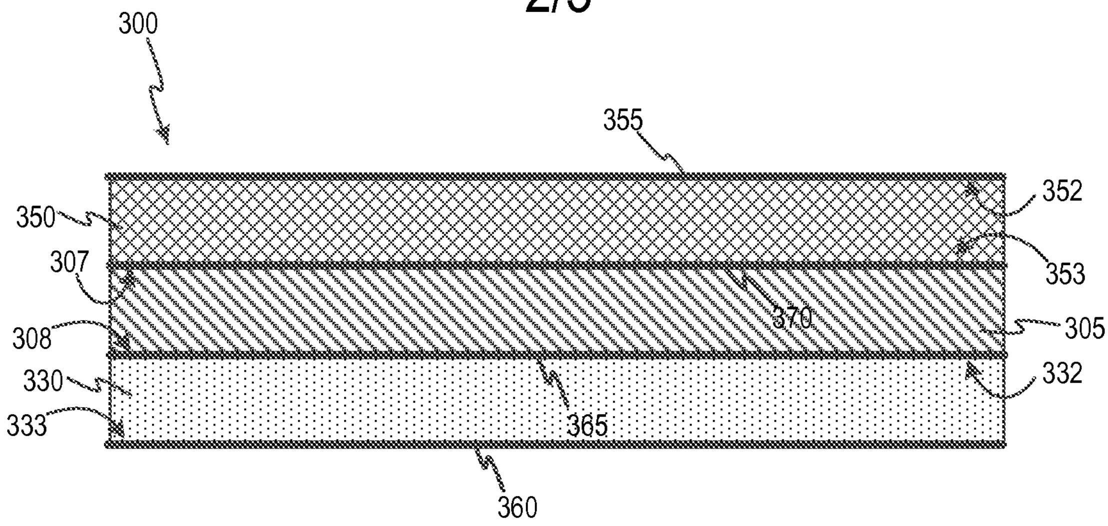
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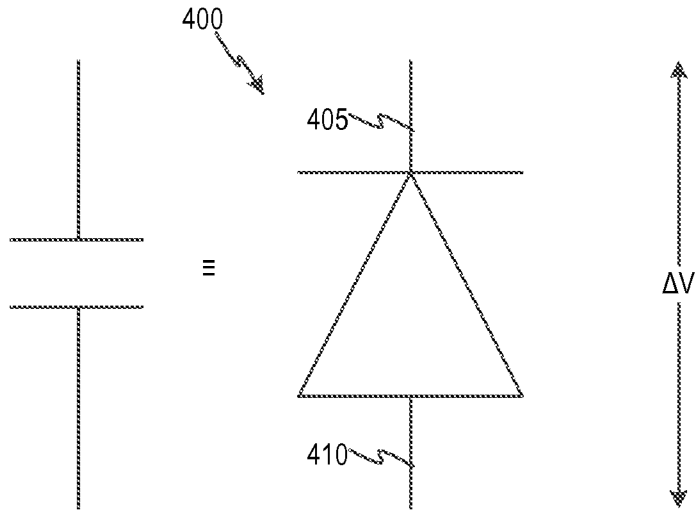
FIG. 3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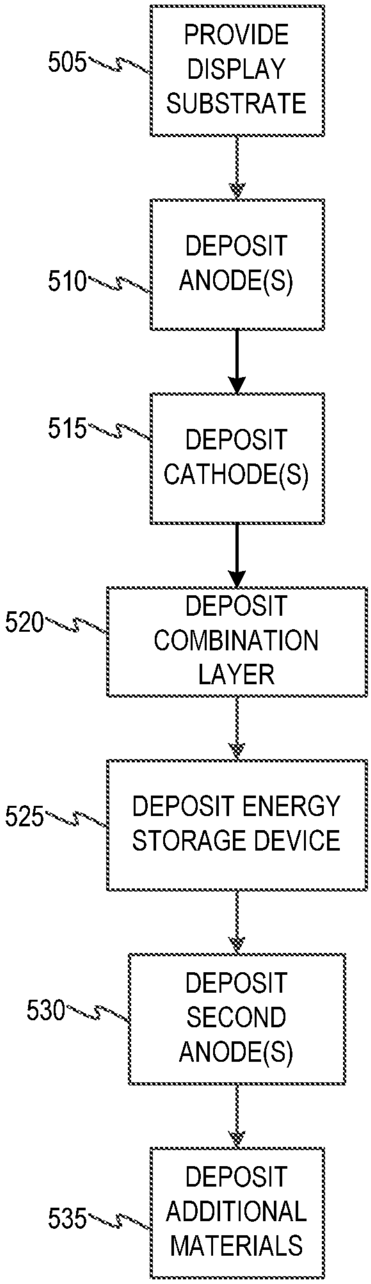
405
≡
ΔV
410

FIG. 4



505
PROVIDE DISPLAY SUBSTRATE
510
DEPOSIT ANODE(S)
515
DEPOSIT CATHODE(S)
520
DEPOSIT COMBINATION LAYER
525
DEPOSIT ENERGY STORAGE DEVICE
530
DEPOSIT SECOND ANODE(S)
535
DEPOSIT ADDITIONAL MATERIALS

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 13/48232

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G02F 1/1343, 1/1337, 1/139 (2013.01)
USPC - 257/59, 72: 349/139
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)
IPC(8): G02F 1/1343, 1/1337, 1/139; H01L 21/28, 29/04; H05K 3/10, 1/02 (2013.01)
USPC: 257/E21 .158, 59, 72; 349/139, 123; 29/846; 174/250

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 practicable, search terms used)
MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-CB, DE-A, DE-T, DE-U, GB-A, FR-A); Google Scholar; Google; ProQuest;
KEYWORDS: display substrate electrode charge storage capacitor electrolyte wave guide back light

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2010/0007825 A1 (KWON, O. et al.) January 14, 2010; abstract; figure 1, 2, 3, 5A-5C, 8A-8C, 9; paragraphs [0033]-[0035], [0037]-[0043], [0086], [0081]-[0084], [0090]-[0094], [01 15]	1-3, 6, 10, 12-20, 23, 27, 29-39, 42-45 --- 4-5, 7-9, 11, 21-22, 24-26, 28
X	US 2006/0050032 A1 (GUNNER, A. et al.) March 9, 2006; figure 3, 4, 8A; paragraphs [0003], [001 1], [0015], [0017], [0070], [0071], [01 11]	40-41
Y	US 5,635,741 A (TSU, R. et al.) June 3, 1997; title; abstract; column 3, lines 66-67; column 4, lines 35-43; column 5, lines 40-65	4, 5, 21, 22
Y	US 2003/0067760 A1 (JAGT, H. et al.) April 10, 2003; abstract; figure 18; paragraphs [0003], [0008], [0053], [0072], [0106]	7, 8, 24, 25
Y	US 2007/0037053 A1 (ANANTHARAMAN, S.) February 15, 2007; title; abstract; paragraphs [0057], [0058], [0062]-[0066]	9, 11, 26, 28

☐ Further documents are listed in the continuation of Box C. ☐

* 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 application or patent 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
29 December 2013 (29.12.2013)	14 JAN 2014

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774