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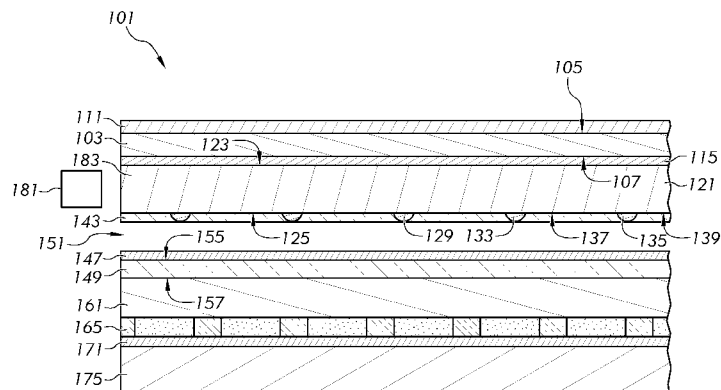


FIG. 1

(57) Abstract: A display apparatus includes a cover substrate including a first cover surface and an opposing second cover surface. A first anti-reflective coating is applied to the first cover surface. A light guide plate includes a first plate surface and an opposing second plate surface. The light guide plate includes a plurality of light extractors positioned at the second plate surface. A second anti-reflective coating is applied to the second plate surface and at least a portion of the plurality of light extractors. The display apparatus includes a third anti-reflective coating spaced a distance apart from the second anti-reflective coating such that a gap is between the second anti-reflective coating and the third anti-reflective coating. Methods of manufacturing a display apparatus are provided.

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METHODS AND APPARATUS FOR MANUFACTURING A DISPLAY APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. §119 of U.S. Provisional Application Serial No. 63/581742 filed on September 11, 2023, the content of which is relied upon and incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates generally to apparatus and methods for manufacturing a display apparatus and, more particularly, to methods for manufacturing a display apparatus comprising one or more anti-reflective coatings.

BACKGROUND

[0003] Glass sheets can be used in display applications, for example, liquid crystal displays (LCDs), electrophoretic displays (EPDs), organic light-emitting diode displays (OLEDs), and plasma display panels (PDPs). It is known to provide a display apparatus in display applications. However, display apparatuses can have an undesirable amount of internal light reflection.

SUMMARY

[0004] The following presents a simplified summary of the disclosure to provide a basic understanding of some aspects described in the detailed description.

[0005] In aspects, a display apparatus can comprise a cover substrate comprising a first cover surface and an opposing second cover surface. The display apparatus can comprise a first anti-reflective coating applied to the first cover surface. The first anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 4% across a visible spectrum within a range from about 380 nanometers to about 750 nanometers. The display apparatus can comprise a light guide plate comprising a first plate

surface and an opposing second plate surface. The first plate surface can face the second cover surface. The light guide plate can comprise a plurality of light extractors positioned at the second plate surface. The display apparatus can comprise a second anti-reflective coating applied to the second plate surface and at least a portion of the plurality of light extractors. The second anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 4% across the visible spectrum. The display apparatus can comprise a third anti-reflective coating spaced a distance apart from the second anti-reflective coating such that a gap is between the second anti-reflective coating and the third anti-reflective coating. The third anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 4% across the visible spectrum.

[0006] In aspects, the display apparatus can comprise a polarizer and a color filter adjacent to the polarizer. A liquid crystal layer can be adjacent to the color filter. A reflector can be adjacent to the liquid crystal layer. A thin-film transistor substrate can be adjacent to the reflector.

[0007] In aspects, the third anti-reflective coating can be applied to the polarizer.

[0008] In aspects, the first anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 3% across the visible spectrum. The second anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 3% across the visible spectrum. The third anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 3% across the visible spectrum.

[0009] In aspects, the display apparatus can comprise an optically-clear adhesive attached to the second cover surface and the first plate surface such that the cover substrate is attached to the light guide plate.

[0010] In aspects, a fourth anti-reflective coating can be applied to the second cover surface.

[0011] In aspects, the fourth anti-reflective coating can comprise a total reflectivity of less than about 2% across the visible spectrum.

[0012] In aspects, a fifth anti-reflective coating can be applied to the first plate surface.

[0013] In aspects, the fifth anti-reflective coating can comprise a total reflectivity of less than about 2% across the visible spectrum.

[0014] In aspects, a display apparatus can comprise a cover substrate comprising a first cover surface and an opposing second cover surface. The display apparatus can comprise a first anti-reflective coating applied to the first cover surface. The first anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 4% across a visible spectrum within a range from about 380 nanometers to about 750 nanometers. The display apparatus can comprise a light guide plate comprising a first plate surface and an opposing second plate surface. The light guide plate can comprise a plurality of light extractors positioned at the second plate surface. The display apparatus can comprise an optically-clear adhesive attached to the second cover surface and the first plate surface such that the cover substrate is attached to the light guide plate. The display apparatus can comprise a second anti-reflective coating applied to the second plate surface and at least a portion of the plurality of light extractors. The second anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 4% across the visible spectrum. The display apparatus can comprise a third anti-reflective coating spaced a distance apart from the second anti-reflective coating such that a gap is between the second anti-reflective coating and the third anti-reflective coating. The third anti-reflective coating can be applied to a polarizer and comprising a total reflectivity within a range from about 1% to about 4% across the visible spectrum.

[0015] In aspects, the display apparatus can comprise a color filter adjacent to the polarizer. A liquid crystal layer can be adjacent to the color filter. A reflector can be adjacent to the liquid crystal layer. A thin-film transistor substrate can be adjacent to the reflector.

[0016] In aspects, the first anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 3% across the visible spectrum. The second anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 3% across the visible spectrum. The third anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 3% across the visible spectrum.

[0017] In aspects, methods of manufacturing a display apparatus can comprise applying a first anti-reflective coating to a first cover surface of a cover substrate. The first anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 4% across a visible spectrum within a range from about 380 nanometers to about 750

nanometers. Methods can comprise positioning a light guide plate adjacent to the cover substrate. The light guide plate can comprise a first plate surface and an opposing second plate surface. The first plate surface can face a second cover surface of the cover substrate. The light guide plate can comprise a plurality of light extractors positioned at the second plate surface. Methods can comprise applying a second anti-reflective coating to the second plate surface and at least a portion of the plurality of light extractors. The second anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 4% across the visible spectrum. Methods can comprise applying a third anti-reflective coating to a polarizer such that the third anti-reflective coating can be spaced a distance apart from the second anti-reflective coating and a gap can be between the second anti-reflective coating and the third anti-reflective coating. The third anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 4% across the visible spectrum.

[0018] In aspects, methods can comprise attaching the second cover surface and the first plate surface with an optically-clear adhesive.

[0019] In aspects, methods can comprise positioning a color filter adjacent to the polarizer. Methods can comprise positioning a liquid crystal layer adjacent to the color filter. Methods can comprise positioning a reflector adjacent to the liquid crystal layer. Methods can comprise positioning a thin-film transistor substrate adjacent to the reflector.

[0020] In aspects, a direct reflection of ambient light from the display apparatus can be within a range from about 5% to about 7%.

[0021] In aspects, the first anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 3% across the visible spectrum. The second anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 3% across the visible spectrum. The third anti-reflective coating can comprise a total reflectivity within a range from about 1% to about 3% across the visible spectrum.

[0022] In aspects, methods can comprise applying a fourth anti-reflective coating to the second cover surface, the fourth anti-reflective coating comprising a total reflectivity of less than about 2% across the visible spectrum.

[0023] In aspects, methods can comprise applying a fifth anti-reflective coating to the first plate surface, the fifth anti-reflective coating comprising a total reflectivity of less than about 2% across the visible spectrum.

[0024] Additional features and advantages of the aspects disclosed herein will be set forth in the detailed description that follows, and in part will be clear to those skilled in the art from that description or recognized by practicing the aspects described herein, including the detailed description which follows, the claims, as well as the appended drawings. It is to be understood that both the foregoing general description and the following detailed description present aspects intended to provide an overview or framework for understanding the nature and character of the aspects disclosed herein. The accompanying drawings are included to provide further understanding and are incorporated into and constitute a part of this specification. The drawings illustrate various aspects of the disclosure, and together with the description explain the principles and operations thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] These and other features, aspects and advantages are better understood when the following detailed description is read with reference to the accompanying drawings, in which:

[0026] **FIG. 1** schematically illustrates an exemplary embodiment of a display apparatus comprising an anti-reflective coating in accordance with aspects of the disclosure;

[0027] **FIG. 2** schematically illustrates an exemplary embodiment of a display apparatus comprising additional anti-reflective coatings in accordance with aspects of the disclosure; and

[0028] **FIG. 3** schematically illustrates methods of manufacturing the display apparatus in accordance with aspects of the disclosure.

DETAILED DESCRIPTION

[0029] Aspects will now be described more fully hereinafter with reference to the accompanying drawings in which example aspects are shown. Whenever possible, the

same reference numerals are used throughout the drawings to refer to the same or like parts. However, this disclosure may be embodied in many different forms and should not be construed as limited to the aspects set forth herein.

[0030] As used herein, the term “about” means that amounts, sizes, formulations, parameters, and other quantities and characteristics are not, and need not be, exact, but may be approximate and/or larger or smaller, as desired, reflecting tolerances, conversion factors, rounding off, measurement error and the like, and other factors known to those of skill in the art.

[0031] Ranges can be expressed herein as from “about” one value, and/or to “about” another value. When such a range is expressed, aspects include from the one value to the other value. Similarly, when values are expressed as approximations by use of the antecedent “about,” it will be understood that the value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

[0032] Directional terms as used herein - for example up, down, right, left, front, back, top, bottom, upper, lower, etc. - are made only with reference to the figures as drawn and are not intended to imply absolute orientation.

[0033] Unless otherwise expressly stated, it is in no way intended that any methods set forth herein be construed as requiring that its steps be performed in a specific order, nor that with any apparatus, specific orientations be required. Accordingly, where a method claim does not actually recite an order to be followed by its steps, or that any apparatus claim does not actually recite an order or orientation to individual components, or it is not otherwise specifically stated in the claims or description that the steps are to be limited to a specific order, or that a specific order or orientation to components of an apparatus is not recited, it is in no way intended that an order or orientation be inferred in any respect. This holds for any possible non-express basis for interpretation, including matters of logic relative to arrangement of steps, operational flow, order of components, or orientation of components; plain meaning derived from grammatical organization or punctuation, and; the number or type of aspects described in the specification.

[0034] As used herein, the singular forms “a,” “an” and “the” include plural references unless the context clearly dictates otherwise. Thus, for example, reference to

“a” component includes aspects having two or more such components, unless the context clearly indicates otherwise.

[0035] The word “exemplary,” “example,” or various forms thereof are used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as “exemplary” or as an “example” should not be construed as preferred or advantageous over other aspects or designs. Furthermore, examples are provided solely for purposes of clarity and understanding and are not meant to limit or restrict the disclosed subject matter or relevant portions of this disclosure in any manner. It can be appreciated that a myriad of additional or alternate examples of varying scope could have been presented but have been omitted for purposes of brevity.

[0036] As used herein, the terms “comprising” and “including”, and variations thereof, shall be construed as synonymous and open-ended, unless otherwise indicated. A list of elements following the transitional phrases comprising or including is a non-exclusive list, such that elements in addition to those specifically recited in the list may also be present.

[0037] The terms “substantial,” “substantially,” and variations thereof as used herein are intended to represent that a described feature is equal or approximately equal to a value or description. For example, a “substantially planar” surface is intended to denote a surface that is planar or approximately planar. Moreover, “substantially” is intended to denote that two values are equal or approximately equal. The term “substantially” may denote values within about 10% of each other, for example, within about 5% of each other, or within about 2% of each other.

[0038] Modifications may be made to the instant disclosure without departing from the scope or spirit of the claimed subject matter. Unless specified otherwise, “first,” “second,” or the like are not intended to imply a temporal aspect, a spatial aspect, an ordering, etc. Rather, such terms are merely used as identifiers, names, etc. for features, elements, items, etc. For example, a first end and a second end generally correspond to end A and end B or two different ends.

[0039] The present disclosure relates to a display apparatus and methods for manufacturing a display apparatus. Methods and apparatus for manufacturing a display apparatus will now be described by way of example aspects. **FIG. 1** schematically

illustrates a cross-sectional view of a display apparatus **101**. The display apparatus **101** can comprise a cover substrate **103** comprising a first cover surface **105** and an opposing second cover surface **107**. The first cover surface **105** and the second cover surface **107** face in opposite directions. In aspects, the cover substrate **103** can comprise a glass substrate, a glass-ceramic substrate, a plastic substrate, or another suitable substrate that may be rigid or flexible. The cover substrate **103** is optically transparent such that light can pass through the cover substrate **103** between the first cover surface **105** and the second cover surface **107**. The cover substrate **103** can comprise a flat substrate or a curved substrate.

[0040] The display apparatus **101** can comprise a first anti-reflective coating **111** applied to the cover substrate **103**, for example, to the first cover surface **105**. In this way, the first anti-reflective coating **111** may form an outermost layer of the display apparatus **101**. In aspects, the first anti-reflective coating **111** can comprise a total reflectivity within a range from about 1% to about 4% across a visible spectrum of light (e.g., within a range from about 380 nanometers to about 750 nanometers), or within a range from about 1% to about 3% across the visible spectrum, or less than about 2% across the visible spectrum. As used herein, the term “visible spectrum” can refer to the portion of the electromagnetic spectrum that is visible to the human eye. The first anti-reflective coating **111** can be applied to the first cover surface **105**, for example, by a discrete deposition process, continuous deposition process, physical vapor deposition, sputtering, etc. In aspects, the first anti-reflective coating **111** can comprise one or more layers of material. For example, when the first anti-reflective coating **111** comprises a plurality of layers, the first anti-reflective coating **111** may comprise alternating layers of differing refractive indices from one another, for example, alternating layers of low refractive index materials and high refractive index materials. For example, a first layer of the first anti-reflective coating **111** can comprise a low refractive index, and an adjacent second layer of the first anti-reflective coating **111** can comprise a high refractive index. In aspects, a difference in the refractive index of a low refractive index and a high refractive index may be greater than about 0.01, greater than about 0.05, greater than about 0.1, or greater than about 0.2. Accordingly, methods of manufacturing the display apparatus **101** can comprise applying (e.g.,

illustrated with arrowhead **301** in **FIG. 3**) the first anti-reflective coating **111** to the first cover surface **105** of the cover substrate **103**.

[0041] In aspects, the first anti-reflective coating **111** can comprise one or more of the following materials: SiO_2 , Al_2O_3 , GeO_2 , SiO , AlO_xN_y , AlN , SiN_x , SiO_xN_y , $\text{Si}_u\text{Al}_v\text{O}_x\text{N}_y$, Ta_2O_5 , Nb_2O_5 , TiO_2 , ZrO_2 , TiN , MgO , MgF_2 , BaF_2 , CaF_2 , SnO_2 , HfO_2 , Y_2O_3 , MoO_3 , DyF_3 , YbF_3 , YF_3 , CeF_3 , polymers, fluoropolymers, plasma-polymerized polymers, siloxane polymers, silsesquioxanes, polyimides, fluorinated polyimides, polyetherimide, polyethersulfone, polyphenylsulfone, polycarbonate, polyethylene terephthalate, polyethylene naphthalate, acrylic polymers, urethane polymers, polymethylmethacrylate, etc.. In aspects, a low refractive index layer may comprise one or more of the following materials: SiO_2 , Al_2O_3 , GeO_2 , SiO , AlO_xN_y , SiO_xN_y , $\text{Si}_u\text{Al}_v\text{O}_x\text{N}_y$, MgO , MgAl_2O_4 , MgF_2 , BaF_2 , CaF_2 , DyF_3 , YbF_3 , YF_3 , and CeF_3 . In aspects, a high refractive index layer may comprise one or more of the following materials: $\text{Si}_u\text{Al}_v\text{O}_x\text{N}_y$, Ta_2O_5 , Nb_2O_5 , AlN , Si_3N_4 , AlO_xN_y , SiO_xN_y , HfO_2 , TiO_2 , ZrO_2 , Y_2O_3 , Al_2O_3 , MoO_3 and diamond-like carbon. In aspects, the nitrogen content of low refractive index layer materials may be minimized, and the oxygen content of high refractive index layer materials may be minimized.

[0042] The display apparatus **101** can comprise an optically-clear adhesive **115** for attaching the cover substrate **103** to a light guide plate **121**. For example, the optically-clear adhesive **115** can be attached to the second cover surface **107** and to a first plate surface **123** of the light guide plate **121**, such that the cover substrate **103** can be attached to the light guide plate **121**. In this way, methods can comprise attaching (e.g., illustrated with arrowhead **309** in **FIG. 3**) the second cover surface **107** and the first plate surface **123** with the optically-clear adhesive **115**. Due to the optically-clear adhesive **115** being bonded to the cover substrate **103** and the light guide plate **121**, an air gap may not exist between the cover substrate **103** and the light guide plate **121**. The optically-clear adhesive **115** can comprise one or more of a polyolefin, a polyamide, a halide-containing polymer (e.g., polyvinylchloride or a fluorine-containing polymer), an elastomer, a urethane, phenolic resin, parylene, polyethylene terephthalate (PET), polyether ether ketone (PEEK), or phenyl silicone. Example aspects of polyolefins include low molecular weight polyethylene (LDPE), high molecular weight polyethylene (HDPE), ultrahigh molecular weight polyethylene (UHMWPE), and polypropylene (PP). Example aspects of fluorine-

containing polymers include polytetrafluoroethylene (PTFE), polyvinylfluoride (PVF), polyvinylidene fluoride (PVDF), perfluoropolyether (PFPE), perfluorosulfonic acid (PFSA), a perfluoroalkoxy (PFA), fluorinated ethylene propylene (FEP) polymers, and ethylene tetrafluoro ethylene (ETFE) polymers. Example aspects of elastomers include rubbers (e.g., polybutadiene, polyisoprene, chloroprene rubber, butyl rubber, nitrile rubber) and block copolymers (e.g., styrene-butadiene, high-impact polystyrene, poly(dichlorophosphazene)). The optically-clear adhesive **115** can comprise one or more optically transparent polymers: an acrylic (e.g., polymethylmethacrylate (PMMA)), an epoxy, silicone, and/or a polyurethane. Exemplary aspects of epoxies include bisphenol-based epoxy resins, novolac-based epoxies, cycloaliphatic-based epoxies, and glycidylamine-based epoxies. In even further aspects, the optically-clear adhesive **115** can comprise, but is not limited to, acrylic adhesives, for example, 3M 8212 adhesive, or an optically transparent liquid adhesive, for example, a LOCTITE optically transparent liquid adhesive. Example aspects of optically clear adhesives comprise transparent acrylics, epoxies, silicones, and polyurethanes. For example, the optically transparent liquid adhesive could comprise one or more of LOCTITE AD 8650, LOCTITE AA 3922, LOCTITE EA E-05MR, LOCTITE UK U-09LV, which are all available from Henkel.

[0043] The display apparatus **101** comprises the light guide plate **121**, which comprises the first plate surface **123** and an opposing second plate surface **125**. The first plate surface **123** and the second plate surface **125** face in opposite directions, with the first plate surface **123** facing the second cover surface **107** of the cover substrate **103**. Methods can comprise positioning (e.g., illustrated with arrowhead **303** in **FIG. 3**) the light guide plate **121** adjacent to the cover substrate **103**. The light guide plate **121** comprises a transparent material used for lighting and display applications. As used herein, the term “transparent” is intended to denote that the light guide plate **121** comprises an optical transmission of greater than about 70 percent over a length of about 500 millimeters in the visible region of the spectrum (e.g., about 380-750 nanometers). In aspects, the light guide plate **121** may comprise an optical transmission of greater than about 50 percent in the ultraviolet (UV) region (about 100-400 nanometers) over a length of 500 millimeters. In aspects, the light guide plate **121** may comprise an optical transmission of at least 95 percent over a path length of 50 millimeters for wavelengths ranging from about 450

nanometers to about 650 nanometers. In aspects, transmission data in the visible spectrum can be measured with a Lambda 950 UV/Vis/NIR Spectrophotometer manufactured by PerkinElmer Inc. (Waltham, Massachusetts USA). In aspects, the Lambda 950 apparatus can be fitted with a 150 mm integrating sphere. Data can be collected using an open beam baseline and a Spectralon[®] reference reflectance disk.

[0044] The light guide plate **121** may comprise a refractive index within a range from about 1.3 to about 1.8. In other aspects, the light guide plate **121** may have a relatively low level of light attenuation (e.g., due to absorption and/or scattering). The light attenuation (a) of the light guide plate **121** may, for example, be less than about 5 decibels per meter for wavelengths ranging from about 380-750 nanometers, and can be determined via testing or based on the material and dimensions of the light guide plate **121**. The light guide plate **121** may comprise a wide range of materials that provide desired optical properties. In aspects, the light guide plate **121** can comprise an amorphous inorganic material (e.g., glass), a crystalline material (e.g., sapphire, single crystal or polycrystalline alumina, spinel (MgAl_2O_4), quartz), or a polymer. Examples of suitable polymers include, without limitation, the following as well as copolymers and blends thereof: thermoplastics including polystyrene (PS), polycarbonate (PC), polyesters including polyethyleneterephthalate (PET), polyolefins including polyethylene (PE), polyvinylchloride (PVC), acrylic polymers including polymethyl methacrylate (PMMA), thermoplastic urethanes (TPU), polyetherimide (PEI), epoxies, and silicones including polydimethylsiloxane (PDMS). Examples of glass, which may be strengthened or non-strengthened and may be free of lithia or not, include soda lime glass, alkali aluminosilicate glass, alkali containing borosilicate glass and alkali aluminoborosilicate glass. As used herein, the term "strengthened" when applied to a substrate, for example glass or another transparent layer, may refer to a substrate that has been chemically strengthened, for example through ion-exchange of larger ions for smaller ions in the surface of the substrate. However, other strengthening methods known in the art, for example thermal tempering, or utilizing a mismatch of the coefficient of thermal expansion between portions of the substrate to create compressive stress and central tension regions, may be utilized to form strengthened substrates. Non-limiting examples of commercially available glasses suitable

for use as the glass light guide plate **121** comprise EAGLE XG®, Lotus, Willow®, Iris™, and Gorilla® glasses from Corning Incorporated.

[0045] The light guide plate **121** can comprise a plurality of light extractors **129** positioned at the second plate surface **125**. In aspects, the plurality of light extractors **129** may comprise a rounded or curved shape that projects outwardly from the second plate surface **125**. For example, the plurality of light extractors **129** can comprise a first light extractor **133**, a second light extractor **135**, etc. The second plate surface **125** can comprise a first surface portion **137**, a second surface portion **139**, etc. In aspects, the light extractors **133**, **135** can be spaced apart and separated by surface portions **137**, **139**. For example, the first surface portion **137** can be positioned between the first light extractor **133** and the second light extractor **135**. The second light extractor **135** can be positioned between the first surface portion **137** and the second surface portion **139**. In this way, the light extractors **133**, **135** and the surface portions **137**, **139** can alternate positions along the second plate surface **125**. In aspects, the plurality of light extractors **129** are not limited to the illustrated circular, round shape. Rather, in aspects, some or all of the plurality of light extractors **129** can comprise other shapes, for example, a quadrilateral shape (e.g., a rectangular shape, a square shape, etc.), a hexagonal shape, etc.

[0046] In aspects, some or all of the plurality of light extractors **129** can comprise diffuse reflectors that can enhance the scattering of light rays at high enough angles such that the light rays can propagate in the light guide plate **121** by total internal reflection. In other aspects, some or all of the plurality of light extractors **129** can comprise specular reflectors, in which a mirror-like reflection of light is provided and incident light is reflected into a single outgoing direction. The plurality of light extractors **129** can be formed by printing e.g., inkjet printing, screen printing, microprinting), a pattern with white ink, black ink, metallic ink, or other suitable ink. The plurality of light extractors **129** may also be formed by first depositing a continuous layer of white or metallic material (e.g., by physical vapor deposition or any number of coating techniques, such as, for example, slot die, or spray coating), and then patterning the layer by photolithography or other known methods of area-selective material removal.

[0047] The display apparatus **101** can comprise a second anti-reflective coating **143** applied to the second plate surface **125** and at least a portion of the plurality of light

extractors **129**. For example, in aspects, the second anti-reflective coating **143** may cover some or all of the second plate surface **125** (e.g., some or all of the surface portions **137**, **139**, etc.) and may cover some or all of the plurality of light extractors **129** (e.g., the light extractors **133**, **135**, etc.). In this way, the second anti-reflective coating **143** can at least partially cover a side of the light guide plate **121**. In aspects, the second anti-reflective coating **143** may comprise the same material as, or a different material than, the first anti-reflective coating **111**. In aspects, the second anti-reflective coating **143** can comprise a total reflectivity within a range from about 1% to about 4% across a visible spectrum, or within a range from about 1% to about 3% across the visible spectrum, or less than about 2% across the visible spectrum. In aspects, the total reflectivity can be measured by shining light on a material (e.g., the anti-reflective coating, for example) and measuring the light reflected from the material, wherein the reflected light may comprise specular reflected light and diffuse reflected light. Together, the specular reflected light and the diffuse reflected light can be combined and referred to as total reflected light, or total reflectivity of the material. In aspects, relative specular reflectance can be measured with a specular reflectance measurement attachment. In aspects, relative diffuse reflectance can be measured by using an integrating sphere to measure the diffuse reflected light with specular reflected light excluded. In addition, or in the alternative, relative total reflectance can be measured using an integrating sphere, wherein light can shine on the material at an incident angle (e.g., less than about 10 degrees, for example), and then using an integrating sphere to measure both the diffuse reflected light and the specular reflected light from the material.

[0048] The second anti-reflective coating **143** can be applied to the second plate surface **125**, for example, by a discrete deposition process, continuous deposition process, physical vapor deposition, sputtering, etc. Methods can comprise applying (e.g., illustrated with arrowhead **305** in **FIG. 3**) the second anti-reflective coating **143** to the second plate surface **125** and at least a portion of the plurality of light extractors **129**. In aspects, the second anti-reflective coating **143** can be applied before or after the formation of the plurality of light extractors **129**. For example, in aspects, the second anti-reflective coating **143** can first be applied to the second plate surface **125**, followed by the formation of the plurality of light extractors **129** via etching, puncturing, and/or laser-printing of the plurality of light extractors **129** onto the second plate surface **125**. In the alternative, the

plurality of light extractors **129** can be formed first, followed by the application of the second anti-reflective coating **143** to the second plate surface **125**. In aspects, the second anti-reflective coating **143** can cover all of the second plate surface **125** and all of the plurality of light extractors **129**.

[0049] In aspects, the second anti-reflective coating **143** can comprise one or more layers of material. For example, when the second anti-reflective coating **143** comprises a plurality of layers, the second anti-reflective coating **143** may comprise alternating layers of differing refractive indices from one another, for example, alternating layers of low refractive index materials and high refractive index materials. For example, a first layer of the second anti-reflective coating **143** can comprise a low refractive index, and an adjacent second layer of the second anti-reflective coating **143** can comprise a high refractive index. In aspects, a difference in the refractive index of a low refractive index and a high refractive index may be greater than about 0.01, greater than about 0.05, greater than about 0.1, or greater than about 0.2.

[0050] In aspects, the second anti-reflective coating **143** can comprise one or more of the following materials: SiO_2 , Al_2O_3 , GeO_2 , SiO , AlO_xN_y , AlN , SiN_x , SiO_xN_y , $\text{Si}_n\text{Al}_m\text{O}_x\text{N}_y$, Ta_2O_5 , Nb_2O_5 , TiO_2 , ZrO_2 , TiN , MgO , MgF_2 , BaF_2 , CaF_2 , SnO_2 , HfO_2 , Y_2O_3 , MoO_3 , DyF_3 , YbF_3 , YF_3 , CeF_3 , polymers, fluoropolymers, plasma-polymerized polymers, siloxane polymers, silsesquioxanes, polyimides, fluorinated polyimides, polyetherimide, polyethersulfone, polyphenylsulfone, polycarbonate, polyethylene terephthalate, polyethylene naphthalate, acrylic polymers, urethane polymers, polymethylmethacrylate, etc.. In aspects, a low refractive index layer may comprise one or more of the following materials: SiO_2 , Al_2O_3 , GeO_2 , SiO , AlO_xN_y , SiO_xN_y , $\text{Si}_n\text{Al}_m\text{O}_x\text{N}_y$, MgO , MgAl_2O_4 , MgF_2 , BaF_2 , CaF_2 , DyF_3 , YbF_3 , YF_3 , and CeF_3 . In aspects, a high refractive index layer may comprise one or more of the following materials: $\text{Si}_n\text{Al}_m\text{O}_x\text{N}_y$, Ta_2O_5 , Nb_2O_5 , AlN , Si_3N_4 , AlO_xN_y , SiO_xN_y , HfO_2 , TiO_2 , ZrO_2 , Y_2O_3 , Al_2O_3 , MoO_3 and diamond-like carbon. In aspects, the nitrogen content of low refractive index layer materials may be minimized, and the oxygen content of high refractive index layer materials may be minimized.

[0051] The display apparatus **101** can comprise a third anti-reflective coating **147** applied to a polarizer **149**, with the third anti-reflective coating **147** spaced a distance apart from the second anti-reflective coating **143** such that a gap **151** is formed between the

second anti-reflective coating **143** and the third anti-reflective coating **147**. The polarizer **149** can comprise a first polarizer surface **155** and an opposing second polarizer surface **157** that can face in opposite directions, with the first polarizer surface **155** facing the light guide plate **121**. In aspects, the third anti-reflective coating **147** is applied to the first polarizer surface **155**, with the third anti-reflective coating **147** covering some, or all, of the first polarizer surface **155**. The third anti-reflective coating **147** may comprise the same material as, or a different material than, the first anti-reflective coating **111** and/or the second anti-reflective coating **143**. In this way, the third anti-reflective coating **147** can comprise a total reflectivity within a range from about 1% to about 4% across a visible spectrum, or within a range from about 1% to about 3% across the visible spectrum, or less than about 2% across the visible spectrum. The gap **151** between the second anti-reflective coating **143** and the third anti-reflective coating **147** can comprise an empty void or space (e.g., an air gap), such that the second anti-reflective coating **143** may not be in contact with the third anti-reflective coating **147**.

[0052] The third anti-reflective coating **147** can be applied to the polarizer **149**, for example, by a discrete deposition process, continuous deposition process, physical vapor deposition, sputtering, etc. Methods can comprise applying (e.g., illustrated with arrowhead **307** in **FIG. 3**) the third anti-reflective coating **147** to the polarizer **149** such that the third anti-reflective coating **147** is spaced a distance apart from the second anti-reflective coating **143** and the gap **151** is between the second anti-reflective coating **143** and the third anti-reflective coating **147**. In aspects, the third anti-reflective coating **147** can comprise one or more layers of material. For example, when the third anti-reflective coating **147** comprises a plurality of layers, the third anti-reflective coating **147** may comprise alternating layers of differing refractive indices from one another, for example, alternating layers of low refractive index materials and high refractive index materials. For example, a first layer of the third anti-reflective coating **147** can comprise a low refractive index, and an adjacent second layer of the third anti-reflective coating **147** can comprise a high refractive index. In aspects, a difference in the refractive index of a low refractive index and a high refractive index may be greater than about 0.01, greater than about 0.05, greater than about 0.1, or greater than about 0.2.

[0053] In aspects, the third anti-reflective coating **147** can comprise one or more of the following materials: SiO_2 , Al_2O_3 , GeO_2 , SiO , AlO_xN_y , AlN , SiN_x , SiO_xN_y , $\text{Si}_u\text{Al}_v\text{O}_x\text{N}_y$, Ta_2O_5 , Nb_2O_5 , TiO_2 , ZrO_2 , TiN , MgO , MgF_2 , BaF_2 , CaF_2 , SnO_2 , HfO_2 , Y_2O_3 , MoO_3 , DyF_3 , YbF_3 , YF_3 , CeF_3 , polymers, fluoropolymers, plasma-polymerized polymers, siloxane polymers, silsesquioxanes, polyimides, fluorinated polyimides, polyetherimide, polyethersulfone, polyphenylsulfone, polycarbonate, polyethylene terephthalate, polyethylene naphthalate, acrylic polymers, urethane polymers, polymethylmethacrylate, etc.. In aspects, a low refractive index layer may comprise one or more of the following materials: SiO_2 , Al_2O_3 , GeO_2 , SiO , AlO_xN_y , SiO_xN_y , $\text{Si}_u\text{Al}_v\text{O}_x\text{N}_y$, MgO , MgAl_2O_4 , MgF_2 , BaF_2 , CaF_2 , DyF_3 , YbF_3 , YF_3 , and CeF_3 . In aspects, a high refractive index layer may comprise one or more of the following materials: $\text{Si}_u\text{Al}_v\text{O}_x\text{N}_y$, Ta_2O_5 , Nb_2O_5 , AlN , Si_3N_4 , AlO_xN_y , SiO_xN_y , HfO_2 , TiO_2 , ZrO_2 , Y_2O_3 , Al_2O_3 , MoO_3 and diamond-like carbon. In aspects, the nitrogen content of low refractive index layer materials may be minimized, and the oxygen content of high refractive index layer materials may be minimized.

[0054] The polarizer **149** comprises an optical filter that allows light waves of a specific polarization to pass through the polarizer **149** while blocking light waves of other polarizations. In this way, the polarizer **149** can filter out one or more specific polarizations (e.g., to limit specific polarizations from passing through the polarizer **149**). The display apparatus **101** can comprise a color filter **161** extending adjacent to the polarizer **149** and attached to the second polarizer surface **157**. The color filter **161** can comprise an array of red, green, and/or blue filters to produce a desired display color. Methods can comprise positioning (e.g., illustrated with arrowhead **311** in **FIG. 3**) the color filter **161** adjacent to the polarizer **149**. The display apparatus **101** can comprise a liquid crystal layer **165** extending adjacent to the color filter **161**. Methods can comprise positioning (e.g., illustrated with arrowhead **313** in **FIG. 3**) the liquid crystal layer **165** adjacent to the color filter **161**. The display apparatus **101** can comprise a reflector **171** extending adjacent to the liquid crystal layer **165**. The reflector **171** comprises a material that is inherently reflective, such as, for example, aluminum, steel, silver, etc. In aspects, the reflector **171** can comprise a material such as polyethyleneterephthalate (PET) or polycarbonate (PC) that is reflective when placed adjacent to another material in the display apparatus **101** having a different refractive index. In aspects, the reflector **171** may comprise an average

reflectance over a wavelength range from about 400 nm to about 700 nm of about 90% or more, about 95% or more, about 96% or more, or about 98% or more. In aspects, the reflector **171** can face the liquid crystal layer **165**. Methods can comprise positioning (e.g., illustrated with arrowhead **315** in **FIG. 3**) the reflector **171** adjacent to the liquid crystal layer **165**. The display apparatus **101** can comprise a thin-film transistor (TFT) substrate **175** extending adjacent to the reflector **171**. Methods can comprise positioning (e.g., illustrated with arrowhead **317** in **FIG. 3**) the thin-film transistor substrate **175** adjacent to the reflector **171**.

[0055] The display apparatus **101** can comprise a light source **181** that can deliver light into a first edge **183** of the light guide plate **121**. The display apparatus **101** can therefore comprise front-lit reflective display apparatus. The first edge **183** can extend along a perimeter of the light guide plate **121** between the first plate surface **123** and the second plate surface **125**. In aspects, the light source **181** can comprise one or more light-emitting diodes (LEDs) positioned along the first edge **183**. In aspects, the light source **181** can comprise a thickness or height that may be less than or equal to the thickness of the light guide plate **121**. While **FIG. 1** illustrates a single edge **183** being injected by light from the light source **181**, additional light sources (e.g., which may be similar or identical to the light source **181**) may be positioned along other edges of the light guide plate **121**. In aspects, the light source **181** can be coupled to the first edge **183**, for example, by being positioned adjacent to, and/or by being attached to, the first edge **183**. In aspects, none, some, or all of the other edges of the light guide plate **121** may comprise an edge reflector that can reflect substantially all of the light impinging thereon. In this way, the edge reflectors can reflect a certain percentage of light. Exemplary percentages of reflection can be greater than about 50%, between about 50% to about 95%, less than or equal to 100%, etc.

[0056] The light source **181** can supply (e.g., inject, direct, etc.) light into the light guide plate **121** from a side (e.g., adjacent to the first edge **183**) of the light guide plate **121**. The light guide plate **121** can receive the light from the light source **181**, and redirect the light to create uniform illumination for the reflective liquid crystal layer **165**. The plurality of light extractors **129** can extract the light from the light source **181** and limit the likelihood

of the light becoming trapped within the light guide plate **121** due to total internal reflection.

[0057] **FIG. 2** illustrates additional aspects of the display apparatus **101**, further comprising additional anti-reflective coatings. For example, the display apparatus **101** can comprise a fourth anti-reflective coating **201** applied to the second cover surface **107** of the cover substrate **103**. The fourth anti-reflective coating **201** can be positioned between, and in contact with, the cover substrate **103** and the optically-clear adhesive **115**, with the optically-clear adhesive **115** bonded to the fourth anti-reflective coating **201**. The fourth anti-reflective coating **201** can comprise a total reflectivity within a range from about 1% to about 4% across a visible spectrum, or within a range from about 1% to about 3% across the visible spectrum, or less than about 2% across the visible spectrum. The fourth anti-reflective coating **201** can be applied, for example, by a discrete deposition process, continuous deposition process, physical vapor deposition, sputtering, etc. Methods can comprise applying (e.g., illustrated with arrowhead **319** in **FIG. 3**) the fourth anti-reflective coating **201** to the second cover surface **107**. In aspects, the fourth anti-reflective coating **201** can comprise one or more layers of material. For example, when the fourth anti-reflective coating **201** comprises a plurality of layers, the fourth anti-reflective coating **201** may comprise alternating layers of differing refractive indices from one another, for example, alternating layers of low refractive index materials and high refractive index materials. For example, a first layer of the fourth anti-reflective coating **201** can comprise a low refractive index, and an adjacent second layer of the fourth anti-reflective coating **201** can comprise a high refractive index. In aspects, a difference in the refractive index of a low refractive index and a high refractive index may be greater than about 0.01, greater than about 0.05, greater than about 0.1, or greater than about 0.2.

[0058] In aspects, the fourth anti-reflective coating **201** can comprise one or more of the following materials: SiO_2 , Al_2O_3 , GeO_2 , SiO , AlO_xN_y , AlN , SiN_x , SiO_xN_y , $\text{Si}_n\text{Al}_m\text{O}_x\text{N}_y$, Ta_2O_5 , Nb_2O_5 , TiO_2 , ZrO_2 , TiN , MgO , MgF_2 , BaF_2 , CaF_2 , SnO_2 , HfO_2 , Y_2O_3 , MoO_3 , DyF_3 , YbF_3 , YF_3 , CeF_3 , polymers, fluoropolymers, plasma-polymerized polymers, siloxane polymers, silsesquioxanes, polyimides, fluorinated polyimides, polyetherimide, polyethersulfone, polyphenylsulfone, polycarbonate, polyethylene terephthalate, polyethylene naphthalate, acrylic polymers, urethane polymers, polymethylmethacrylate,

etc.. In aspects, a low refractive index layer may comprise one or more of the following materials: SiO_2 , Al_2O_3 , GeO_2 , SiO , AlO_xN_y , SiO_xN_y , $\text{Si}_u\text{Al}_v\text{O}_x\text{N}_y$, MgO , MgAl_2O_4 , MgF_2 , BaF_2 , CaF_2 , DyF_3 , YbF_3 , YF_3 , and CeF_3 . In aspects, a high refractive index layer may comprise one or more of the following materials: $\text{Si}_u\text{Al}_v\text{O}_x\text{N}_y$, Ta_2O_5 , Nb_2O_5 , AlN , Si_3N_4 , AlO_xN_y , SiO_xN_y , HfO_2 , TiO_2 , ZrO_2 , Y_2O_3 , Al_2O_3 , MoO_3 and diamond-like carbon. In aspects, the nitrogen content of low refractive index layer materials may be minimized, and the oxygen content of high refractive index layer materials may be minimized.

[0059] In aspects, the display apparatus **101** can comprise a fifth anti-reflective coating **203** applied to the first plate surface **123** of the light guide plate **121**. The fifth anti-reflective coating **203** can be positioned between, and in contact with, the light guide plate **121** and the optically-clear adhesive **115**, with the optically-clear adhesive **115** bonded to the fifth anti-reflective coating **203**. The fifth anti-reflective coating **203** can comprise a total reflectivity within a range from about 1% to about 4% across a visible spectrum, or within a range from about 1% to about 3% across the visible spectrum, or less than about 2% across the visible spectrum. The fifth anti-reflective coating **203** can be applied, for example, by a discrete deposition process, continuous deposition process, physical vapor deposition, sputtering, etc. Methods can comprise applying (e.g., illustrated with arrowhead **321** in **FIG. 3**) the fifth anti-reflective coating **203** to the first plate surface **123**. In aspects, the fifth anti-reflective coating **203** can comprise one or more layers of material. For example, when the fifth anti-reflective coating **203** comprises a plurality of layers, the fifth anti-reflective coating **203** may comprise alternating layers of differing refractive indices from one another, for example, alternating layers of low refractive index materials and high refractive index materials. For example, a first layer of the fifth anti-reflective coating **203** can comprise a low refractive index, and an adjacent second layer of the fifth anti-reflective coating **203** can comprise a high refractive index. In aspects, a difference in the refractive index of a low refractive index and a high refractive index may be greater than about 0.01, greater than about 0.05, greater than about 0.1, or greater than about 0.2.

[0060] In aspects, the fifth anti-reflective coating **203** can comprise one or more of the following materials: SiO_2 , Al_2O_3 , GeO_2 , SiO , AlO_xN_y , AlN , SiN_x , SiO_xN_y , $\text{Si}_u\text{Al}_v\text{O}_x\text{N}_y$, Ta_2O_5 , Nb_2O_5 , TiO_2 , ZrO_2 , TiN , MgO , MgF_2 , BaF_2 , CaF_2 , SnO_2 , HfO_2 , Y_2O_3 , MoO_3 , DyF_3 ,

YbF₃, YF₃, CeF₃, polymers, fluoropolymers, plasma-polymerized polymers, siloxane polymers, silsesquioxanes, polyimides, fluorinated polyimides, polyetherimide, polyethersulfone, polyphenylsulfone, polycarbonate, polyethylene terephthalate, polyethylene naphthalate, acrylic polymers, urethane polymers, polymethylmethacrylate, etc.. In aspects, a low refractive index layer may comprise one or more of the following materials: SiO₂, Al₂O₃, GeO₂, SiO, AlO_xN_y, SiO_xN_y, Si_{1-x}Al_xO_xN_y, MgO, MgAl₂O₄, MgF₂, BaF₂, CaF₂, DyF₃, YbF₃, YF₃, and CeF₃. In aspects, a high refractive index layer may comprise one or more of the following materials: Si_{1-x}Al_xO_xN_y, Ta₂O₅, Nb₂O₅, AlN, Si₃N₄, AlO_xN_y, SiO_xN_y, HfO₂, TiO₂, ZrO₂, Y₂O₃, Al₂O₃, MoO₃ and diamond-like carbon. In aspects, the nitrogen content of low refractive index layer materials may be minimized, and the oxygen content of high refractive index layer materials may be minimized.

[0061] The display apparatus **101** illustrated and described herein provides several benefits. For example, the anti-reflective coatings **111**, **143**, **147**, **201**, **203** can reduce direct reflection. For example, in aspects, direct reflection of ambient light from the display apparatus **101** may be within a range from about 5% to about 7%. That is, in an example, when the display apparatus **101** comprises the three anti-reflective coatings **111**, **143**, **147**, the display apparatus **101** may comprise a direct reflection of ambient light of about 6% and light transmission of about 94.1%. In contrast, for a display apparatus without any anti-reflective coatings, a direct reflection of ambient light is about 12% and transmission is about 88%. The anti-reflective coatings **143**, **147** applied to the light guide plate **121** and the polarizer **149** can further reduce Fresnel reflection by about 50% or more, as compared to a display apparatus without an anti-reflective coating applied to a light guide plate and polarizer. Fresnel reflection refers to when light reaches an interface between two different and transparent media, that a portion of the light is transmitted into the other material while another portion of the light is reflected back into the original material. Further, the anti-reflective coatings **111**, **143**, **147**, **201**, **203** can increase the contrast ratio as compared to a display apparatus without an anti-reflective coating.

[0062] It should be understood that while various aspects have been described in detail relative to certain illustrative and specific examples thereof, the present disclosure should not be considered limited to such, as numerous modifications and combinations of

the disclosed features are possible without departing from the scope of the following claims.

What is claimed is:

1. A display apparatus comprising:
 - a cover substrate comprising a first cover surface and an opposing second cover surface;
 - a first anti-reflective coating applied to the first cover surface, the first anti-reflective coating comprising a total reflectivity within a range from about 1% to about 4% across a visible spectrum within a range from about 380 nanometers to about 750 nanometers;
 - a light guide plate comprising a first plate surface and an opposing second plate surface, the first plate surface facing the second cover surface, the light guide plate comprising a plurality of light extractors positioned at the second plate surface;
 - a second anti-reflective coating applied to the second plate surface and at least a portion of the plurality of light extractors, the second anti-reflective coating comprising a total reflectivity within a range from about 1% to about 4% across the visible spectrum;
 - and
 - a third anti-reflective coating spaced a distance apart from the second anti-reflective coating such that a gap is between the second anti-reflective coating and the third anti-reflective coating, the third anti-reflective coating comprising a total reflectivity within a range from about 1% to about 4% across the visible spectrum.
2. The display apparatus of claim 1, further comprising:
 - a polarizer;
 - a color filter adjacent to the polarizer;
 - a liquid crystal layer adjacent to the color filter;
 - a reflector adjacent to the liquid crystal layer; and
 - a thin-film transistor substrate adjacent to the reflector.
3. The display apparatus of claim 2, wherein the third anti-reflective coating is applied to the polarizer.

4. The display apparatus of any one of claims 1-3, wherein one or more of:
the first anti-reflective coating comprises a total reflectivity within a range from about 1% to about 3% across the visible spectrum;
the second anti-reflective coating comprises a total reflectivity within a range from about 1% to about 3% across the visible spectrum; or
the third anti-reflective coating comprises a total reflectivity within a range from about 1% to about 3% across the visible spectrum.
5. The display apparatus of any one of claims 1-4, further comprising an optically-clear adhesive attached to the second cover surface and the first plate surface such that that the cover substrate is attached to the light guide plate.
6. The display apparatus of any one of claims 1-4, further comprising a fourth anti-reflective coating applied to the second cover surface.
7. The display apparatus of claim 6, wherein the fourth anti-reflective coating comprises a total reflectivity of less than about 2% across the visible spectrum.
8. The display apparatus of any one of claims 6-7, further comprising a fifth anti-reflective coating applied to the first plate surface.
9. The display apparatus of claim 8, wherein the fifth anti-reflective coating comprises a total reflectivity of less than about 2% across the visible spectrum.
10. A display apparatus comprising:
a cover substrate comprising a first cover surface and an opposing second cover surface;
a first anti-reflective coating applied to the first cover surface, the first anti-reflective coating comprising a total reflectivity within a range from about 1% to about 4% across a visible spectrum within a range from about 380 nanometers to about 750 nanometers;

a light guide plate comprising a first plate surface and an opposing second plate surface, the light guide plate comprising a plurality of light extractors positioned at the second plate surface;

an optically-clear adhesive attached to the second cover surface and the first plate surface such that the cover substrate is attached to the light guide plate;

a second anti-reflective coating applied to the second plate surface and at least a portion of the plurality of light extractors, the second anti-reflective coating comprising a total reflectivity within a range from about 1% to about 4% across the visible spectrum; and

a third anti-reflective coating spaced a distance apart from the second anti-reflective coating such that a gap is between the second anti-reflective coating and the third anti-reflective coating, the third anti-reflective coating applied to a polarizer and comprising a total reflectivity within a range from about 1% to about 4% across the visible spectrum.

11. The display apparatus of claim 10, further comprising:

a color filter adjacent to the polarizer;
a liquid crystal layer adjacent to the color filter;
a reflector adjacent to the liquid crystal layer; and
a thin-film transistor substrate adjacent to the reflector.

12. The display apparatus of claim 11, wherein one or more of:

the first anti-reflective coating comprises a total reflectivity within a range from about 1% to about 3% across the visible spectrum;

the second anti-reflective coating comprises a total reflectivity within a range from about 1% to about 3% across the visible spectrum; or

the third anti-reflective coating comprises a total reflectivity within a range from about 1% to about 3% across the visible spectrum.

13. A method of manufacturing a display apparatus comprising:

applying a first anti-reflective coating to a first cover surface of a cover substrate, the first anti-reflective coating comprising a total reflectivity within a range from about 1% to about 4% across a visible spectrum within a range from about 380 nanometers to about 750 nanometers;

positioning a light guide plate adjacent to the cover substrate, the light guide plate comprising a first plate surface and an opposing second plate surface, the first plate surface facing a second cover surface of the cover substrate, the light guide plate comprising a plurality of light extractors positioned at the second plate surface;

applying a second anti-reflective coating to the second plate surface and at least a portion of the plurality of light extractors, the second anti-reflective coating comprising a total reflectivity within a range from about 1% to about 4% across the visible spectrum; and

applying a third anti-reflective coating to a polarizer such that the third anti-reflective coating is spaced a distance apart from the second anti-reflective coating and a gap is between the second anti-reflective coating and the third anti-reflective coating, the third anti-reflective coating comprising a total reflectivity within a range from about 1% to about 4% across the visible spectrum.

14. The method of claim 13, further comprising attaching the second cover surface and the first plate surface with an optically-clear adhesive.

15. The method of any one of claims 13-14, further comprising:
positioning a color filter adjacent to the polarizer;
positioning a liquid crystal layer adjacent to the color filter;
positioning a reflector adjacent to the liquid crystal layer; and
positioning a thin-film transistor substrate adjacent to the reflector.

16. The method of claim 15, wherein a direct reflection of ambient light from the display apparatus is within a range from about 5% to about 7%.

17. The method of any one of claims 13-16, wherein one or more of:

the first anti-reflective coating comprises a total reflectivity within a range from about 1% to about 3% across the visible spectrum;

the second anti-reflective coating comprises a total reflectivity within a range from about 1% to about 3% across the visible spectrum; or

the third anti-reflective coating comprises a total reflectivity within a range from about 1% to about 3% across the visible spectrum.

18. The method of any one of claims 13-17, further comprising applying a fourth anti-reflective coating to the second cover surface, the fourth anti-reflective coating comprising a total reflectivity of less than about 2% across the visible spectrum.

19. The method of any one of claims 13-18, further comprising applying a fifth anti-reflective coating to the first plate surface, the fifth anti-reflective coating comprising a total reflectivity of less than about 2% across the visible spectrum.

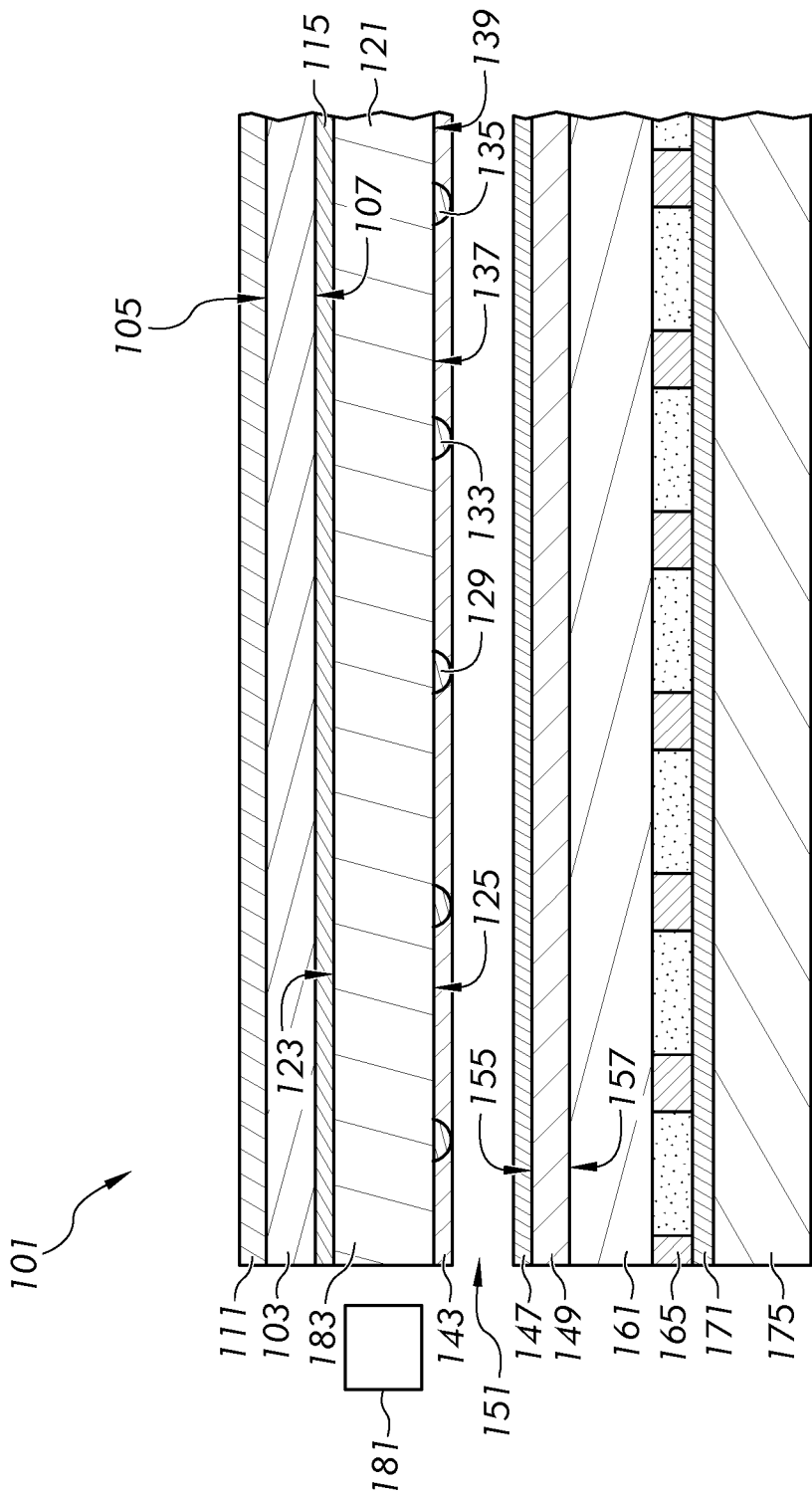


FIG. 1

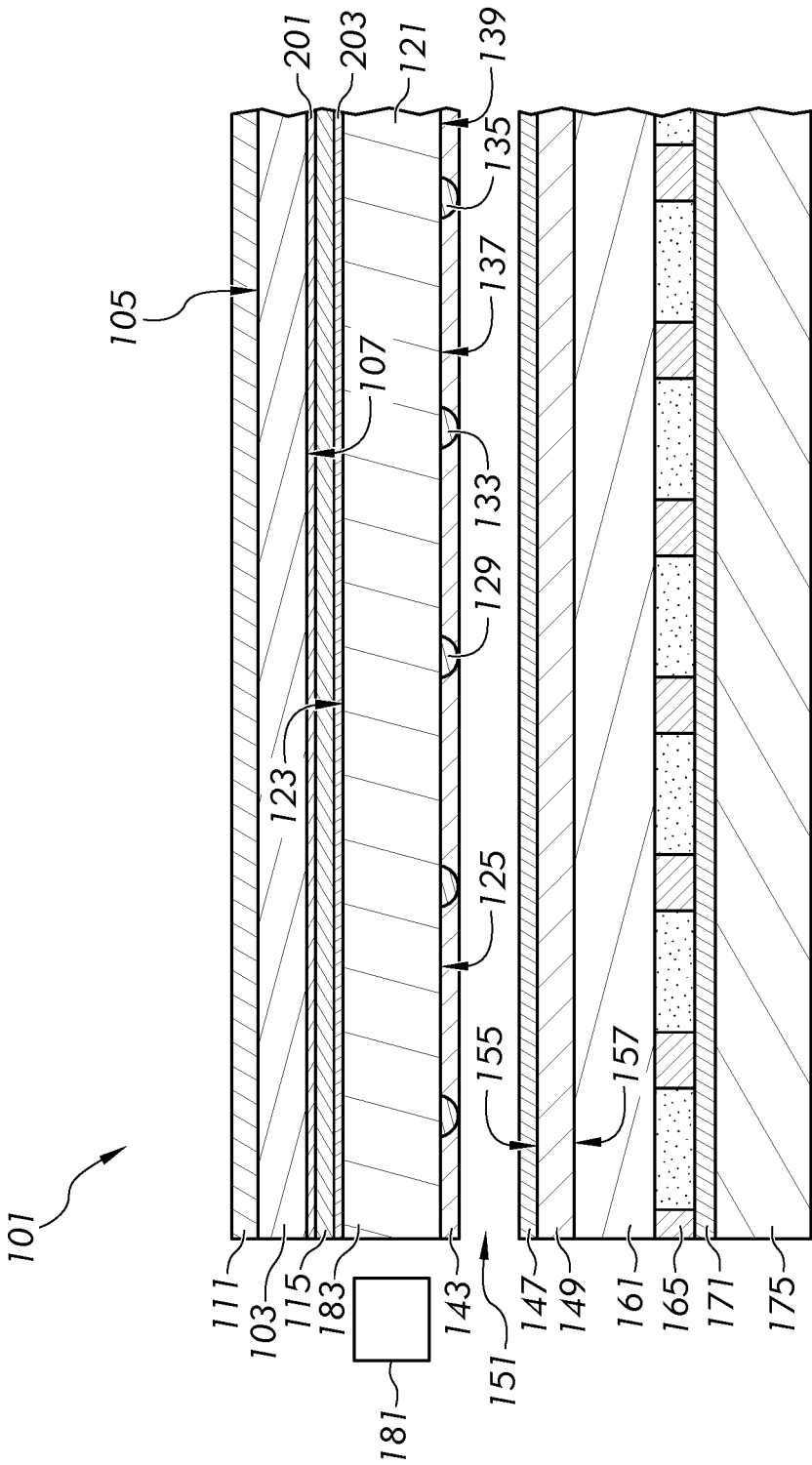


FIG. 2

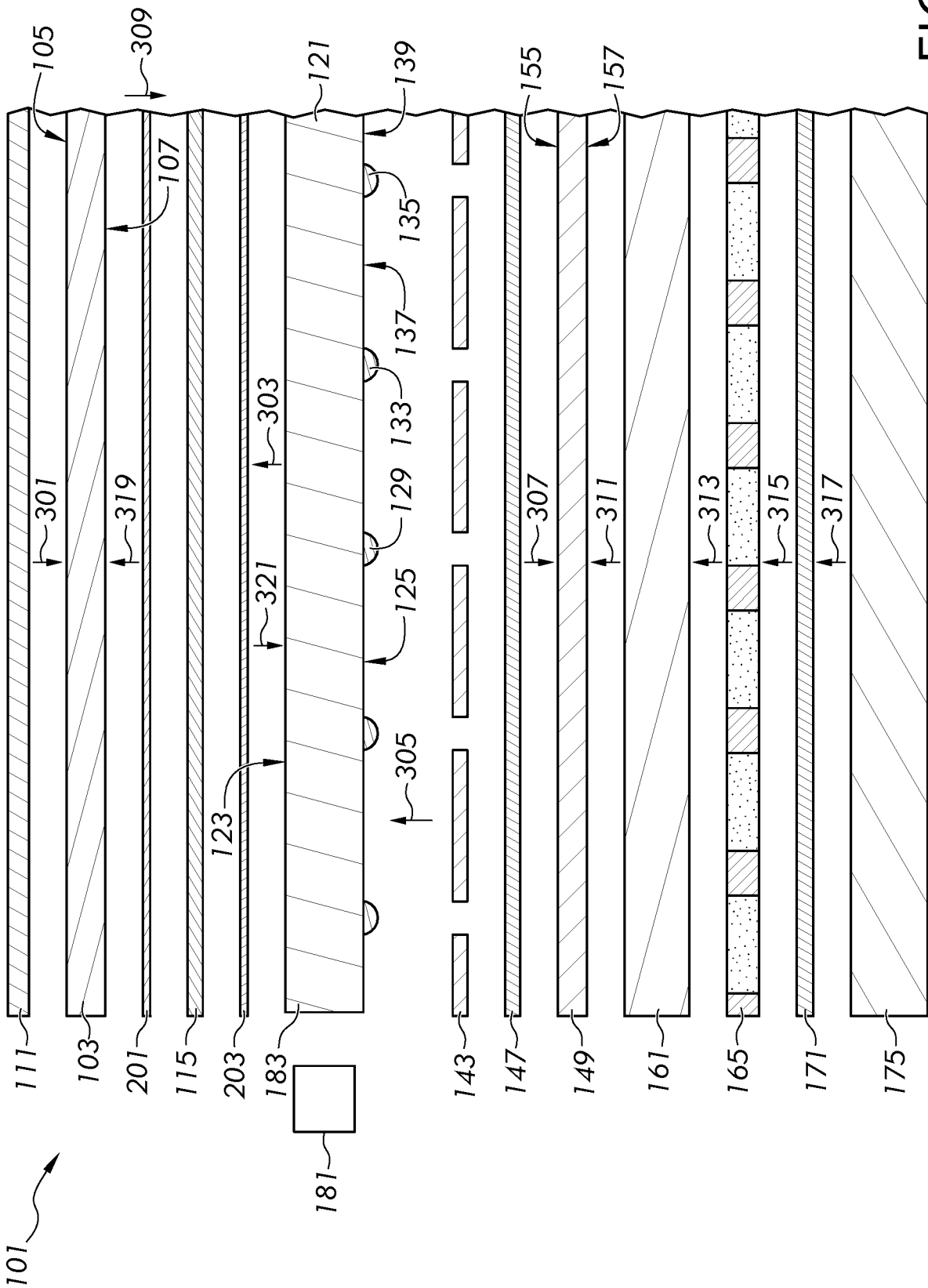


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/041862

A. CLASSIFICATION OF SUBJECT MATTER G02F 1/1335(2006.01)i; G02F 1/13357(2006.01)i; G02B 1/11(2006.01)i; G02B 6/00(2006.01)i 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) G02F 1/1335(2006.01); C23C 14/34(2006.01); G02B 1/10(2006.01); G02B 1/11(2006.01); G02B 1/115(2015.01); G02B 1/14(2015.01); G02F 1/167(2006.01); H01L 27/32(2006.01); H10K 50/844(2023.01); H10K 50/86(2023.01) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & Keywords: display, cover substrate, anti-reflective, light guide, reflectivity, color filter, polarizer, transistor		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 9720141 B1 (AMAZON TECHNOLOGIES, INC.) 01 August 2017 (2017-08-01) column 4, lines 40-43; column 5, lines 16-17, 20-22; column 8, lines 33-40; column 8, line 65 - column 9, line 4; claim 10; and figures 1, 4	1-19
Y	US 2016-0170281 A1 (E INK HOLDINGS INC.) 16 June 2016 (2016-06-16) paragraphs [0052]-[0053]; and figure 5	1-19
Y	US 2023-0209869 A1 (LG DISPLAY CO., LTD.) 29 June 2023 (2023-06-29) paragraphs [0076], [0093], [0121]; and figures 3-4	1-19
Y	US 2019-0384110 A1 (NIPPON KAYAKU KABUSHIKI KAISHA) 19 December 2019 (2019-12-19) paragraphs [0030]-[0031], [0038]; and figures 1-2	2-3,11-12,15-16
Y	US 2018-0313978 A1 (LG CHEM, LTD.) 01 November 2018 (2018-11-01) paragraphs [0015], [0032]	3-4,7,9,12,17-19
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “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 02 December 2024		Date of mailing of the international search report 02 December 2024
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer YANG, Jeong Rok Telephone No. +82-42-481-5709

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2024/041862

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