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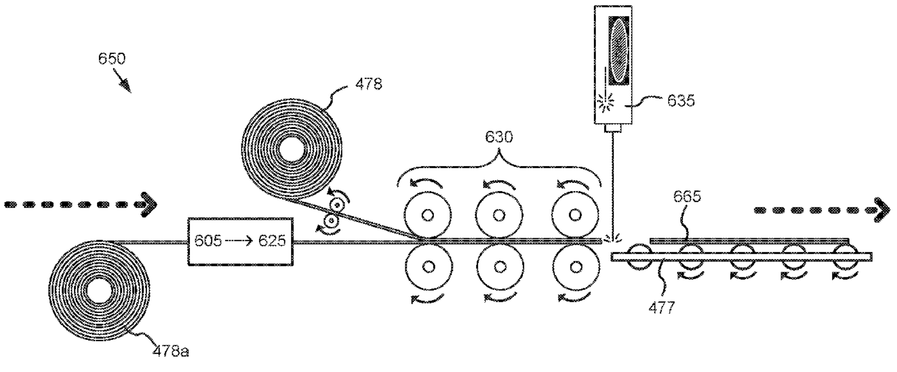

Fig. 5B

(57) Abstract: Thin-film devices, for example electrochromic devices for windows, and methods of manufacturing are described. Particular focus is given to methods of patterning optical devices. Various edge deletion and isolation scribes are performed, for example, to ensure the optical device has appropriate isolation from any edge defects. Methods described herein apply to any thin-film device having one or more material layers sandwiched between two thin film electrical conductor layers. The described methods create novel optical device configurations.

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ELECTROCHROMIC LAMINATES

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims benefit of and priority to U.S. Provisional Patent Application 62/190,201, titled "ELECTROCHROMIC LAMINATES" and filed on July 8, 2015, which is hereby incorporated by reference in its entirety and for all purposes. This application is also a continuation-in-part of international PCT application PCT/US2015/000411, titled "THIN-FILM DEVICES AND FABRICATION" and filed on December 24, 2015, which claims priority to U.S. Provisional Patent Application 62/096,783, titled "THIN-FILM DEVICES AND FABRICATION" and filed on December 24, 2014; both of which are hereby incorporated by reference in their entireties and for all purposes. This application is also a continuation-in-part of U.S. Patent Application No. 14/822,732, titled "THIN-FILM DEVICES AND FABRICATION" and filed on August 10, 2015, which is a continuation of U.S. Patent Application No.14/362,863, titled "THIN-FILM DEVICES AND FABRICATION" and filed on June 4, 2014; both of which are hereby incorporated by reference in their entireties and for all purposes. U.S. Patent Application No.14/362,863 is a national stage application under 35 U.S.C. § 371 of International PCT Application Number to PCT/US12/68817, titled "THIN-FILM DEVICES AND FABRICATION" and filed on December 10, 2012, which is hereby incorporated by reference in its entirety and for all purposes. International PCT Application PCT/US12/68817 claims benefit of and priority to U.S. Provisional Patent Application No. 61/569,716, titled "THIN-FILM DEVICES AND FABRICATION" and filed on December 12, 2011, U.S. Provisional Patent Application No. 61/664,638, titled "THIN-FILM DEVICES AND FABRICATION" and filed on June 26, 2012, and U.S. Provisional Patent Application No. 61/709,046, titled "THIN-FILM DEVICES AND FABRICATION" and filed on October 2, 2012; all of these applications are hereby incorporated by reference in their entireties and for all purposes.

FIELD

[0002] Embodiments disclosed herein relate generally to optical devices, and more particularly to methods of fabricating optical devices.

BACKGROUND

[0003] Electrochromism is a phenomenon in which a material exhibits a reversible electrochemically-mediated change in an optical property when placed in a different electronic state, typically by being subjected to a voltage change. The optical property is typically one or more of color, transmittance, absorbance, and reflectance. For example, one well known electrochromic material is tungsten oxide (WO_3). Tungsten oxide is a cathodically coloring electrochromic material in which a coloration transition, bleached (non-colored) to blue, occurs by electrochemical reduction. When electrochemical oxidation takes place, tungsten oxide transitions from blue to a bleached state.

[0004] Electrochromic materials may be incorporated into, for example, windows for home, commercial and other uses. The color, transmittance, absorbance, and/or reflectance of such windows may be changed by inducing a change in the electrochromic material, that is, electrochromic windows are windows that can be darkened and lightened reversibly via application of an electric charge. A small voltage applied to an electrochromic device of the window will cause it to darken; reversing the voltage causes it to lighten. This capability allows control of the amount of light that passes through the windows, and presents an opportunity for electrochromic windows to be used as energy-saving devices.

[0005] While electrochromism was discovered in the 1960's, electrochromic devices, and particularly electrochromic windows, still unfortunately suffer various problems and have not begun to realize their full commercial potential despite many recent advancements in electrochromic technology, apparatus, and related methods of making and/or using electrochromic devices.

SUMMARY

[0006] Thin-film devices, for example, electrochromic devices for windows, and methods of manufacturing are described. Particular focus is given to methods of patterning and fabricating optical devices. Various edge deletion and isolation scribes are performed, for example, to ensure the optical device has appropriate isolation from any edge defects, but also to address unwanted coloration and charge buildup in areas of the device. Edge treatments are applied to one or more layers of optical devices during fabrication. Methods described herein apply to any thin-film device having one or more material layers sandwiched between two thin-film electrical conductor layers. The described methods create novel optical device configurations.

[0007] One embodiment is an optical device including: (i) a first conductor layer on a substrate, the first conductor layer including an area less than that of the substrate, the first conductor layer surrounded by a perimeter area of the substrate which is substantially free of the first conductor layer; (ii) one or more material layers including at least one optically switchable material, the one or more material layers configured to be within the perimeter area of the substrate and co-extensive with the first conductor layer but for at least one exposed area of the first conductor layer, the at least one exposed area of the first conductor layer free of the one or more material layers; and (iii) a second conductor layer on the one or more material layers, the second conductor layer transparent and co-extensive with the one or more material layers, where the one or more material layers and the second conductor layer overhang the first conductor layer but for the at least one exposed area of the first conductor layer. The optical device may further include a vapor barrier layer coextensive with the second conductor layer. The optical device may include a diffusion barrier between the first conductor layer and the substrate. In some embodiments, the optical device does not include an isolation scribe, i.e., there are no inactive portions of the device isolated by a scribe.

[0008] In certain embodiments, the at least one optically switchable material is an electrochromic material. The first and second conductor layers may both be transparent, but at least one is transparent. In certain embodiments, the optical device is all solid-state and inorganic. The substrate may be float glass, tempered or not. The substrate may be sodium free fusion glass, e.g. sold by Corning, Inc. of Corning, New York.

[0009] Certain embodiments include an insulated glass unit (IGU) which includes optical devices described herein. In certain embodiments, any exposed areas of the first conducting layer are configured to be within the primary seal of the IGU. In certain embodiments, any bus bars are also configured to be within the primary seal of the IGU. In certain embodiments, any isolation or other scribes are also within the primary seal of the IGU. Optical devices described herein may be of any shape, e.g., regular polygon shaped such as rectangular, round or oval, triangular, trapezoidal, etc., or irregularly-shaped.

[0010] Some embodiments are methods of making optical devices as described herein. One embodiment is a method of fabricating an optical device including one or more material layers sandwiched between a first and a second conducting layer, the method including: (i) receiving a substrate including the first conducting layer over its work surface (e.g., an underlying glass layer with or without a diffusion barrier); (ii) removing a first width of the first conducting layer from between about 10% and about 90% of the perimeter of the substrate; (iii) depositing the one or more material layers of the optical device and the second conducting layer such that they cover the first conducting layer and, where possible (except where the portion the substrate where the first conducting layer was not removed), extend beyond the first conducting layer about its perimeter; (iv) removing a second width, narrower than the first width, of all the layers about substantially the entire perimeter of the substrate, where the depth of removal is at least sufficient to remove the first conducting layer; (v) removing at least one portion of the second transparent conducting layer and the one or more layers of the optical device thereunder thereby revealing at least one exposed portion of the first conducting layer; and (vi) applying an electrical connection, e.g. a bus bar, to the at least one exposed portion of the first transparent conducting layer; where at least one of the first and second conducting layers is transparent.

[0011] In one embodiment, (ii) includes removing the first width of the first conducting layer from between about 50% and about 75% around the perimeter of the substrate. In one embodiment, the at least one exposed portion of the first conducting layer exposed is fabricated along the perimeter portion of the optical device proximate the side or sides of the substrate where the first conducting layer was not removed in (ii). Methods may further include applying at least one additional electrical connection (e.g., a second bus bar) to the second conducting layer. Aspects of methods described herein may be performed in an all vacuum integrated deposition apparatus. Methods may further include fabricating an IGU using optical devices as described herein.

[0012] Certain embodiments include fabrication methods, and resulting devices, having particular edge treatments which create more robust and better performing devices. For example the edge of an electrochromic device layer or layers may be tapered in order to avoid stress and cracking in overlying layers of the device construct. In another example, lower conductor exposure for bus bar application is carried out to ensure good electrical contact and uniform coloration front in the electrochromic device. In certain embodiments, device edge treatments, isolation scribes and lower conductor layer exposures are performed using variable depth laser scribes.

[0013] These and other features and advantages will be described in further detail below, with reference to the associated drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The following detailed description can be more fully understood when considered in conjunction with the drawings in which:

[0015] **Figures 1A**, **1B**, and **1C** are cross-section, end view, and top view drawings respectively of an electrochromic device fabricated on a glass substrate.

[0016] **Figure 1D** is a detailed portion of the cross-section shown in **Figure 1A**.

[0017] **Figure 2A** is a partial cross-section of an improved electrochromic device architecture on a substrate, according to disclosed embodiments.

[0018] **Figures 2B-2C**-are cross-sectional and end view drawings respectively of an improved device architecture similar to that described in relation to **Figure 2A**.

[0019] **Figures 2D-E** are partial cross-sectional and top view drawings respectively of a device with an architecture similar to that described in relation to **Figures 2A-C**.

[0020] **Figure 3** is a partial cross-section showing an improved device architecture where the diffusion barrier is removed along with the lower conducting layer.

[0021] **Figure 4A** is a flowchart of a process flow describing aspects of a method of fabricating an electrochromic device, according to embodiments.

[0022] **Figure 4B** depicts top views of steps in the process flow described in relation to **Figure 4A**.

[0023] **Figure 4C** depicts cross-sections of the electrochromic lite described in relation to **Figure 4B**.

[0024] **Figure 4D** is a top view schematic depicting steps during fabrication on a round substrate.

[0025] **Figure 4E** is a top view schematic depicting steps during fabrication of an electrochromic device.

[0026] **Figure 4F** is a schematic drawing in the perspective view depicting fabrication of an IGU with an optical device.

[0027] **Figure 4G** is a schematic drawing of top views of devices similar to that described in relation to **Figure 4B**.

[0028] **Figures 4H** and **4I** are schematic drawings depicting steps of a process flow similar to that described in relation to **Figure 4A** and carried out on a large-area substrate as applied to coat then cut methods.

[0029] **Figure 4J** is a drawing depicting roll-to-roll processing forming laminates of electrochromic devices where the lamination uses a flexible mate lite.

[0030] **Figure 5A** is a schematic drawing depicting roll-to-roll fabrication of electrochromic devices on flexible substrates and optional lamination with rigid substrates.

[0031] **Figure 5B** is a schematic drawing depicting lamination of electrochromic devices on flexible glass substrates and lamination with flexible substrates.

[0032] **Figure 6A** is a schematic drawing of a multi-faceted complex architectural shape, according to an embodiment.

[0033] **Figure 6B** is a schematic drawing of a multi-faceted complex architectural shape, according to an embodiment.

[0034] **Figure 7A** is a drawing of a cross-sectional view through a portion of a laminate of a monolithic EC window with an EC flexible substrate inboard, according to an embodiment.

[0035] **Figure 7B** is a drawing of a cross-sectional view through a portion of a laminate of a monolithic EC window with an EC flexible substrate inboard and with IR reflective material outboard, according to an embodiment.

[0036] **Figure 8A** is a drawing of a cross-sectional view through a portion of a laminate of a monolithic EC window with an EC support substrate inboard, according to an embodiment.

[0037] **Figure 8B** is a drawing of a cross-sectional view through a portion of a laminate of a monolithic EC window with an EC support substrate inboard and with IR reflective material outboard, according to an embodiment.

[0038] **Figure 8C** is a drawing of a cross-sectional view through a portion of a laminate of a monolithic EC window with an EC flexible substrate outboard, according to an embodiment.

[0039] **Figure 9A** is a drawing of a cross-sectional view through a portion of a laminate of a monolithic EC window with an EC flexible substrate inboard, according to an embodiment.

[0040] **Figure 9B** is a drawing of a cross-sectional view through a portion of a laminate of a monolithic EC window with EC flexible substrate inboard with IR reflective material outboard, according to an embodiment.

[0041] **Figure 9C** is a cross-sectional view through a portion of a laminate of a monolithic EC window with an EC flexible substrate inboard, according to an embodiment.

DETAILED DESCRIPTION

[0042] For the purposes of brevity, embodiments are described in terms of electrochromic devices; however, the scope of the disclosure is not so limited. One of ordinary skill in the art would appreciate that methods described can be used to fabricate virtually any thin-film device where one or more layers are sandwiched between two thin-film conductor layers. Certain embodiments are directed to optical devices, that is, thin-film devices having at least one transparent conductor layer. In the simplest form, an optical device includes a substrate and one or more material layers sandwiched between two conductor layers, one of which is transparent. In one embodiment, an optical device includes a transparent substrate and two transparent conductor layers. In another embodiment, an optical device includes a transparent substrate upon which is deposited a transparent conductor layer (the lower conductor layer) and the other (upper) conductor layer is not transparent. In another embodiment, the substrate is not transparent, and one or both of the conductor layers is transparent. Some examples of optical devices include electrochromic devices, flat panel displays, photovoltaic devices, suspended particle devices (SPD's), liquid crystal devices (LCD's), and the like. For context, a description of electrochromic devices is presented below. For convenience, all solid-state and inorganic electrochromic devices are described; however, embodiments are not limited in this way.

[0043] *I. Electrochromic Devices*

[0044] A particular example of an electrochromic lite is described with reference to **Figures 1A-1D**, in order to illustrate embodiments described herein. The electrochromic lite includes an electrochromic device fabricated on a substrate. **Figure 1A** is a cross-sectional representation (see cut X-X' of **Figure 1C**) of an electrochromic lite, **100**, which is fabricated starting with a glass sheet, **105**. **Figure 1B** shows an end view (see perspective Y-Y' of **Figure 1C**) of electrochromic lite **100**, and **Figure 1C** shows a top-down view of electrochromic lite **100**.

[0045] **Figure 1A** shows the electrochromic lite **100** after fabrication on glass sheet **105** and the edge has been deleted to produce area **140** around the perimeter of the lite. Edge deletion refers to removing one or more material layers from the device about some perimeter portion of the substrate. Typically, though not necessarily, edge deletion removes material down to and including the lower conductor layer (e.g., layer **115** in the example depicted in **Figures 1A-1D**), and may include removal of any diffusion barrier layer(s) down to the substrate itself. In **Figures 1A-1B**, the electrochromic lite **100** has also been laser scribed and bus bars have been attached. The glass lite, **105**, has a diffusion barrier, **110**, and a first transparent conducting oxide (TCO) **115** on the diffusion barrier.

[0046] In this example, the edge deletion process removes both TCO **115** and diffusion barrier **110**, but in other embodiments, only the TCO is removed, leaving the diffusion barrier intact. The TCO layer **115** is the first of two conductive layers used to form the electrodes of the electrochromic device fabricated on the glass sheet. In some examples, the glass sheet may be prefabricated with the diffusion barrier formed over underlying glass. Thus, the diffusion barrier is formed, and then the first TCO **115**, an EC stack **125** (e.g., stack having electrochromic, ion conductor, and counter electrode layers), and a second TCO, **130**, are formed. In other examples, the glass sheet may be prefabricated with both the diffusion barrier and the first TCO **115** formed over underlying glass.

[0047] In certain embodiments, one or more layers may be formed on a substrate (e.g., glass sheet) in an integrated deposition system where the substrate does not leave the integrated deposition system at any time during fabrication of the layer(s). In one embodiment, an electrochromic device including an EC stack and a second TCO may be fabricated in the integrated deposition system where the glass sheet does not leave the integrated deposition system at any time during fabrication of the layers. In one case, the first TCO layer may also be formed using the integrated deposition system where the glass sheet does not leave the integrated deposition system during deposition of the EC stack, and the TCO layer(s). In one embodiment, all of the layers (e.g., diffusion barrier, first TCO, EC stack, and second TCO) are deposited in the integrated deposition system where the glass sheet does not leave the integrated deposition system during deposition. In this example, prior to deposition of EC stack **125**, an isolation trench, **120**, may be cut through first TCO **115** and diffusion barrier **110**. Trench **120** is made in contemplation of electrically isolating an area of first TCO **115** that will reside under bus bar 1 after fabrication is complete (see **Figure 1A**). Trench **120** is sometimes referred to as the “L1” scribe, because it is the first laser scribe in certain processes. This is done to avoid charge buildup and coloration of the EC device under the bus bar, which can be undesirable. This undesirable result is explained in more detail below and was the impetus for certain embodiments described herein. That is, certain embodiments are directed toward eliminating the need for isolation trenches, such as trench **120**, for example, to avoid charge buildup under a bus bar, but also to simplify fabrication of the device by reducing or even eliminating laser isolation scribe steps.

[0048] After formation of the EC device, edge deletion processes and additional laser scribing are performed. **Figures 1A** and **1B** depict areas **140** where the EC device has been removed, in this example, from a perimeter region surrounding laser scribe trenches, **150**, **155**, **160** and **165**. Laser scribes **150**, **160** and **165** are sometimes referred to as “L2” scribes, because they are the second scribes in certain processes. Laser scribe **155** is sometimes referred to as the “L3” scribe, because it is the third scribe in certain processes. The L3 scribe passes through second TCO, **130**, and in this example (but not necessarily) the EC stack **125**, but not the first TCO **115**. Laser scribe trenches **150**, **155**, **160**, and **165** are made to isolate portions of the EC device, **135**, **145**, **170**, and **175**, which were potentially damaged during edge deletion processes from the operable EC device. In one embodiment, laser scribe trenches **150**, **160**, and **165** pass through the first TCO to aid in isolation of the device (laser scribe trench **155** does not pass through the first TCO, otherwise it would cut off bus bar 2’s electrical communication with the first TCO and thus the EC stack). In some embodiments, such as those depicted in **Figures 1A-1D**, laser scribe trenches **150**, **160**, and **165** may also pass through a diffusion barrier.

[0049] The laser or lasers used for the laser scribe processes are typically, but not necessarily, pulse-type lasers, for example, diode-pumped solid state lasers. For example, the laser scribe processes can be performed using a suitable laser. Some examples of suppliers that may provide suitable lasers include IPG Photonics Corp. (of Oxford, Massachusetts), Ekspla (of Vilnius, Lithuania), TRUMPF Inc. (Farmington, Connecticut), SPI Lasers LLC (Santa Clara, California), Spectra-Physics Corp. (Santa Clara, California), nLIGHT Inc. (Vancouver, Washington), and Fianium Inc. (Eugene, Oregon). Certain scribing steps can also be performed mechanically, for example, by a diamond tipped scribe; however, certain embodiments describe depth control during scribes or other material removal processing, which is well controlled with lasers. For example, in one embodiment, edge deletion is performed to the depth of the first TCO, in another embodiment edge deletion is performed to the depth of a diffusion barrier (the first TCO is removed), in yet another embodiment edge deletion is performed to the depth of the substrate (all material layers removed down to the substrate). In certain embodiments, variable depth scribes are described.

[0050] After laser scribing is complete, bus bars are attached. Non-penetrating bus bar (1) is applied to the second TCO. Non-penetrating bus bar (2) is applied to an area where the device including an EC stack and a second TCO was not deposited (for example, from a mask protecting the first TCO from device deposition) or, in this example, where an edge deletion process (e.g. laser ablation using an apparatus e.g. having a XY or XYZ galvanometer) was used to remove material down to the first TCO. In this example, both bus bar 1 and bus bar 2 are non-penetrating bus bars. A penetrating bus bar is one that is typically pressed into (or soldered) and through one or more layers to make contact with a lower conductor, e.g. TCO located at the bottom of or below one or more layers of the EC stack). A non-penetrating bus bar is one that does not penetrate into the layers, but rather makes electrical and physical contact on the surface of a conductive layer, for example, a TCO. A typical example of a non-penetrating bus bar is a conductive ink, e.g. a silver-based ink, applied to the appropriate conductive surface.

[0051] The TCO layers can be electrically connected using a non-traditional bus bar, for example, a bus bar fabricated with screen and lithography patterning methods. In one embodiment, electrical communication is established with the device's transparent conducting layers via silk screening (or using another patterning method) a conductive ink followed by heat curing or sintering the ink. Advantages to using the above described device configuration include simpler manufacturing, for example, and less laser scribing than conventional techniques which use penetrating bus bars.

[0052] After the bus bars are fabricated or otherwise applied to one or more conductive layers, the electrochromic lite may be integrated into an insulated glass unit (IGU), which includes, for example, wiring for the bus bars and the like. In some embodiments, one or both of the bus bars are inside the finished IGU. In particular embodiments, both bus bars are configured between the spacer and the glass of the IGU (commonly referred to as the primary seal of the IGU); that is, the bus bars are registered with the spacer used to separate the lites of an IGU. Area **140** is used, at least in part, to make the seal with one face of the spacer used to form the IGU. Thus, the wires or other connection to the bus bars runs between the spacer and the glass. As many spacers are made of metal, e.g., stainless steel, which is conductive, it is desirable to take steps to avoid short circuiting due to electrical communication between the bus bar and connector thereto and the metal spacer. Particular methods and apparatus for achieving this end are described in U.S. Patent Application, serial number 13/312,057 (now U.S. Patent No. 8,711,465), filed December 6, 2011, and titled “Improved Spacers for Insulated Glass Units,” which is hereby incorporated by reference in its entirety. In certain embodiments described herein, methods and resulting IGUs include having the perimeter edge of the EC device, bus bars and any isolation scribes are all within the primary seal of the IGU.

[0053] **Figure 1D** depicts a portion of the cross section in **Figure 1A**, where a portion of the depiction is expanded to illustrate an issue for which certain embodiments disclosed herein may overcome. Prior to fabrication of EC stack **125** on TCO **115**, an isolation trench, **120**, is formed through TCO **115** and diffusion barrier **110** in order to isolate a portion of the **115/110** stack from a larger region. This isolation trench is intended to cut off electrical communication of the lower TCO **115**, which is ultimately in electrical communication with bus bar 2, with a section of TCO **115** that lies directly below bus bar 1, which lies on TCO **130** and supplies electrical energy thereto. For example, during coloration of the EC device, bus bar 1 and bus bar 2 are energized in order to apply a potential across the EC device; for example, TCO **115** has a negative charge and TCO **130** has a positive charge or visa versa.

[0054] Isolation trench **120** is desirable for a number of reasons. It is sometimes desirable not to have the EC device color under bus bar 1 since this area is not viewable to the end user (the window frame typically extends beyond the bus bars and the isolation trench and/or these features are under the spacer as described above). Also, sometimes area **140** includes the lower TCO and the diffusion barrier, and in these instances it is undesirable for the lower TCO to carry charge to the edge of the glass, as there may be shorting issues and unwanted charge loss in areas that are not seen by the end user. Also, because the portion of the EC device directly under the bus bar experiences the most charge flux, there is a predisposition for this region of the device to form defects, e.g., delamination, particle dislodging (pop-off defects), and the like, which can cause abnormal or no coloring regions that become visible in the viewable region and/or negatively affect device performance. Isolation trench **120** was designed to address these issues. Despite these desired outcomes, it has been found that coloration below the first bus bar still occurs. This phenomenon is explained in relation to the expanded section of device **100** in the lower portion of **Figure 1D**.

[0055] When EC stack **125** is deposited on first TCO **115**, the electrochromic materials, of which EC stack **125** is comprised, fill isolation trench **120**. Though the electrical path of first TCO **115** is cut off by trench **120**, the trench becomes filled with material that, although not as electrically conductive as the TCO, is able to carry charge and is permeable to ions. During operation of EC lite **100**, e.g. when first TCO **115** has a negative charge (as depicted in **Figure 1D**), small amounts of charge pass across trench **120** and enter the isolated portion of first TCO **115**. This charge buildup may occur over several cycles of coloring and bleaching EC lite **100**. Once the isolated area of TCO **115** has charge built up, it allows coloration of the EC stack **125** under bus bar 1, in area **180**. Also, the charge in this portion of first TCO **115**, once built up, does not drain as efficiently as charge normally would in the remaining portion of TCO **115**, e.g., when an opposite charge is applied to bus bar 2. Another problem with isolation trench **120** is that the diffusion barrier may be compromised at the base of the trench. This can allow sodium ions to diffuse into the EC stack **125** from the glass substrate. These sodium ions can act as charge carriers and enhance charge buildup on the isolated portion of first TCO **115**. Yet another issue is that charge buildup under the bus bar can impose excess stress on the material layers and promote defect formation in this area. Finally, fabricating an isolation scribe in the conductor layer on the substrate adds further complication to the processing steps. Embodiments described herein may overcome these problems and others.

[0056] **Figure 2A** is a partial cross-section showing an improved architecture of an EC device, **200**. In this illustrated embodiment, the portion of first TCO **115** that would have extended below bus bar 1 is removed prior to fabrication of EC stack **125**. In this embodiment, diffusion barrier **110** extends to under bus bar 1 and to the edge of the EC device. In some embodiments, the diffusion barrier extends to the edge of glass **105**, that is, it covers area **140**. In other embodiments, a portion of the diffusion barrier may also be removed under the bus bar 1. In the aforementioned embodiments, the selective TCO removal under bus bar 1 is performed prior to fabrication of EC stack **125**. Edge deletion processes to form areas **140** (e.g., around the perimeter of the glass where the spacer forms a seal with the glass) can be performed prior to device fabrication or after. In certain embodiments, an isolation scribe trench, **150a**, is formed if the edge delete process to form **140** creates a rough edge or otherwise unacceptable edge due to, e.g., shorting issues, thus isolating a portion, **135a**, of material from the remainder of the EC device. As exemplified in the expanded portion of EC device **200** depicted in **Figure 2A**, since there is no portion of TCO **115** under bus bar 1, the aforementioned problems such as unwanted coloring and charge buildup may be avoided. Also, since diffusion barrier **110** is left intact, at least co-extensive with EC stack **125**, sodium ions are prevented from diffusing into the EC stack **125** and causing unwanted conduction or other problems.

[0057] In certain embodiments, a band of TCO **115** is selectively removed in the region under where bus bar 1 will reside once fabrication is complete. That is, the diffusion barrier **110** and first TCO **115** may remain on the area **140**, but a width of the first TCO **115** is selectively removed under bus bar 1. In one embodiment, the width of the removed band of TCO **115** may greater than the width of the bus bar 1 which resides above the removed band of TCO once device fabrication is complete. Embodiments described herein include an EC device having the configuration as depicted and described in relation to **Figure 2A** with a selectively removed band of TCO **115**. In one embodiment, the remainder of the device is as depicted and described as in relation to **Figures 1A-C**.

[0058] A device **200** similar to device **100** is depicted in **Figures 2A -2C**, showing the device architecture including laser isolation trenches and the like. **Figures 2B** and **2C** are drawings of an improved device architecture of disclosed embodiments. In certain embodiments, there are fewer, or no, laser isolation trenches made during fabrication of the device. These embodiments are described in more detail below.

[0059] **Figures 2D** and **2E** depict an electrochromic device, **205**, which has architecture very similar to device **200**, but it has neither a laser isolation scribe **150a**, nor an isolated region, **135a**, of the device that is non-functional. Certain laser edge delete processes leave a sufficiently clean edge of the device such that laser scribes like **150a** are not necessary. One embodiment is an optical device as depicted in **Figures 2D** and **2E** but not having isolation scribes **160** and **165**, nor isolated portions

170 and **175**. One embodiment is an optical device as depicted in **Figures 2D** and **2E** but not having isolation scribe **155**, nor isolated portion **145**. One embodiment is an optical device as depicted in **Figures 2D** and **2E** but not having isolation scribes **160**, **165**, or **155**, nor isolated portions **145**, **170**, and **175**. In certain embodiments, fabrication methods do not include any laser isolation scribes and thus produce optical devices having no physically isolated non-functional portions of the device.

[0060] As described in more detail below, certain embodiments include devices where the one or more material layers of the device and the second (upper) conductor layer are not co-extensive with the first (lower) conductor layer; specifically, these portions overhang the first conductor layer about some portion of the perimeter of the area of the first conductor. These overhanging portions may or may not include a bus bar. As an example, the overhanging portions as described in relation to **Figure 2A** or **3** do have a bus bar on the second conductor layer.

[0061] **Figure 3** is a partial cross-section showing an improved electrochromic device architecture, **300** of disclosed embodiments. In this illustrated embodiment, the portions of TCO **315** and diffusion barrier **310** that would have extended below bus bar 1 are removed prior to fabrication of EC stack **325**. That is, the first TCO and diffusion barrier removal under bus bar 1 is performed prior to fabrication of EC stack **325**. Edge deletion processes to form areas **340** (e.g., around the perimeter of the glass where the spacer forms a seal with the glass) can be performed prior to device fabrication (e.g., removing the diffusion barrier and using a mask thereafter) or after device fabrication (removing all materials down to the glass). In certain embodiments, an isolation scribe trench, analogous to **150a** in **Figure 2A**, is formed if the edge deletion process to form **340** creates a rough edge, thus isolating a portion, **135a** (as shown in **Figure 2A**), of material from the remainder of the EC device.

[0062] Referring again to **Figure 3**, as exemplified in the expanded portion of device **300**, since there is no portion of TCO **315** under bus bar 1, therefore the aforementioned problems such as unwanted coloring and charge buildup may be avoided. In this example, since diffusion barrier3 is also removed, sodium ions may diffuse into the EC stack in the region under bus bar 1; however, since there is no corresponding portion of TCO **115** to gain and hold charge, coloring and other issues are less problematic. In certain embodiments, a band of TCO **315** and diffusion barrier **310** is selectively removed in the region under where bus bar 1 will reside; that is, on the area **340**, the diffusion barrier and TCO may remain, but a width of TCO **315** and diffusion barrier **310** is selectively removed under and at least co-extensive with bus bar 1. In one embodiment, the width of the removed band of TCO and diffusion barrier is greater than the width of the bus bar which resides above the removed band once device fabrication is complete. Embodiments described herein include an EC device having the configuration as depicted and described in relation to **Figure 3**. In one embodiment, the remainder of the device is as depicted and described as in relation **to Figures 1A-C**. In certain embodiments, there are fewer, or no, laser isolation trenches made during fabrication of the device.

[0063] Embodiments include an optical device as described in relation to **Figure 3**, where the remainder is as optical device **205** described in relation to **Figures 2D** and **2E**. One embodiment is an optical device as depicted in **Figure 3**, but not having isolation scribes **160** and **165**, nor isolated portions **170** and **175**, as depicted **Figures 2D** and **2E**. One embodiment is an optical device as depicted in **Figure 3**, but not having isolation scribe **155**, nor isolated portion **145**, as depicted in **Figures 2D** and **2E**. One embodiment is an optical device as depicted in **Figure 3**, but not having isolation scribes **160**, **165**, or **155**, nor isolated portions **145**, **170**, and **175**, as depicted in **Figures 2D** and **2E**. Any of the aforementioned embodiments may also include an isolation scribe analogous to scribe **150** as depicted in relation to **Figures 1A-D**, but not an isolation scribe analogous to scribe **120**. All embodiments described herein obviate the need for a laser isolation scribe analogous to scribe **120**, as described in relation to **Figures 1A-D**. In addition, the goal is to reduce the number of laser isolation scribes needed, but depending upon the device materials or lasers used for example, the scribes other than scribe **120** may or may not be necessary.

[0064] As described above, in certain embodiments, devices are fabricated without the use of laser isolation scribes, that is, the final device has no isolated portions that are non-functional. Exemplary fabrication methods are described below in terms of having no isolation scribes; however, it is to be understood that one embodiment is any device as described below, where the device has the functional equivalent (depending on its geometry) of the isolation scribes as described in relation to **Figures 1A-D**, but not isolation scribe **120**. More specifically, one embodiment is an optical device as described below, but not having isolation scribes **160** and **165** as depicted

Figures 2D and **2E**. One embodiment is an optical device as described below, but not having isolation scribe **155** as depicted in **Figures 2D** and **2E**. One embodiment is an optical device as described below, but not having isolation scribes **160**, **165**, or **155** as depicted in **Figures 2D** and **2E**. Any of the aforementioned embodiments may also include an isolation scribe analogous to scribe **150** as depicted in relation to **Figures 1A-D**.

[0065] One embodiment is a method of fabricating an optical device including one or more material layers sandwiched between a first conducting layer (e.g., first TCO **115**) and a second conducting layer (e.g., second TCO **130**). The method includes: (i) receiving a substrate including the first conducting layer over its work surface; (ii) removing a first width of the first conducting layer from between about 10% and about 90% of the perimeter of the substrate; (iii) depositing the one or more material layers of the optical device and the second conducting layer such that they cover the first conducting layer and, where possible, extend beyond the first conducting layer about its perimeter; (iv) removing a second width, narrower than the first width, of all the layers about substantially the entire perimeter of the substrate, where the depth of removal is at least sufficient to remove the first conducting layer; (v) removing at least one portion of the second transparent conducting layer and the one or more layers of the optical device thereunder thereby revealing at least one exposed portion of the first conducting layer; and (vi) applying a bus bar to the at least one exposed portion of the first transparent conducting layer; where at least one of the first and second conducting layers is transparent. In one embodiment, (ii) includes removing the first width of the first conducting layer from between about 50% and about 75% around the perimeter of the substrate.

[0066] In one embodiment, a portion of the edge of the first conducting layer remaining after (ii) is tapered as described in more detail below. The tapered portion of the edge may include one, two or more sides if the transparent conductor is of a polygonal shape after (ii). In some cases, the first conducting layer is polished before (ii), and then optionally edge tapered. In other cases, the first conducting layer is polished after (ii), with or without edge tapering. In the latter cases, tapering can be prior to polish or after polishing.

[0067] In one embodiment, the at least one exposed portion of the first conducting layer exposed is fabricated along the perimeter portion of the optical device proximate the side or sides of the substrate where the first conducting layer was not removed in (ii). In certain embodiments, the exposed portion of the first conducting layer is not an aperture, or hole, through the one or more material layers and second conducting layer, but rather the exposed portion is an area that sticks out from an edge portion of the functional device stack layers. This is explained in more detail below with reference to particular examples.

[0068] The method may further include applying at least one second bus bar to the second conducting layer, particularly on a portion that does not cover the first conducting layer. In one embodiment, the optical device is an electrochromic device and may be all solid-state and inorganic. The substrate may be float glass and the first conducting layer may include tin oxide, e.g. fluorinated tin oxide. In one embodiment, (iii) is performed in an all vacuum integrated deposition apparatus. In certain embodiments, the method further includes depositing a vapor barrier layer on the second conducting layer prior to (iv).

[0069] In one embodiment, the at least one exposed portion of the first conducting layer is fabricated along the length of one side of the optical device, in one embodiment along the length of the side of the optical device proximate the side of the substrate where the first conducting layer was not removed in (ii). In one embodiment, the at least one second bus bar is applied to the second conducting layer proximate the side of the optical device opposite the at least one exposed portion of the first conducting layer. If a vapor barrier is applied a portion is removed in order to expose the second conductor layer for application of the at least one second bus bar. These methods are described below in relation to specific embodiments with relation to **Figures 4A-D**.

[0070] **Figure 4A** is a process flow, **400**, describing aspects of a method of fabricating an electrochromic device or other optical device having opposing bus bars, each applied to one of the conductor layers of the optical device. The dotted lines denote optional steps in the process flow. An exemplary device, **440**, as described in relation to **Figures 4B-C**, is used to illustrate the process flow. **Figure 4B** provides top views depicting the fabrication of device **440** including numerical indicators of process flow **400** as described in relation to **Figure 4A**. **Figure 4C** shows cross-sections of the lite including device **440** described in relation to **Figure 4B**. Device **440** is a rectangular device, but process flow **400** applies to any shape of optical device having opposing bus bars, each on one of the conductor layers. This aspect is described in more detail below, e.g. in relation to **Figure 4D** (which illustrates process flow **400** as it relates to fabrication of a round electrochromic device).

[0071] Referring **to Figures 4A** and **4B**, after receiving a substrate with a first conductor layer thereon, process flow **400** begins with an optional polishing of the first conductor layer, see **401**. In certain embodiments, polishing a lower transparent conductor layer has been found to enhance the optical properties of, and performance of, EC devices fabricated thereon. Polishing of transparent conducting layers prior to electrochromic device fabrication thereon is described in U.S. Patent application 14/347,227, titled "Optical Device Fabrication," and filed on September 27, 2012, which is hereby incorporated by reference in its entirety. Polishing, if performed, may be done prior to an edge deletion, see **405**, or after an edge deletion in the process flow. In certain embodiments, the lower conductor layer may be polished both before and after edge deletion. Typically, the lower conductor layer is polished only once.

[0072] Referring again to **Figure 4A**, if polishing **401** is not performed, process **400** begins with edge deleting a first width about a portion of the perimeter of the substrate, see **405**. The edge deletion may remove only the first conductor layer or may also remove a diffusion barrier, if present. In one embodiment, the substrate is glass and includes a sodium diffusion barrier and a transparent conducting layer thereon, e.g. a tin-oxide based transparent metal oxide conducting layer. The substrate may be rectangular (e.g., the square substrate depicted in see **Figure 4B**). The dotted area in **Figure 4B** denotes the first conductor layer. Thus, after edge deletion according to process **405**, a width **A** is removed from three sides of the perimeter of substrate **430**. This width is typically, but not necessarily, a uniform width. A second width, **B**, is described below. Where width **A** and/or width **B** are not uniform, then their relative magnitudes with respect to each other are in terms of their average width.

[0073] As a result of the removal of the first width **A** at **405**, there is a newly exposed edge of the lower conductor layer. In certain embodiments, at least a portion of this edge of the first conductive layer may be optionally tapered, see **407** and **409**. The underlying diffusion barrier layer may also be tapered. The inventors have found that tapering the edge of one or more device layers, prior to fabricating subsequent layers thereon, has unexpected advantages in device structure and performance.

[0074] In certain embodiments, the lower conductor layer is optionally polished after edge tapering, see **408**. It has been found, that with certain device materials, it may be advantageous to polish the lower conductor layer after the edge taper, as polishing can have unexpected beneficial effects on the edge taper as well as the bulk conductor surface which may improve device performance (as described above). In certain embodiments, the edge taper is performed after polish **408**, see **409**. Although edge tapering is shown at both **407** and **409** in **Figure 4A**, if performed, edge tapering would typically be performed once (e.g., at **407** or **409**).

[0075] After removal of the first width **A**, and optional polishing and/or optional edge tapering as described above, the EC device is deposited over the surface of substrate **430**, see **410**. This deposition includes one or more material layers of the optical device and the second conducting layer, e.g. a transparent conducting layer such as indium tin oxide (ITO). The depicted coverage is the entire substrate, but there could be some masking due to a carrier that must hold the glass in place. In one embodiment, the entire area of the remaining portion of the first conductor layer is covered including overlapping the first conductor about the first width **A** previously removed. This allows for overlapping regions in the final device architecture as explained in more detail below.

[0076] In particular embodiments, electromagnetic radiation is used to perform edge deletion and provide a peripheral region of the substrate, e.g. to remove transparent conductor layer or more layers (up to and including the top conductor layer and any vapor barrier applied thereto), depending upon the process step. In one embodiment, the edge deletion is performed at least to remove material including the transparent conductor layer on the substrate, and optionally also removing a diffusion barrier if present. In certain embodiments, edge deletion is used to remove a surface portion of the substrate, e.g. float glass, and may go to a depth not to exceed the thickness of the compression zone. Edge deletion is performed, e.g., to create a good surface for sealing by at least a portion of the primary seal and the secondary seal of the IGU. For example, a transparent conductor layer can sometimes lose adhesion when the conductor layer spans the entire area of the substrate and thus has an exposed edge, despite the presence of a secondary seal. Also, it is believed that when metal oxide and other functional layers have such exposed edges, they can serve as a pathway for moisture to enter the bulk device and thus compromise the primary and secondary seals.

[0077] Edge deletion is described herein as being performed on a substrate that is already cut to size. However, edge deletion can be done before a substrate is cut from a bulk glass sheet in other disclosed embodiments. For example, non-tempered float glass may be cut into individual lites after an EC device is patterned thereon. Methods described herein can be performed on a bulk sheet and then the sheet cut into individual EC lites. In certain embodiments, edge deletion may be carried out in some edge areas prior to cutting the EC lites, and again after they are cut from the bulk sheet. In certain embodiments, all edge deletion is performed prior to excising the lites from the bulk sheet. In embodiments employing “edge deletion” prior to cutting the panes, portions of the coating on the glass sheet can be removed in anticipation of where the cuts (and thus edges) of the newly formed EC lites will be. In other words, there is no actual substrate edge yet, only a defined area where a cut will be made to produce an edge. Thus “edge deletion” is meant to include removing one or more material layers in areas where a substrate edge is anticipated to exist. Methods of fabricating EC lites by cutting from a bulk sheet after fabrication of the EC device thereon are described in U.S. Patent Application, serial number 12/941,882 (now U.S. Patent No. 8,164,818), filed November 8, 2010, and U.S. Patent Application, serial number 13/456,056, filed April 25, 2012, each titled “Electrochromic Window Fabrication Methods” each of which is hereby incorporated by reference in its entirety. One of ordinary skill in the art would appreciate that if one were to carry out methods described herein on a bulk glass sheet and then cut individual lites therefrom, in certain embodiments masks may have to be used, whereas when performed on a lite of desired end size, masks are optional.

[0078] Exemplary electromagnetic radiation includes UV, lasers, and the like. For example, material may be removed with directed and focused energy one of the wavelengths 248 nm, 355 nm (UV), 1030 nm (IR, e.g. disk laser), 1064 nm (e.g. Nd:YAG laser), and 532 nm (e.g. green laser). Laser irradiation is delivered to the substrate using, e.g. optical fiber or open beam path. The ablation can be performed from either the substrate side or the EC film side depending on the choice of the substrate handling equipment and configuration parameters. The energy density required to ablate the film thickness is achieved by passing the laser beam through an optical lens. The lens focuses the laser beam to the desired shape and size. In one embodiment, a "top hat" beam configuration is used, e.g., having a focus area of between about 0.005 mm^2 to about 2 mm^2. In one embodiment, the focusing level of the beam is used to achieve the required energy density to ablate the EC film stack. In one embodiment, the energy density used in the ablation is between about 2 J/cm^2 and about 6 J/cm^2.

[0079] During a laser edge delete process, a laser spot is scanned over the surface of the EC device, along the periphery. In one embodiment, the laser spot is scanned using a scanning F theta lens. Homogeneous removal of the EC film is achieved, e.g., by overlapping the spots' area during scanning. In one embodiment, the overlap is between about 5% and about 100%, in another embodiment between about 10% and about 90%, in yet another embodiment between about 10% and about 80%. Various scanning patterns may be used, e.g., scanning in straight lines, curved lines, and various patterns may be scanned, e.g., rectangular or other shaped sections are scanned which, collectively, create the peripheral edge deletion area. In one embodiment the scanning lines (or "pens," i.e. lines created by adjacent or overlapping laser spots, e.g. square, round, etc.) are overlapped at the levels described above for spot overlap. That is, the area of the ablated material defined by the path of the line previously scanned is overlapped with later scan lines so that there is overlap. That is, a pattern area ablated by overlapping or adjacent laser spots is overlapped with the area of a subsequent ablation pattern. For embodiments where overlapping is used, spots, lines or patterns, a higher frequency laser, e.g. in the range of between about 11 KHz and about 500 KHz, may be used. In order to minimize heat related damage to the EC device at the exposed edge (a heat affected zone or "HAZ"), shorter pulse duration lasers are used. In one example, the pulse duration is between about 100 fs (femtosecond) and about 100 ns (nanosecond), in another embodiment the pulse duration is between about 1 ps (picosecond) and about 50 ns, in yet another embodiment the pulse duration is between about 20 ps and about 30 ns. Pulse duration of other ranges can be used in other embodiments.

[0080] Referring again to **Figures 4A** and **4B**, process flow **400** continues with removing a second width, **B**, narrower than the first width **A**, about substantially the entire perimeter of the substrate, see **415**. This may include removing material down to the glass or to a diffusion barrier, if present. After process flow **400** is complete up to **415**, e.g. on a rectangular substrate as depicted in **Figure 4B**, there is a perimeter area, with width **B**, where there is none of the first transparent conductor, the one or more material layers of the device, or the second conducting layer –removing width **B** has exposed diffusion barrier or substrate. Within this perimeter area is the device stack, including the first transparent conductor surrounded on three sides by overlapping one or more material layers and the second conductor layer. On the remaining side (e.g., the bottom side in **Figure 4B**) there is no overlapping portion of the one or more material layers and the second conductor layer. It is proximate this remaining side (e.g., bottom side in **Figure 4B**) that the one or more material layers and the second conductor layer are removed in order to expose a portion (bus bar pad expose, or “BPE”), **435**, of the first conductor layer, see **420**. The BPE **435** need not run the entire length of that side, it need only be long enough to accommodate the bus bar and leave some space between the bus bar and the second conductor layer so as not to short on the second conductor layer. In one embodiment, the BPE **435** spans the length of the first conductor layer on that side.

[0081] As described above, in various embodiments, a BPE is where a portion of the material layers are removed down to and sometimes penetrating into the lower electrode or other conductive layer (e.g. a transparent conducting oxide layer), in order to create a surface for a bus bar to be applied and thus make electrical contact with the electrode. The bus bar applied can be a soldered bus bar, an ink bus bar, and the like. A BPE typically has a rectangular area, but this is not necessary; the BPE may be any geometrical shape or an irregular shape. For example, depending upon the need, a BPE may be circular, triangular, oval, trapezoidal, and other polygonal shapes. The shape may be dependent on the configuration of the EC device, the substrate bearing the EC device (e.g. an irregular shaped window), or even, e.g., a more efficient (e.g. in material removal, time, etc.) laser ablation pattern used to create it. In one embodiment, the BPE spans at least about 50% of the length of one side of an

EC device. In one embodiment, the BPE spans at least about 80% of the length of one side of an EC device. Typically, but not necessarily, the BPE is wide enough to accommodate the bus bar, but should allow for some space at least between the active EC device stack and the bus bar. In one embodiment, the BPE is substantially rectangular, the length approximating one side of the EC device and the width is between about 5 mm and about 15 mm, in another embodiment between about 5 mm and about 10 mm, and in yet another embodiment between about 7 mm and about 9 mm. As mentioned, a bus bar may be between about 1 mm and about 5 mm wide, typically about 3 mm wide.

[0082] As mentioned, the BPE is fabricated wide enough to accommodate the bus bar's width and also leave space between the bus bar and the EC device (as the bus bar is only supposed to touch the lower conductive layer). The bus bar width may exceed that of the BPE (and thus there is bus bar material touching both the lower conductor and glass (and/or diffusion barrier) on area **140**), as long as there is space between the bus bar and the EC device (in embodiments where there is an L3 isolation scribe, the bus bar may contact the deactivated portion, e.g. see **145** in **Figure 1A**). In embodiments where the bus bar width is fully accommodated by the BPE, that is, the bus bar is entirely atop the lower conductor, the outer edge, along the length, of the bus bar may be aligned with the outer edge of the BPE, or inset by about 1 mm to about 3 mm. Likewise, the space between the bus bar and the EC device is between about 1 mm and about 3 mm, in another embodiment between about 1 mm and 2 mm, and in another embodiment about 1.5 mm. Formation of BPEs is described in more detail below, with respect to an EC device having a lower electrode that is a TCO. This is for convenience only, the electrode could be any suitable electrode for an optical device, transparent or not.

[0083] To make a BPE, an area of the bottom TCO (e.g. first TCO) is cleared of deposited material so that a bus bar can be fabricated on the TCO. In one embodiment, this is achieved by laser processing which selectively removes the deposited film layers while leaving the bottom TCO exposed in a defined area at a defined location. In one embodiment, the absorption characteristics of the bottom electrode and the deposited layers are exploited in order to achieve selectivity during laser ablation, that is, so that the EC materials on the TCO are selectively removed while leaving the TCO material intact. In certain embodiments, an upper portion (depth) of the TCO layer is also removed in order to ensure good electrical contact of the bus bar, e.g., by removing any mixture of TCO and EC materials that might have occurred during deposition. In certain embodiments, when the BPE edges are laser machined so as to minimize damage at these edges, the need for an L3 isolation scribe line to limit leakage currents can be avoided – this eliminates a process step, while achieving the desired device performance results.

[0084] In certain embodiments, the electromagnetic radiation used to fabricate a BPE is the same as described above for performing edge deletion. The (laser) radiation is delivered to the substrate using either optical fiber or the open beam path. The ablation can be performed from either glass side or the film side depending on the choice of the electromagnetic radiation wavelength. The energy density required to ablate the film thickness is achieved by passing the laser beam through an optical lens. The lens focuses the laser beam to the desired shape and size, e.g. a “top hat” having the dimensions described above, in one embodiment, having an energy density of between about 0.5 J/cm^2 and about 4 J/cm^2. In one embodiment, laser scan overlapping for BPE is done as described above for laser edge deletion. In certain embodiments, variable depth ablation is used for BPE fabrication. This is described in more detail below.

[0085] In certain embodiments, e.g. due to the selective nature of the absorption in an EC film, the laser processing at the focal plane results in some amount (between about 10 nm and about 100 nm) of residue, e.g. tungsten oxide, remaining on the exposed area of the lower conductor. Since many EC materials are not as conductive as the underlying conductor layer, the bus bar fabricated on this residue does not make full contact with the underlying conductor, resulting in voltage drop across the bus bar to lower conductor interface. The voltage drop impacts coloration of the device as well as impacts the adhesion of the bus bar to the lower conductor. One way to overcome this problem is to increase the amount of energy used for film removal, however, this approach results in forming a trench at the spot overlap, unacceptably depleting the lower conductor. To overcome this problem the laser ablation *above the focal plane* is performed, i.e. the laser beam is defocused. In one embodiment, the defocusing profile of the laser beam is a modified top hat, or “quasi top hat.” By using a defocused laser profile, the fluence delivered to the surface can be increased without damaging the underlying TCO at spot overlap region. This method minimizes the amount of residue left in on the exposed lower conductor layer and thus allows for better contact of the bus bar to the lower conductor layer.

[0086] Referring again to **Figures 4A** and **4B**, after forming the BPE, bus bars are applied to the device, one on exposed area **435** of the first conductor layer (e.g., first TCO) and one on the opposite side of the device, on the second conductor layer (e.g., second TCO), on a portion of the second conductor layer that is not above the first conductor layer, see **425**. This placement of the bus bar 1 on the second conductor layer avoids coloration under the bus bar (analogous to bus bar 1 in **Figures 2A** or **3**) and the other associated issues with having a functional device under this bus bar. In this example, there are no laser isolation scribes necessary in fabrication of the device – this is a radical departure from conventional fabrication methods, where one or more isolation scribes leave non-functional device portions remaining in the final construct.

[0087] **Figures 4B** indicates cross-section cuts **Z-Z'** and **W-W'** of device **440**. The cross-sectional views of device **440** at **Z-Z'** and **W-W'** are shown in **Figure 4C**. The depicted layers and dimensions are not to scale, but are meant to represent functionally the configuration. In this example, the diffusion barrier was removed when width **A** and width **B** were fabricated. Specifically, perimeter area **140** is free of first conductor layer and diffusion barrier; although in one embodiment the diffusion barrier is left intact to the edge of the substrate about the perimeter on one or more sides. In another embodiment, the diffusion barrier is co-extensive with the one or more material layers and the second conductor layer (thus width **A** is fabricated at a depth to the diffusion barrier, and width **B** is fabricated to a depth sufficient to remove the diffusion barrier). In this example, there is an overlapping portion, **445**, of the one or more material layers about three sides of the functional device. On one of these overlapping portions, on the second TCO, bus bar 1 is fabricated. In one embodiment, a vapor barrier layer is fabricated co-extensive with the second conductor layer. A vapor barrier is typically highly transparent, e.g. aluminum zinc oxide, a tin oxide, silicon dioxide and mixtures thereof, amorphous, crystalline or mixed amorphous-crystalline. In this embodiment, a portion of the vapor barrier is removed in order to expose the second conductor layer for bus bar 1. This exposed portion is analogous to area **435**, the BPE for bus bar 2. In certain embodiments, the vapor barrier layer is also electrically conductive, and exposure of the second conductor layer need not be performed, i.e. the bus bar may be fabricated on the vapor barrier layer. For example, the vapor barrier layer may be ITO, e.g. amorphous ITO, and thus be sufficiently electrically conductive for this purpose. The amorphous morphology of the vapor barrier may provide greater hermeticity than a crystalline morphology.

[0088] **Figure 4C** depicts the device layers overlying the first **TCO**, particularly the overlapping portion, **445**. Although not to scale, cross section Z-Z' for example, depicts the conformal nature of the layers of the EC stack and the second TCO following the shape and contour of the first TCO including the overlapping portion **445**. The transition to overlap **445**, where the upper device layers overlay the edge of the first TCO, e.g. depending upon the device materials and thickness of the layers, may form fissures. It is believed that these fissures are due to the stress related to the upper device layers having to follow an abrupt transition over the edge of the first TCO (in this example). Fissures may form along the edges of the device where the overlying layers cover such abrupt edges. These fissures may cause electrical shorting, as there is an exposed path between the first and second TCO's, and ions may short the device as the ion conducting layer (or functional equivalent) is breached at the fissure. These shorts cause coloration aberrations and poor performance of the electrochromic device. Embodiments herein overcome this problem by tapering (sloping or otherwise modifying) the lower device layers about at least a portion of their edge, particularly the lower transparent conducting layer, so that the overlying layers will not encounter such stresses. This is referred to herein as "edge tapering." Although edge tapering is described in certain embodiments, other stress mitigation topology may be used such as edge rounding, stepping, and beveling. Also, combinations of stress mitigation topology may be used.

[0089] After device fabrication a resulting electrochromic device as described above has overlapping portions of the one or more material layers and the top conductor layer around three sides. The portion of the upper layers overlaps edge portion. Because of the sloped nature of edge portion, it is believed the overlying device layers in portion no longer experience the stress levels otherwise encountered when an abrupt edge portion is below them. Portion gradually transitions to portion which lies on the glass substrate (or the diffusion barrier, the portion is analogous to portion **445** in **Figure 4C**). In this example, the edge taper is fabricated on three sides of the first TCO in accord with fabrication methods described herein, though, it can be done along any fraction of the perimeter of the TCO remaining after edge deletion (including the edge portion of the TCO along the substrate edge, i.e. that not removed by edge deletion). In one embodiment, edge taper is performed only about the perimeter edge of the TCO formed by edge deletion. In one embodiment, edge taper is performed only along that portion of the perimeter edge of the TCO formed by edge deletion and opposite side of the device as the BPE.

[0090] Although the above example describes the lower conductor layer as tapered, this need not be the case. Edge tapering can be done, e.g., after one or more other layers have been deposited on the lower conductor layer so long as the overall result is lowering of stress of subsequently deposited layers. One embodiment is an electrochromic device with one or more layers below the uppermost layer having an edge taper on at least some portion of their perimeter edge. One embodiment is an electrochromic device with one or more layers below the uppermost layer having a stress mitigation topology on at least some portion of their perimeter edge. The stress mitigation topology may include edge taper, edge rounding, stepping and/or beveling.

[0091] One embodiment is a method of fabricating an optical device, the method including tapering one or more edges of an underlying material layer prior to fabrication of overlapping layers thereon. In one embodiment, the underlying material layer is the lower conductor layer. In one embodiment, tapering one or more edges of the lower conductor layer includes laser ablation. In one embodiment the laser is defocused so as to create smooth contours in the tapered edge portion. In one embodiment, the lower conductor layer is polished before the edge taper. In one embodiment, the lower conductor layer is polished after the edge taper.

[0092] As described, one or more laser isolation scribes may be needed, depending upon design tolerances, material choice and the like. **Figure 4G** depicts top-views of three devices, **440a**, **440b** and **440c**, each of which are variations on device **440** as depicted in **Figures 4B** and **4C**. Device **440a** is similar to device **440**, but includes L2 scribes (see above) that isolate first portions of the EC device along the sides orthogonal to the sides with the bus bars. Device **440b** is similar to device **440**, but includes an L3 scribe isolating and deactivating a second portion of the device between the bus bar on the first (lower) conductor layer and the active region of the device. Device **440c** is similar to device **440**, but includes both the L2 scribes and the L3 scribe. Although the scribe line variations in **Figure 4G** are described in reference to devices **440a**, **440b** and **440c**, these variations can be used for any of the optical devices and lites of embodiments described herein. For example, one embodiment is a device analogous to device **440c**, but where the edge deletion does not span three sides, but rather only the side bearing the bus bar on the top TCO (or a portion long enough to accommodate the bus bar). In this embodiment, since there are no edge delete portions on the two sides orthogonal to the bus bars (the right and left side of **440c** as depicted), the L2 scribes may be closer to these edges in order to maximize viewable area. Depending upon device materials, process conditions, aberrant defects found after fabrication, etc., one or more of these scribes may be added to ensure proper electrical isolation of the electrodes and therefore device function. Any of these devices may have a vapor barrier applied prior to, or after, one or all of these scribes. If applied after, the vapor barrier is not substantially electrically conductive; otherwise it would short out the device's electrodes when filling the laser scribe trenches. The above-described edge tapering may obviate the need for such scribes.

[0093] In some cases, during laser ablation of the bus bar pad expose area, upon which bus bar 2 resides in this figure, the laser may not ablate away the top layers or ablate the lower conductor layer (first TCO in this instance) uniformly. Thus, there may be problematic issues with proper electrical connectivity between the bus bar and the lower conductor layer in areas.

[0094] In one example, the lower TCO is ablated in areas along one side to form a BPE. In this example, each of three areas is ablated with a defocused laser such that the cross section is concave has depicted. In this example, each of the scribe lines is made at the same laser fluence level. Also, no overlap of the laser ablations was used, so that there are raised regions (in this case ridges) of the TCO material remaining between adjacent ablation lines. This is one example of using laser ablation of an overlying material down to an underlying conductor layer using varying laser ablation levels along a plurality of individual scribes. There are essentially three "knobs" for achieving variable ablation depth: pulse duration, fluence level (power density) and overlap of laser spot and/or pattern (line, shape formed by positioning of individual spots). In certain embodiments 100% overlap is used, e.g., multiple shots on a single spot location or multiple lines across the same area. Embodiments herein for achieving varying ablation depth use any one of these or any combination thereof.

[0095] One embodiment is a method of fabricating a BPE, the method including laser ablation of overlying material down to an underlying TCO layer using varying laser ablation levels along a plurality of individual scribe lines during fabrication of the BPE. In one embodiment, each of the individual scribe lines, of the plurality of scribe lines, is scribed using a quasi-top hat at the same fluence level. Other patterns, besides lines, may be used so long as there is varying ablation depth. For example, a laser spot may be applied in a checkerboard pattern, with or without overlap of adjacent spots, where individual spots apply different pulse times to achieve varying ablation depth. In certain embodiments, at least two individual scribe lines, of the plurality of scribe lines, are scribed using a different fluence level for each line. Such embodiments are described in more detail below.

[0096] In one example, the electrochromic device has a BPE formed via laser ablation of the lower TCO using varying ablation depth along a plurality of laser ablation lines along one edge of the device. In this example, the lines are formed by overlapping laser spots along each line, but where each line uses a different overlap percentage of the individual spots. In this example, there is also overlap of the lines; however in some embodiments there is no overlap between one or more lines.

[0097] In one embodiment, the BPE is made from three lines. These lines each are of varying depth of ablation into the TCO relative to the other lines, but have substantially the same depth of ablation within any given line. By using varying ablation depth, e.g. using different fluence level of the laser spot, overlap in the spots or lines, pulse duration, and combinations thereof, the BPE has multiple depth profiles and accounts for problems associated with variation in film absorption during laser ablation. That is, if the laser doesn’t ablate deeply enough, or ablates too deeply, there is still a sufficient amount of exposed TCO in order to make good electrical contact with the bus bar along the device edge and thus good performance and coloration front during operation of the device. In this example, the TCO is ablated progressively more deeply as the laser is moved from each line to the next, so that the BPE is progressively thinner at the outer edge and thicker at the innermost surface near the device stack. The BPE may have gently sloped transitions between lines indicating that laser ablation paths were overlapping partially. By using varying ablation depth, good electrical contact between the bus bar and the BPE is ensured because even if there is absorption variation, there will be complete penetration to the lower TCO by at least one of the ablation lines.

[0098] In one embodiment, laser ablation is used to remove material from at least two lines along the edge of the EC device, along each line at a different ablation depth. In one embodiment, the ablation depth is selected from at least the upper 10% of the lower TCO, at least the upper 25% of the lower TCO, at least the upper 50% of the lower TCO, and at least the upper 75% of the lower TCO.

[0099] In one example, varying depth of the laser lines need not be from less depth to more depth as one moves from inner portion of BPE to outer portion of BPE. In this example, the laser ablation depth is configured such that the BPE is thicker furthest from the EC device and thinnest closest to the device edge. This pattern may have advantage when, e.g., it is desirable to make absolutely sure there is no stack material between where the bus bar is fabricated on the BPE and the device stack. By penetrating more deeply into the TCO on the line proximate the EC device, this is achieved. In one embodiment, the laser is configured to progressively remove more of the underlying conductor layer in each of the plurality of scribe lines, the ablation area of each scribe line is overlapped at least partially with the ablation area of the previous scribe line, and plurality of scribe lines are fabricated with most removal of underlying conductor layer nearest to the device stack and least removal of underlying conductive layer furthest from the device stack. In one embodiment, the laser is configured to progressively remove more of the underlying conductor layer in each of the plurality of scribe lines, the ablation area of said at least two scribe lines is overlapped at least partially with the ablation area, and plurality of scribe lines are fabricated with least removal of underlying conductor layer nearest to the device stack and most removal of underlying conductive layer furthest from the device stack.

[0100] Although varying fluence and/or overlap and/or pulse duration of laser ablation spots, lines or patterns can be used to vary the ablation depth is described in reference to BPE fabrication, it can also be used to create the edge taper as described herein. Nor are these methods limited to those embodiments, e.g., they can also be used to create isolation trenches, e.g., where two or more lines are ablated at different depths to ensure proper electrical (and optionally ionic) isolation of one section of an EC device from another. In one embodiment, an L3 scribe is fabricated where two or more scribe lines are used to fabricate the L3 scribe and at least two scribe lines each have a different ablation depth, with or without overlap of the lines.

[0101] The above described fabrication methods are described in terms of rectangular optical devices, e.g. rectangular EC devices. This is not necessary, as they also apply to other shapes, regular or irregular. Also, the arrangement of overlapping device layers as well as BPE and other features may be along one or more sides of the device, depending upon the need. In order to more fully describe the scope of the embodiments, these features are described in more detail below with respect to other shapes and configurations. As described in relation to **Figures 4A** and **4B**, the fabrications described below may also include other features such as polish of the lower transparent conductor layer, edge taper, multi-depth ablated BPE, etc. Description of these features was not given so as to avoid repetition, but one embodiment is any of the device configurations described below with one or more of the features described in relation to **Figures 4A** and **4B**.

[0102] **Figure 4D** is a top view schematic drawing depicting fabrication steps analogous to that described in relation to the rectangular substrate in **Figure 4B**, but on a round substrate, according to an embodiment. The substrate could also be oval. Thus as described previously, a first width **A** is removed, see **405**. The one or more material layers and second conductor layer (and optionally a vapor barrier) are applied over the substrate, see **410**. A second width **B** is removed from the entire perimeter of the substrate, see **415** (**140a** is analogous to **140**). A BPE, **435a**, is fabricated as described herein, see **420**. Bus bars are applied, see **425**, to make device **440d** (thus, for example, in accord with methods described above, the at least one second bus bar is applied to the second conducting layer proximate the side of the optical device opposite the at least one exposed portion of the first conducting layer).

[0103] **Figure 4E** is a top view schematic depicting fabrication analogous to that described in relation to the rectangular substrate in **Figure 4B**, but for angled bus bar application of an embodiment. Thus as described previously, a first width **A** is removed, see **405**, in this example from two orthogonal sides (one or both of the resulting edges of the lower TCO may have edge taper). The one or more material layers and second conductor layer (and optionally a vapor barrier) are applied over the substrate, see **410**. A second width **B** is removed from the entire perimeter of the substrate, see **415**. A BPE, **435b**, is fabricated as described herein; see **420**, in this example along orthogonal sides opposite those from which width **A** was removed. Bus bars are applied, see **425**, to make device **440e** (thus, for example, in accord with methods described above, the at least one second bus bar is applied to the second conducting layer proximate the side of the optical device opposite the at least one exposed portion of the first conducting layer). Angled bus bars are described in U.S. Patent Application, serial number 13/452,032, filed April 20, 2012, and titled "Angled Bus Bar," which is hereby incorporated by reference in its entirety. Angled bus bars have the advantages of decreasing switching speed and localized current "hot spots" in the device as well as more uniform transitions.

[0104] Whatever the shape of the device, it can be incorporated into an insulated glass unit. Preferably, the device is configured inside the IGU so as to protect it from moisture and the ambient. **Figure 4F** depicts IGU fabrication where the optical device, e.g. an electrochromic device is sealed within the IGU. IGU, **460**, including a first substantially transparent substrate, **445**, a spacer, **450**, and a second substantially transparent substrate, **455**. Substrate **445** has an electrochromic device fabricated thereon (bus bars are shown as dark vertical lines on substrate **445**). When the three components are combined, where spacer **450** is sandwiched in between and registered with substrates **445** and **455**, IGU **460** is formed. The IGU has an associated interior space defined by the faces of the substrates in contact with adhesive sealant between the substrates and the interior surfaces of the spacer, in order to hermetically seal the interior region and thus protect the interior from moisture and the ambient. This is commonly referred to as the primary seal of an IGU. A secondary seal includes an adhesive sealant applied around the spacer and between the panes of glass (the spacer has smaller length and width than the substrates so as to leave some space between the glass substrates from the outer edge to the spacer; this space is filled with sealant to form the secondary seal). In certain embodiments, any exposed areas of the first conducting layer are configured to be within the primary seal of the IGU. In one embodiment, any bus bars are also configured to be within the primary seal of the IGU. In one embodiment, the area of the second conductor layer that is not over the first conductor layer is also configured to be within the primary seal of the IGU.

Conventional electrochromic IGU's configure the bus bars either outside the spacer (in the secondary seal) or inside the spacer (in the interior volume of the IGU) in the viewable area of the IGU (sometimes one in the secondary seal, the other in the viewable area). Conventional electrochromic IGU's also configure the EC device edges either running to the substrate edge or inside the spacer (within the interior volume of the IGU). The inventors have found it advantageous to configure the bus bars, laser scribes, and the like to be under the spacer, so as to keep them from the viewable area and, e.g., to free up the secondary seal so that electrical components therein do not interfere with the aforementioned features. Such IGU configurations are described in U.S. Patent Application, serial number 13/456,056, titled "Electrochromic Window Fabrication Methods," filed April 25, 2012, which is hereby incorporated by reference in its entirety. Controllers that fit into the secondary seal are described in U.S. Patent number 8,213,074, titled "Onboard Controllers for Multistate Windows," filed March 16, 2011, which is hereby incorporated by reference in its entirety. Methods described herein include sealing any exposed areas of the first conductor layer, edges of the device or overlapping regions of the one or more material layers, and the second conductor layer in the primary seal of the IGU. With or without a vapor barrier layer, such as silicon oxide, silicon aluminum oxide, silicon oxynitride, and the like, this sealing protocol provides superior moisture resistance to protect the electrochromic device while maximizing viewable area.

[0105] In certain embodiments, the fabrication methods described herein are performed using large-area float glass substrates, where a plurality of EC lites are fabricated on a single monolithic substrate and then the substrate is cut into individual EC lites. Similar, "coat then cut" methods are described in U.S. Patent number 8,164,818, filed November 8, 2010, and titled, "Electrochromic Window Fabrication Methods," which is hereby incorporated by reference in its entirety. In some embodiments, these fabrication principles are applied to the methods described herein, e.g., in relation to **Figures 4A – 4G**.

[0106] **Figures 4H** and **4I** depict an EC lite fabrication process flow, similar to that described in relation to **Figure 4A**, but carried out on a large-area substrate as applied to coat then cut methods, according to embodiments. These fabrication methods can be used to make EC lites of varying shapes, e.g., as described herein, but in this example, rectangular EC lites are described. In this example, substrate **430** (e.g. as described in relation to **Figure 4A**, coated with a transparent conducting oxide layer) is a large-area substrate, such as float glass, e.g. a sheet of glass that is 5 feet by 10 feet. Analogous to operation **405** as described in relation to **Figure 4A**, edge deletion at a first width, **A**, is performed. Edge taper and/or polish may also be performed. In this example, since there are to be a plurality of EC devices (in this example, 12 devices) fabricated on a large substrate, the first width **A** may have one or more components. In this example, there are two components, $\mathbf{A_1}$ and $\mathbf{A_2}$, to width **A**. First, there is a width $\mathbf{A_1}$, along the vertical (as depicted) edges of the substrate. Since there are neighboring EC devices, the width $\mathbf{A_1}$ is reflected in a coating removal that is twice the width $\mathbf{A_1}$. In other words, when the individual devices are cut from the bulk sheet, the cuts in between neighboring devices along the vertical (as depicted) dimension will evenly bi-furcate the area where the coating is removed. Thus “edge deletion” in these areas accounts for where glass edges will eventually exist after the glass is cut (see for example Figure 4I). Second, along the horizontal dimension, a second **A**-width component, $\mathbf{A_2}$, is used. Note, in certain embodiments width $\mathbf{A_1}$ is used about the entire perimeter of the substrate; however, in this example more width is provided to accommodate the bus bar that will fabricated on the top transparent conductor layer (e.g. see **Figure 4C**, bus bar 1). In this example, width $\mathbf{A_2}$ is the same both at the top and bottom edge of the substrate and between neighboring EC devices. This is because the fabrication is analogous to that described in relation to **Figure 4B**, i.e., where the EC devices are cut from the substrate along the bottom of edge of the transparent conductor area for each device (see **Figure 4G**).

[0107] Next, in operation **410**, the remaining layers of the EC device are deposited over the entire substrate surface (save any areas where clamps might hold the glass in a carrier, for example). The substrate may be cleaned prior to operation **410**, e.g., to remove contaminants from the edge deletion. Also edge taper on each of the TCO areas may be performed. The remaining layers of the EC device encapsulate the isolated regions of the transparent conductor on the substrate, because they surround these areas of transparent conductor (except for the back face which resides against the substrate or intervening ion barrier layer). In one embodiment, operation **410** is performed in a controlled-ambient all PVD process, where the substrate doesn’t leave the coating apparatus or break vacuum until all the layers are deposited.

[0108] In operation **415**, edge deletion at a second width, **B**, narrower than the first width **A**, is performed. In this example, second width **B** is uniform. In between neighboring devices, second width **B** is doubled to account for cutting the substrate along lines evenly between two devices so that the final devices have a uniform edge delete about them for the spacer to seal to the glass when an IGU is fabricated from each EC device. As illustrated in **Figure 4H**, this second edge deletion isolates individual EC lites on the substrate. In certain embodiments, the second width **B** may be much smaller than that needed to accommodate a spacer for IGU fabrication. That is, the EC lite may be laminated to another substrate and thus only a small edge delete at width **B**, or in some embodiments no edge delete at the second width **B** is necessary.

[0109] Referring to **Figure 4I**, operation **420** includes fabricating a BPE, **435**, where a portion of the EC device layers are removed to expose the lower conductor layer proximate the substrate. In this example, that portion is removed along the bottom (as depicted) edge of each EC device. Next, during operation **425**, bus bars are added to each device. In certain embodiments, the EC lites are excised from the substrate prior to bus bar application. The substrate now has completed EC devices. Next, the substrate is cut, operation **470**, to produce a plurality of EC lites **440**, in this example 12 lites. This is a radical departure from conventional coat then cut methods, where here, fully functional EC devices can be fabricated, including bus bars on a large area format glass sheet. In certain embodiments the individual EC lites are tested and optionally any defects mitigated prior to cutting the large format sheet.

[0110] Coat and then cut methods allow for high throughput manufacture because a plurality of EC devices can be fabricated on a single large area substrate, as well as tested and defect-mitigated prior to cutting the large format glass sheet into individual lites. In one embodiment, the large format glass pane is laminated with individual strengthening panes registered with each EC device prior to cutting the large format sheet. The bus bars may or may not be attached prior to lamination; for example, the mate lite may be coextensive with an area allowing some exposed portions of the top and bottom TCO's for subsequent bus bar attachment. In another example, the mate lite is a thin flexible material, such as a thin flexible glass described below, which is substantially co-extensive with the EC device or the entire large format sheet. The thin flexible mate lite is ablated (and lamination adhesive, if present in these areas) down to the first and second conductor layers so that bus bars may be attached to them as described herein. In yet another embodiment, the thin flexible mate lite, whether co-extensive with the entire large format sheet or the individual EC devices, is configured with apertures which are registered with the top conductor layer and the BPE during lamination. The bus bars are attached either before or after lamination with the mate lite, as the apertures allow for either operation sequence. The lamination and bus bar attachment may separately be performed prior to cutting the large sheet, or after.

[0111] In certain embodiments, when laminating, bus bar ink may be applied prior to lamination, where the ink is applied to the BPE and upper TCO, then pressed out from between these areas when laminated, e.g. to an aperture in the mate lite or continuing around the edge of the laminate, to allow lead attach at a point located outside the laminated area. In another embodiment, a flat foil tape is applied to the top conductor and the BPE, the foil tape extends beyond the laminated region, such that wires can be soldered to the tape after lamination. In these embodiments, cutting must precede lamination unless, e.g., the lamination mate lites do not cover the entire surface of the large format substrate (e.g. as described in relation to roll-to-roll embodiments herein).

[0112] Lites **440**, laminated or not, may be incorporated into an IGU, e.g. as depicted in **Figure 4F**. In one embodiment, the individual EC lites are incorporated into an IGU and then one or more of the EC lites of the IGU is laminated with a strengthening pane (mate lite) as described herein or in U.S. Patent number 8,164,818. In other embodiments, e.g. as described herein, lamination may include a flexible substrate, e.g. the aforementioned lamination of an IGU where the mate lite is a flexible substrate, or e.g., lamination of the EC lite directly to a flexible substrate. Further such embodiments are described in relation to **Figure 4J**.

[0113] **Figure 4J** depicts roll-to-roll processing, **475**, forming laminates of electrochromic devices where the lamination uses a flexible mate lite. A substrate, **476**, is fed into a lamination line, in this example including a conveyer **477**. Substrate **476** may be an IGU with at least one EC lite incorporated, or substrate **476** can be a monolithic EC device, e.g., as described herein or substrate **476** can be a large format substrate with a plurality of EC lites fabricated thereon. In this example, a thin and flexible substrate, **478**, in this case a glass substrate is fed from a roll into the lamination line. In one embodiment one or more rolls are applied in parallel to a large format glass sheet including a plurality of EC devices, e.g., as described in relation to **Figure 4I**. For example, three separate and parallel rolls of the flexible substrate are fed into a lamination line that laminates the large format glass substrate lengthwise or widthwise such that three columns or rows of EC devices (see **Figure 4I**, upper portion) are each laminated with the flexible substrate. Thus using roll-to-roll processing, large format glass sheets can be laminated with flexible mate lite material and cut into individual EC lites. The large format glass sheet may be cut as each row is laminated or after the entire sheet is laminated. In certain embodiments, individual EC lites, or IGU's containing them, are laminated with roll-to-roll processing. More detail of roll-to-roll processing is described below.

[0114] Exemplary flexible substrates include thin and durable glass materials, such as Gorilla® Glass (e.g. between about 0.5 mm and about 2.0 mm thick) and Willow™ Glass, commercially available from Corning, Incorporated of Corning New York. In one embodiment, the flexible substrate is less than 0.3 mm thick, in another embodiment the flexible substrate is less 0.2 mm thick, and in another embodiment the flexible substrate is about 0.1 mm thick. Such substrates can be used in roll-to-roll processing. Referring again to **Figure 4J**, adhesive is applied to substrate **476**, flexible substrate **478**, or both. Rollers **479** apply sufficient pressure to ensure good bonding between substrate **476** and flexible substrate **478**. Flexible substrate **478** is cut to match its lamination partner **476**, e.g., using a laser **480**. The final laminate structure, **481**, results. Using this roll-to-roll method, monolithic EC devices, IGU's or large format glass sheets bearing a plurality of EC lites can be strengthened with a thin flexible strengthening pane. These methods apply to any EC substrate, described herein or otherwise. In one embodiment, the monolithic EC lites as depicted in **Figure 4I**, e.g. having been cut from the large area substrate, are fed into the lamination line to be laminated with the flexible substrate. In another embodiment, the large area substrate, having a plurality of EC devices fabricated thereon, is laminated with a flexible substrate of corresponding width, and after lamination, the individual, now laminated, EC devices are cut from the large area laminate, e.g., by row as lamination finishes or after lamination of the entire large format sheet. In another embodiment, the large area substrate, having a plurality of EC devices fabricated thereon, is laminated with a plurality of flexible substrates of corresponding width or length to individual EC lites, and after lamination, the EC devices, now laminated, are cut from the large area laminate, e.g. individually, or by row (or column).

[0115] As described, e.g. in relation to **Figures 4A-E**, EC devices may have two bus bars, one for each transparent conducting layer. However, methods herein also include fabrication of devices having more than one bus bar for each transparent conducting layer, specifically bus bars on opposing sides of each of the first and second conductor layer. This may be particularly important when fabricating larger EC devices that would otherwise require longer switching times due to the sheet resistance and having large-area devices.

[0116] The methods described herein can be used to fabricate optical devices of virtually any shape (e.g., triangular, rectangular, trapezoidal, etc.). Also, various masking steps may be used to fabricate devices as described herein, although masking adds extra steps.

[0117] One embodiment is an optical device including: (i) a first conductor layer on a substrate, the first conductor layer including an area less than that of the substrate, the first conductor layer surrounded by a perimeter area of the substrate which is substantially free of the first conductor layer; (ii) one or more material layers including at least one optically switchable material, the one or more material layers configured to be within the perimeter area of the substrate and co-extensive with the first conductor layer but for at least one exposed area of the first conductor layer, the at least one exposed area of the first conductor layer free of the one or more material layers; and (iii) a second conductor layer on the one or more material layers, the second conductor layer transparent and co-extensive with the one or more material layers, where the one or more material layers and the second conductor layer overhang the first conductor layer but for the at least one exposed area of the first conductor layer. In one embodiment, the optical device further includes a vapor barrier layer coextensive with the second conductor layer. There may be a diffusion barrier between the substrate and the first conductor layer. The perimeter area of the substrate can include the ion diffusion barrier. In one embodiment, the at least one optically switchable material is an electrochromic material. In one embodiment, the substrate and the first conductor layer are also transparent. In one embodiment, the at least one exposed area of the first conductor layer includes a strip proximate the perimeter area of the substrate. The device may include a first bus bar on and within the area of the strip. The device may also include a second bus bar on the second conductor layer, the second bus bar configured to be on or disposed on a portion of the second conducting layer that does not cover the first conducting layer, the portion proximate the perimeter area and opposite the first bus bar. In one embodiment, the first and second conductor layers and the one or more material layers are all solid-state and inorganic. In one embodiment, the substrate is float glass, tempered or untempered, and the first conducting layer includes tin oxide, e.g. fluorinated tin oxide. In one embodiment, the substrate is registered with a second substrate in an IGU. In one embodiment, any otherwise exposed areas of the first conducting layer are configured to be within the primary seal of the IGU, the bus bars may also be configured to be within the primary seal of the IGU as well as the area of the second conductor layer that is not over the first conductor layer. The optical device may be rectangular, round, oval, triangular and the like.

[0118] In certain embodiments, opposing bus bars on each conductor layer are used. In one embodiment, the at least one exposed area of the first conductor layer includes a pair of strips, each strip of the pair of strips on opposing sides of the first conductor layer proximate the perimeter area of the transparent substrate. Depending upon the shape of the device, the strips may be linear or curved, for example. The strips can include a first pair of bus bars, each of the first pair of bus bars on and within the area of each strip of the pair of strips. A second pair of bus bars on the second conductor layer can be included, each of the second pair of bus bars configured to be on or disposed on each of two portions of the second conducting layer that do not cover the first conducting layer, each of the two portions proximate the perimeter area and on opposing sides of the second conducting layer.

[0119] The first and second conductor layers and the one or more material layers of optical devices described herein may be all solid-state and inorganic. In one embodiment, the substrate is float glass, tempered or untempered, and the first conducting layer includes tin oxide, e.g. fluorinated tin oxide. The substrate may be registered in an IGU with an additional EC device or not. As described, the bus bars, any laser scribes, device edges, and/or exposed portions of the first conductor layer may be sealed in the primary seal of the IGU. Dual EC device IGU's are described in US Patent Application, serial number 12/851,514 (now U.S. Patent No. 8,270,059), filed August 5, 2010, and titled "Multi-pane Electrochromic Windows," which is hereby incorporated by reference in its entirety. One embodiment is a multi-pane window as described in that application, having one or more EC devices as described herein. One embodiment is any optical device described herein which does not include a laser isolation scribe. One embodiment is any optical device described herein which does not include an inactive portion of the optical device.

[0120] As described above in relation to **Figures 4H** and **4I**, some embodiments include coat then cut fabrication. . The lamination embodiments described above also apply to the coat then cut embodiments described below.

[0121] In some cases, thin flexible substrates may be used as strengthening panes (mate lites) for EC lites, e.g. EC lites fabricated as described herein. In certain embodiments, thin flexible substrates are used as *substrates* for the EC lite fabrication process. For example, one embodiment includes any of the EC device fabrication methods described herein performed on a thin flexible substrate as described herein, e.g. Gorilla® Glass or Willow™ Glass. In some embodiments, fabrication is performed using a roll-to-roll fabrication scheme. Examples of this embodiment are described below in relation to **Figures 5A** and **5B**.

[0122] **Figure 5A** depicts roll-to-roll fabrication, **600**, of electrochromic devices on thin flexible substrates and optional lamination with rigid substrates. **Figure 5A** is a fusion of a chart-type process flow with block diagrams including functional descriptions of apparatus and device features. The actual apparatus for performing the described fabrication may be in any orientation, but in one embodiment, the flexible substrate is preferably vertical. In another embodiment, the substrate is vertical and the process operations are performed in a "top down" format, where the substrate is fed into the line from a first height, passes downward through the fabrication process, and ends at a second height, lower than the first height. In this example, a thin flexible substrate, **478a** (as described above), includes a transparent conductive oxide layer. An example of this substrate is Willow Glass™, which is commercially available with an ITO coating from Corning, Incorporated of Corning, New York. The heavy dotted arrow in **Figure 5A** indicates the direction of motion of the flexible substrate through various modules.

[0123] First, the flexible substrate is fed into an edge deletion module, **605**. In this module, the edge deletion of a first width (as described herein) from the transparent conductor layer is performed. The substrate may optionally be cleaned (not depicted in **Figure 5A**) of any contaminants resulting from the first edge delete. Also, in accord with embodiments described herein, e.g. in relation to **Figures 4A** and **4B**, the transparent conducting layer may be given an edge taper and/or polishing process (not depicted). Next, the thin flexible substrate enters a coater, **610**, where the remaining layers of the EC device are deposited, in this example, using a vacuum integrated all-PVD sputter apparatus. Such apparatus are described in US Patent number 8,243,357, titled, “Fabrication of Low Defectivity Electrochromic Devices,” filed on May 11, 2011, which is hereby incorporated by reference in its entirety. After the flexible substrate is coated with the EC device, a second edge delete (as described herein) is carried out, in this example, in a module **615**. Edge deletion may optionally be followed by edge taper (not shown). Next is BPE fabrication, **620**, followed by application of bus bars, see **625**. Optionally, the flexible substrate may be laminated with a mate lite, see **630**, e.g. as described in relation to **Figure 4J**. The mate lite may be flexible as the substrate, or a rigid substrate, such as annealed glass or a polymeric substrate. In this example, the flexible substrate is laminated with annealed glass. The flexible substrate is then cut, either to match the rigid substrate to which it is laminated (as depicted) which produces laminated EC devices **640**, or as a monolithic flexible EC device (not shown). In the latter embodiment, the flexible EC device may be coated with a vapor barrier and/or encapsulation layer prior to or after cutting from the bulk material.

[0124] Depending upon the width of the flexible substrate, there may be one or more EC devices fabricated along the width of the flexible substrate as it passes through modules/process flows **605-635**. For example, if the flexible substrate is as wide as a large area float glass substrate as described herein, lamination with the large area substrate will produce a corresponding large-area laminate. Individual EC lite laminates can be cut from that large area laminate, e.g. as described above.

[0125] In some embodiments, a flexible EC device laminate is desired. In one embodiment, the flexible substrate bearing the plurality of EC devices is itself laminated with another flexible substrate. **Figure 5B** depicts fabrication, **650**, of electrochromic devices on flexible glass substrates and subsequent lamination with flexible substrates. In this example, flexible substrate **478a** (as described above) having a transparent conductor layer thereon is fed through fabrication line processes **605** – **625** as described in relation to **Figure 5A**. Then, the flexible substrate, having a plurality of EC devices thereon, is laminated with another flexible substrate, in this example substrate **478** as described above, via appropriate application of lamination adhesive and rollers **630**. The newly formed laminate is cut, e.g. via laser, see **635**, to form individual flexible EC laminates. **665**, which, e.g., can pass along conveyer **477** for further processing. As described above, the flexible substrate "mate lite" may be patterned with apertures to accommodate the bus bars, or ablated to reveal TCO and the bus bars (process **625**) added after lamination, either before or after cutting into individual laminated EC lites.

[0126] *II. Monolithic Electrochromic Laminate Windows*

[0127] In certain aspects, two or more substrates (at least one having an EC device thereon) may be laminated together to form an EC laminate. Some examples of EC laminates are described with respect to the fabrication processes depicted in in **Figure 4J, Figure 5A** and **Figure 5B**. These and other EC laminates described herein can be a lite in an IGU or used in a monolithic EC laminate window design. In a monolithic design, the EC laminate includes two or more substrates laminated together and an adhesive at the substrate interface(s). Relative to an IGU construct that requires a gas space between the lites and associated sealing structures, monolithic EC laminates described herein are thin and lightweight providing more design freedom especially when used in complex architectural shapes. For example, monolithic EC laminate windows may be particularly desirable as lightweight architectural elements such as those used in multi-faceted, complex-shaped building façades. **Figures 6A** and **6B** provides schematic examples of multi-faceted constructions **690**, **695** respectively, for complex shapes, as an example. Other examples include canopy type glass constructs that use electrochromic laminates as described herein. For example, modern architecture may include more open spaces for occupant activity, and to accommodate these open air spaces, glass canopies, sometimes quite large, are used to protect the open air spaces from the elements while allowing the spaces to be well illuminated with natural light. In convention canopy systems, fabric is often used so that the sunlight striking the open air architecture is not too intense for occupants, thus such fabric canopies are essentially full time shading systems. By using electrochromic glass, particularly lightweight electrochromic laminates, canopies can be constructed that allow full sunlight or varying degrees of shading simply by changing the tint state of the electrochromic laminates. Also, since each electrochromic laminate can be independently tinted, e.g. with automated tinting with sun tracking, such as Intelligence®, a commercially available automatic tinting software platform by View, Inc., of Milpitas, California, the canopy can have different portions shading at different levels providing customized shading for various areas of the structure under the canopy. Moreover, since monolithic EC laminate windows are not bound by the size and sealing constraints of an IGU construction, a monolithic laminate window can be fabricated in larger sizes, which provides additional design flexibility.

[0128] One embodiment is a glass canopy including electrochromic laminates. The electrochromic laminates may be lightweight and flexible. In certain examples, each of the electrochromic laminates weighs less than 3 pounds per square foot, less than 2 pounds per square foot, less than 1 pound per square foot. The laminate substrates may be thin glass, plastic, or both, e.g. one lite is plastic and the other glass. In one example, the one lite of a laminate is thin glass and has an electrochromic coating thereon. The other lite of the laminate is thin glass and optionally has an electrochromic lite thereon. The laminate may have a lamination adhesive that binds to the glass irreversibly so that if the laminate is damaged the glass pieces will stay adhered to the lamination adhesive. In embodiments where both lites have electrochromic device coatings thereon, each electrochromic device may be made thinner than it otherwise would in a single EC coated lite laminate. Such "dual pane" electrochromic devices may achieve dark tinting while each individual devices' lowest tint state is e.g. 10% transmission. Some examples of multi-pane electrochromic devices/windows can be found in U.S. Patent Application 12/851,514 (now U.S. Patent No. 8,270,059), titled "MULTI-PANE ELECTROCHROMIC WINDOWS" and filed on February 9, 2012, which is hereby incorporated by reference in its entirety. Such glass/glass laminates may have a protective coating, such as a polymer, on one or both outside surfaces to protect against breakage of the thin glass substrates. By using thin flexible substrates, electrochromic laminates can be made in large sizes, be lightweight and yet strong, and allow electrochromic canopies, for example, as well as other structures not heretofore realized. In another example, one lite of an EC laminate includes an electrochromic device coating while the mate lite of the laminate includes a thermochromic coating and/or a photochromic coating. In this way one lite of the laminate allows for passive tinting, while the other lite provide active tinting to augment the passive tinting, or not, depending upon the need of the end user. Complimentary tinting also allows for each tintable coating, whether actively or passively tinting, to tint to a lesser degree, while together providing more tinting/shading than each film could otherwise singly.

[0129] Electrochromic canopies described herein may be constructed using cable suspension systems to hold the EC laminates. Each EC laminate is held by a frame. The frame may be rigid or provide some flex. In certain embodiments, the frame is an extruded plastic that is formed around and bound to the perimeter edge and some of each outer surface of the EC laminate. The frame may be an extruded plastic or aluminum that includes a channel in which the perimeter edge of the laminate is inserted, e.g. with an adhesive to hold the edge and seal the perimeter of the laminate from the elements. In some embodiments, the frame holds the EC laminate as well as wiring for powering the EC laminates and optionally a window controller. Cables of the suspension system may pass through the frame, e.g. apertures in the frame, loops, or other features, or the frame may have attachment elements to attach the frame to the cable system, e.g. bolt and clamp systems, which may be applied at variable positions through holes in the frame about the perimeter of the frame. Frames described herein may include PV cells to power the EC laminates. Adjoining frames may also be attached to each other in a flexible manner, e.g. by links or cables. The frames provide spacing elements between cables. The EC laminates may be rectangular, triangular, trapezoidal or other shapes depending upon the canopy configuration desired. In certain embodiments, the EC laminates are self-contained, wirelessly controlled and self-powered, e.g. by onboard PV, or wireless powering, e.g. as described in U.S. Provisional Application 62/313,587, titled "PHOTOVOLTAIC-ELECTROCHROMIC WINDOWS" and filed on March 25, 2016; U.S. Provisional Patent Application 62/247,719, titled "PHOTOVOLTAIC-ELECTROCHROMIC WINDOWS" and filed on October 28, 2015; U.S. Patent No. 9,081,246 titled

"WIRELESS POWERED ELECTROCHROMIC WINDOWS" and issued on July 14, 2015; U.S. Patent No. 8,213,074 titled "ONBOARD CONTROLLER FOR MULTISTATE WINDOWS" and issued on July 3, 2012; U.S. 14/951,410, titled "SELF-CONTAINED EC IGU" and filed on June 2, 2016; and U.S. Provisional Patent Application No. 62/305,892, titled "METHOD OF COMISSIONING ELECTROCHROMIC WINDOWS" and filed on March 9, 2016; all of which are hereby incorporated by reference in their entireties. Such self-contained systems allow for ease of installation and commissioning, e.g. where the canopy is installed and self-meshes during commissioning.

[0130] For heat control, a monolithic EC laminate window can be fabricated with low E material and/or IR reflective material at one or more of the substrate interfaces or outer surfaces. The low E material or IR reflective material may be a discrete layer or may be incorporated into a layer such as, for example, an adhesive at an interface between substrates. An example of an optically transparent IR reflective coating is a $TiO_2/Ag/TiO_2$ multilayer coating. A discussion of a process of depositing this optically transparent IR reflective film can be found in Yoldas, Bulent E. and O'Keefe, Terry "Deposition of Optically transparent IR reflective Coatings on Glass," Applied Optics, Vol. 23, Issue 20, pp. 3638-3643 (1984). Another example of an IR reflective material coating is an infrared reflecting plastic film such as polyester film (e.g., polyethyleneterephthalate). In one case, the infrared reflecting plastic film can be formed by sequentially coating a tungsten oxide layer, a silver layer, and a tungsten oxide layer on a plastic film, with the infrared reflecting plastic film held between a pair of polyvinyl butyral interlayer films (e.g., one or more polyvinyl butyral interlayer films with an ultraviolet absorbent). An example of a low emissivity coating material is fluorinated tin oxide, while more complex layered materials are known in the art to have low E properties. In some aspects, an IR reflective material coating in a laminate can reflect infrared solar rays to prevent heat load from entering the room. In some cases, an IR reflective coating may be placed outboard of the EC device layer in order to reflect infrared radiation away from the EC device and to the outside of the building. In other aspects, a low E coating is placed at an inner surface facing the room.

[0131] The EC laminates described herein include at least one flexible substrate. In some cases, an EC laminate includes two or more flexible substrates. In other cases, an EC laminate includes a flexible substrate laminated to a more rigid (e.g., thicker) support substrate. In some of these cases, the more rigid support substrate may be located outboard of a flexible substrate for higher durability from foreign objects such as, for example, bird strike. A more rigid support substrate may be, for example, of tempered or heat strengthened glass such as soda-lime glass (SLG). In certain aspects, the support substrate has a thickness of between about 3 mm and about 25 mm thick. In other aspects, the support substrate has a thickness of between about 3 mm and about 12 mm thick. In other aspects, the support substrate has a thickness of between about 3 mm and about 6 mm thick. In certain aspects, an EC laminate is made of SLG having a thickness between about 2.2 mm and 10 mm. In one example, an EC laminate is made of SLG having a thickness of about 3.6 mm.

[0132] Some examples of commercially available flexible substrates are EAGLE XG® Glass (EXG), Gorilla® Glass, or Willow® Glass from Corning, Incorporated of Corning, New York, which typically have an indium tin oxide (ITO) coating. In certain aspects, an EC laminate includes a flexible substrate having a thickness between about 0.1 mm to about 1 mm. In certain aspects, an EC laminate includes a flexible substrate (e.g., EXG) having a thickness of about 0.7 mm. In certain aspects, an EC laminate includes a flexible substrate (e.g., substrate of Gorilla® Glass) having a thickness of between about 0.5 mm to about 1.6 mm. In certain aspects, an EC laminate includes a flexible substrate having a thickness of between about 0.01 mm to about 0.1 mm. In certain aspects, an EC laminate includes a flexible substrate (e.g., Willow® Glass) has a thickness of about 0.05mm.

[0133] In some aspects, a flexible substrate of an EC laminate is prefabricated in the form of flat sheets. In other aspects, a flexible substrate of an EC laminate is prefabricated in roll form for ease in manufacturing. For example, the fabrications processes depicted in **Figures 4J, 5A and 5B** use flexible substrates **478** and **478a** in roll form. Willow® Glass is an example of a thin, flexible substrate that is commercially available in roll form. In some cases, flexible substrates may be prefabricated in a large format rolls such as, for example, rolls that are one-half meter to three meters wide and tens of meters to hundreds of meters in length (e.g., 300 meters long).

[0134] As mentioned above, the flexible substrate **478** used in the process depicted in **Figure 4J** is in roll format. **Figure 4J** depicts roll-to-roll processing **475** forming laminates by laminating a flexible substrate **478** onto, for example, a support substrate having one or more electrochromic devices disposed thereon. For example, the flexible substrate **478** may be laminated onto a large area support substrate such that multiple columns or rows of EC devices (e.g., EC devices shown in **Figure 4I**, upper portion) are each laminated with the flexible substrate **478**. After lamination, the laminates can be cut into individual EC lites. In some cases, multiple separate and parallel rolls of flexible substrate can be fed into a lamination line that laminates a large areas support substrate lengthwise or widthwise.

[0135] As another example, **Figure 5A** depicts roll-to-roll processing **600** of electrochromic devices onto a flexible substrate **478a** in roll format and then laminating the flexible substrate **478a** with an EC device(s) thereon onto a more rigid support substrate. In **Figure 5A**, the flexible substrate **478a** enters the coater **610** where layers of the EC device are deposited and then is laminated to the more rigid support substrate at **630**.

[0136] In certain embodiments, a laminate is comprised of two or more flexible substrates for high flexibility. For example, a flexible substrate bearing one or more EC devices may be itself laminated with one or more additional flexible substrates to form a flexible EC laminate. **Figure 5B** depicts a fabrication process **650** wherein the electrochromic device(s) are deposited on the flexible substrate **478a** during operations **605-625**. Then, the first flexible substrate **478a** with the electrochromic device(s) thereon is laminated with a second flexible substrate **478** via the appropriate application of lamination adhesive and rollers **630**. In the example described with respect to **Figure 5A**, the flexible substrate **478a** is prefabricated with a transparent conductor layer before operations **605-625**. In other cases, the flexible substrate **478a** is prefabricated with a diffusion barrier and/or a transparent conductor layer before operations **605-625**. In the illustrated example, the newly formed laminates may be cut, e.g., by laser scribing (see **635**), to form individual monolithic EC laminates **665**.

In **Figure 5B**, the monolithic EC laminates **665** can pass along the conveyor **477** for further processing.

[0137] In embodiments with EC laminates, an EC device may be located at the substrate interface and/or at outer surface(s) of the laminated substrate. In some aspects, locating an EC device at a substrate interface can help protect the EC coatings at the substrate interface between the substrates. In other examples, the EC device coatings may be applied to one or more outer surfaces of the substrates. The EC device coatings are generally comprised of a first TCO, an EC stack (e.g., electrochromic layer, ion conductor layer, and counter electrode layer), and a second TCO.

[0138] In some aspects, a diffusion barrier lies between the EC device coatings and a substrate of the laminated substrate. In some cases, the substrate of the laminated substrate may be prefabricated with a diffusion barrier over underlying transparent material. For example, a sodium or potassium based glass is typically fabricated with a diffusion barrier. In these aspects, the first TCO, EC stack (e.g., electrochromic layer, ion conductor layer, and counter electrode layer), and a second TCO are deposited over the diffusion barrier prefabricated on the substrate. In other cases, the substrate may be prefabricated with both a diffusion barrier over the underlying transparent material and a first TCO over the diffusion barrier, or the substrate is alkali free glass and no diffusion barrier is necessary. For example, EAGLE XG® Glass (EXG), Gorilla® Glass, or Willow® Glass are available with a transparent conducting layer in the form of an indium tin oxide (ITO) coating. In these aspects, the EC stack and then the second TCO are deposited over the first TCO with or without a diffusion barrier prefabricated on the substrate.

[0139] ***- EC Flexible Substrate (e.g., EXG) Inboard***

[0140] **Figure 7A** is a cross-sectional view through a portion of a laminate, **3010**, of a monolithic EC window, according to an embodiment. The laminate **3010** includes a flexible substrate **3012** with an EC device **3014** thereon and more rigid support substrate **3016**. As illustrated by the depicted eye located inboard and looking outboard, the laminate **3010** is oriented so that the more rigid support substrate **3016** is outboard of the flexible substrate **3012**. In this configuration, the support substrate

3016 may provide protection for the EC device **3014** from the elements and foreign objects impinging the outboard surface of the monolithic EC window. The laminate **3010** also includes a laminate adhesive **3018** at the interface between the flexible substrate **3012** and the more rigid support substrate **3016**. The laminate **3010** is also shown having an optional low emissivity layer **3019** at the inboard surface of the monolithic EC window.

[0141] To fabricate the laminate **3010** of the monolithic EC window shown in **Figure 7A**, certain similar to those described with respect to the fabrication process shown in **Figure 5A** can be used. The flexible substrate **3012** may be in a roll format or prefabricated in sheets. In some cases, the flexible substrate **3012** and/or the support substrate **3016** may be prefabricated with a diffusion barrier and/or a first TCO layer (e.g., an ITO coating). The flexible substrate **3012** may be fed into an edge deletion module such as, for example, described with respect to edge deletion module, **605** of **Figure 5A**. The flexible substrate **3012** may be optionally cleaned of any contaminants resulting from the first edge delete. Also, if the flexible substrate **3012** is prefabricated with a first TCO layer, the TCO layer may optionally be given an edge taper and/or polishing process. Next, the flexible substrate **3012** enters a coater e.g., coater **610** shown in **Figure 5A**, where the layers of the EC device **3014** are deposited. In the example shown with respect to **Figure 5A**, the EC device layers are deposited using a vacuum integrated all-PVD sputter apparatus. Such an apparatus is described in U.S. Patent No. 8,243,357, titled "Fabrication of Low Defectivity Electrochromic Devices," filed on May 11, 2011, which is hereby incorporated by reference in its entirety. After the flexible substrate **3012** is coated with the EC device **3014**, a second edge delete may be carried out such as, for example, provided by module **615** described with respect to **Figure 5A**. Optionally, edge deletion may be followed by edge taper. Next, a bus bar pad expose operation is performed such as, for example, provided by module **620** described with respect to **Figure 5A**. After the bus bar pad expose operation is performed, bus bars are applied as provided by module **625** described with respect to **Figure 5A**. Next, the flexible substrate **3012** with the EC device **3014** thereon is laminated with the more rigid support substrate **3016** (e.g., annealed glass or a polymeric substrate) via the appropriate application of lamination adhesive **3018** and pressure applying mechanisms such as, for example, rollers **630** described with respect to **Figure 4J**. If multiple EC devices **3014** are deposited onto the flexible substrate **3012** laminated with the support substrate **3016**, individual EC laminates can be cut from the larger area of the EC laminate such as, for example, in module **635** described with respect to **Figure 5A**. In some cases, multiple EC devices on a single flexible substrate **3012** may be used in a single monolithic EC window so that the cutting operation may not be needed. The optional low emissivity layer **3018** may be prefabricated on the flexible substrate **3012** or may be deposited on the inboard surface during the fabrication process. The apparatus for performing the fabrication may be in any orientation, but in one embodiment, the flexible substrate is in a vertical orientation.

[0142] In some aspects, a laminate can be fabricated with an IR reflective material layer between the EC device and its support substrate (for example between substrate **3016** and EC device coating **3014**). In these cases, the IR reflective material layer reflects IR solar radiation outboard so that the solar radiation is reflected before impinging the EC device located inboard of the IR reflective material layer. This configuration may be a desired option for controlling heat load at the monolithic EC window since it not only prevents solar radiation from entering the monolithic EC window, but also prevents the solar radiation from impinging upon the EC device. In one case, the IR reflective material layer may be deposited onto the support substrate prior to lamination with the flexible substrate so that the IR reflective material layer lies between the support substrate and the laminate adhesive. In another case, the IR reflective material may be incorporated into the lamination adhesive. In another case, the IR reflective material layer may be fabricated onto the EC device before lamination with the support substrate so that the IR reflective material layer is located between the lamination adhesive and the EC device. The support substrate, if an alkali based glass for example, may include a barrier layer to prevent alkali ion diffusion into the lamination adhesive and/or the IR reflective coating.

[0143] ***- EC Flexible Substrate (e.g., EXG) Inboard with IR reflective material outboard***

[0144] **Figure 7B** is a drawing of a cross-sectional view through a portion of a laminate **3020** of a monolithic EC window, according to an embodiment. The laminate **3020** includes a flexible substrate **3022** with an EC device **3024** thereon, a more rigid support substrate **3026** with an IR reflective material layer **3027** thereon, and a substrate adhesive **3028** at the interface between the EC device **3024** and the IR reflective material layer **3027**. In this configuration, the laminate **3020** includes an IR reflective material layer **3027** between the EC device **3024** and the support substrate **3026**. As illustrated by the depicted eye located inboard and looking outboard, the IR reflective material layer **3027** is located outboard of the EC device **3024**. This configuration may be a desired option for controlling heat load at the monolithic EC window since it not only prevents solar radiation from entering the monolithic EC window, but also prevents solar radiation from impinging upon the EC device. Moreover, since the more rigid support substrate **3026** is located outboard of the flexible substrate **3022**, the support substrate **3026** may provide protection for the EC device **3024** from the elements and foreign objects impinging the outboard surface of the monolithic EC window.

[0145] To fabricate the laminate **3020** of the monolithic EC window shown in **Figure 7B**, similar operations described with respect to similar layers in the laminate **3010** shown in **Figure 7A** can be used. However, an additional operation will be needed to deposit the IR reflective material layer **3027** on the support substrate **3026**. In one case, the IR reflective material layer **3027** may be deposited onto the support substrate **3026** prior to lamination with the flexible substrate **3022** with the EC device **3024**. In another case, the IR reflective material may be incorporated into the lamination adhesive layer **3028**.

[0146] - *EC Support Substrate (e.g., SLG) Outboard*

[0147] **Figure 7C** is a drawing of a cross-sectional view through a portion of a laminate **3030** of a monolithic EC window, according to an embodiment. The laminate **3030** includes a flexible substrate **3032** and more rigid support substrate **3036** with an EC device **3034** thereon. As illustrated by the depicted eye located inboard and looking outboard, the laminate **3030** is oriented so that the more rigid support substrate **3036** is outboard of the flexible substrate **3032**. In this configuration, the support substrate **3036** may provide protection for the EC device **3034** from the elements and foreign objects impinging the outboard surface of the monolithic EC window. The laminate **3030** also includes a laminate adhesive **3038** at the interface between the flexible substrate **3032** and the more rigid support substrate **3036**. The laminate **3030** is also shown having an optional low emissivity layer **3039**

at the inboard surface of the monolithic EC window. The support substrate, if an alkali based glass for example, may include a barrier layer to prevent alkali ion diffusion into the EC device coating **3034**.

[0148] From a manufacturability standpoint, the illustrated configuration of the monolithic EC window in **Figure 7C** may be more desirable than the configuration in **Figure 7B** since the fabrication process need only provide coatings on a single substrate (i.e. the support substrate **3036**). The illustrated configuration may be less desirable from a heat control standpoint relative to the configuration in **Figure 7B** since the laminates substrate **3030** does not include an IR reflective material layer outboard of the EC device **3034**.

[0149] To fabricate the laminate **3030** of the monolithic EC window shown in **Figure 7C**, certain operations similar to those described with respect to the fabrication process shown in **Figure 4J** and **Figure 5A** can be used. Although shown in roll format, the flexible substrate **3032** may be prefabricated in sheets. The flexible substrate **3032** and/or the support substrate **3036** may be prefabricated with a diffusion barrier and/or a first TCO layer (e.g., an ITO coating). If the support substrate **3036** prefabricated with a first TCO layer, the support substrate **3036** may be fed into an edge deletion module such as, for example, described with respect to edge deletion module, **605** of **Figure 5A**. The support substrate **3036** may be optionally cleaned of any contaminants resulting from the first edge delete. Also, the first TCO layer may optionally be given an edge taper and/or polishing process. Next, the support substrate **3036** enters a coater e.g., coater **610** shown in **Figure 5A**, where the layers of the EC device **3034** are deposited. In the example shown with respect to **Figure 5A**, the EC device layers are deposited using a vacuum integrated all-PVD sputter apparatus. After the support substrate **3036** is coated with the EC device **3034**, a second edge delete may be carried out such as, for example, provided by module **615** described with respect to **Figure 5A**. Optionally, edge deletion may be followed by edge taper. Next, a bus bar pad expose operation is performed such as, for example, provided by module **620** described with respect to **Figure 5A**. After the bus bar pad expose operation is performed, bus bars are applied as provided by module **625** described with respect to **Figure 5A**. Next, the support substrate **3036** with the EC device **3034** thereon is laminated with the flexible substrate **3032** via the appropriate application of lamination adhesive **3038** and pressure applying mechanisms such as, for example, rollers **479** described with respect to **Figure 5A**. The flexible substrate **3032** is fed into the lamination line. If multiple EC devices **3034** were deposited on the support substrate **3036**, the substrate may be cut (e.g., by laser **480** shown in **Figure 4J**) as each row is laminated or after the entire sheet is laminated. In some cases, multiple EC devices on a single laminated substrate **3030** may be used in a single monolithic EC window so that the cutting operation may not be needed. In some cases, the final laminates **3030** may be sent to further processing such as shown in **Figure 4J**. The optional low emissivity layer **3039** may be prefabricated on the flexible substrate **3032** or may be deposited on the inboard surface during the fabrication process described above. The apparatus for performing the fabrication process may be in any orientation, but in one embodiment, the flexible substrate is in a vertical orientation.

[0150] ***- EC Support Substrate (e.g., SLG) Inboard***

[0151] **Figure 8A** is a drawing of a cross-sectional view through a portion of a laminate **3050** of a monolithic EC window, according to an embodiment. The laminate **3050** includes a flexible substrate **3052** and more rigid support substrate **3056** with an EC device **3054** thereon. As illustrated by the depicted eye located inboard and looking outboard, the laminate **3050** is oriented so that the more rigid support substrate **3056** is inboard of the flexible substrate **3052**. The laminate **3050** also includes a laminate adhesive **3058** at the interface between the flexible substrate **3052** and the more rigid support substrate **3056**. The laminate **3050** is also shown having an optional low emissivity layer **3059** at the inboard surface of the monolithic EC window. The support substrate, **3056**, if an alkali based glass for example, may include a barrier layer to prevent alkali ion diffusion into the EC device coating **3054**.

[0152] To fabricate the laminate **3050** of the monolithic EC window shown in **Figure 8A**, similar operations described with respect to similar layers in the laminate **3050** shown in **Figure 7C** can be used. However, since the more rigid support substrate **3059** is located inboard in this case, the optional low emissivity layer **3059** is fabricated on the inboard face of the more rigid support substrate **3059** in the laminate **3050**. The optional low emissivity layer **3059** may be prefabricated on the support substrate **3059** or may be deposited on the inboard surface during the fabrication process described with respect to the fabrication of the laminate **3050** shown in **Figure 7C**.

[0153] From a manufacturability standpoint, the configuration in **Figure 8A** might be slightly more difficult to manufacture than the configuration in **Figure 7C** since fabrication requires coating both surfaces of the support substrate **3056** on the inboard surface with low emissivity coating **3059** and on the outboard surface with layers of the EC device **3054**. Also, the configuration in **Figure 8A** may more fragile than the configuration in **Figure 7C** since the flexible substrate **3052** is located outboard where it may be impinged by objects. The configuration in **Figure 8A** may be less desirable from a heat control standpoint relative to the configuration in **Figure 7B** since there is no IR reflective layer outboard of the EC device **3054** to protect it from IR radiation.

[0154] ***- EC Support Substrate (e.g., SLG) Inboard and with IR reflective material outboard***

[0155] **Figure 8B** is a drawing of a cross-sectional view through a portion of a laminate **3060** of a monolithic EC window, according to an embodiment. The laminate **3060** includes a flexible substrate **3062** with an IR reflective material layer **3067** thereon, a more rigid support substrate **3066** with an EC device **3064** thereon, and a substrate adhesive **3068** at the interface between the EC device **3064** and the IR reflective material layer **3067**. In this configuration, the laminate **3060** includes an IR reflective material layer **3067** between the EC device **3064** and the flexible substrate **3062**. As illustrated by the depicted eye located inboard and looking outboard, the IR reflective material layer **3067** is located outboard of the EC device **3064**. The support substrate, **3066**, if an alkali based glass for example, may include a barrier layer to prevent alkali ion diffusion into the EC device coating **3064**.

[0156] For controlling heat load at the monolithic EC window, the configuration in **Figure 8B** may be more desirable than the configuration shown in **Figure 8A** since it not only prevents solar radiation from entering the monolithic EC window, but also prevents solar radiation from impinging upon the EC device **3064**. The configuration in **Figure 8B** may more susceptible to damage than the configuration in **Figure 7B**

since the flexible substrate **3062** is located outboard where it may more likely be impinged upon by objects.

[0157] To fabricate the laminate **3060** of the monolithic EC window shown in **Figure 8B**, similar operations described with respect to similar layers in the laminate **3050** shown in **Figure 8A** can be used. However, an additional operation will be needed to deposit the IR reflective material layer **3067** on the flexible substrate **3062**. In one case, the IR reflective material layer **3067** may be deposited onto the flexible substrate **3062** prior to lamination with the support substrate **3066** with the EC device **3064**. In another case, the IR reflective material may be incorporated into the lamination adhesive layer **3068**.

[0158] ***- EC Flexible Substrate (e.g., EXG) Outboard***

[0159] **Figure 8C** is a drawing of a cross-sectional view through a portion of a laminate **3070** of a monolithic EC window, according to an embodiment. The laminate **3070** includes a flexible substrate **3072** with an EC device **3074** thereon and more rigid support substrate **3076**. As illustrated by the depicted eye located inboard and looking outboard, the laminate **3070** is oriented so that the more flexible substrate **3072** is outboard of the more rigid substrate **3076**. The laminate **3070** also includes a laminate adhesive **3078** at the interface between the flexible substrate **3072** having the EC device **3074** thereon and the more rigid support substrate **3076**. The laminate **3070** is also shown having an optional low emissivity layer **3079** at the inboard surface of the monolithic EC window. The flexible substrate, **3072**, if an alkali based glass for example, may include a barrier layer to prevent alkali ion diffusion into the EC device coating **3074**.

[0160] To fabricate the laminate **3070** of the monolithic EC window shown in **Figure 8C**, similar operations described with respect to similar layers in the laminate **3010** shown in **Figure** 7A can be used. However, since the more rigid support substrate **3076** is located inboard in this case, the optional low emissivity layer **3079** is fabricated on inboard surface of the more rigid support substrate **3079**. The optional low emissivity layer **3079** may be prefabricated on the support substrate **3076** or may be deposited on the inboard surface during the fabrication process described with respect to the fabrication of the laminate **3070** shown in **Figure 8C**. In some cases, rigid support substrates may be commercially available with low emissivity coatings. If such a commercially available substrate is used, this configuration may be easier to manufacture than the configuration shown in **Figure 7A**. The configuration in **Figure 8C** may more fragile than the configuration in **Figure 7A** since the flexible substrate **3072** is located outboard where it may be impinged by objects. For controlling heat load at the monolithic EC window, the configuration in **Figure 8C** may be less desirable than the configuration shown in **Figure 8B** since it does not have an IR reflective layer outboard of the EC device protecting it from IR

[0161] ***- EC Flexible Substrate (e.g., EXG) Inboard***

[0162] **Figure 9A** is a drawing of a cross-sectional view through a portion of a laminate **3100** of a monolithic EC window, according to an embodiment. The laminate **3100** includes a first flexible substrate **3102** with an EC device **3106** thereon, a second flexible substrate **3104**, and a laminate adhesive **3108** at the interface between the first flexible substrate **3102** and the second flexible substrate **3104**. As illustrated by the depicted eye located inboard and looking outboard, the laminate **3100** is oriented so that the second flexible substrate **3104** is located outboard of the first flexible substrate **3102**. Optionally, the laminate **3100** may also have a low emissivity layer **3108** at the inboard surface of the monolithic EC window. The support substrate, **3102**, if an alkali based glass for example, may include a barrier layer to prevent alkali ion diffusion into the EC device coating **3106**.

[0163] To fabricate the laminate **3100** of the monolithic EC window shown in **Figure 9A**, certain similar operations to those described with respect to the fabrication process shown in **Figure 5B**. Although the first flexible substrate **3102** and/or the second flexible substrate **3104** are shown as provided in roll form, the flexible substrates may be prefabricated in sheets. In some cases, one or both flexible substrates **3102**, **3104** may be prefabricated with a diffusion barrier and/or a first TCO layer (e.g., an ITO coating). The first flexible substrate **3102** is fed into an edge deletion module such as, for example, described with respect to edge deletion module, **605** of **Figure 5A**. The first flexible substrate **3102** may be optionally cleaned of any contaminants resulting from the first edge delete. Also, if the first flexible substrate **3102** is prefabricated with a first TCO layer, the TCO layer may optionally be given an edge taper and/or polishing process. Next, the first flexible substrate **3102** enters a coater e.g., coater **610** shown in **Figure 5A**, where the layers of EC devices are deposited. In the example shown with respect to **Figure 5A**, the EC device layers are deposited using a vacuum integrated all-PVD sputter apparatus. Such an apparatus is described in U.S. Patent No. 8,243,357, titled "Fabrication of Low Defectivity Electrochromic Devices," filed on May 11, 2011. After the first flexible substrate **3102** is coated with the EC device **3106**, a second edge delete may be carried out such as, for example, provided by module **615** described with respect to **Figure 5A**. Optionally, edge deletion may be followed by edge taper. Next, a bus bar pad expose operation is performed such as, for example, provided by module **620** described with respect to **Figure 5A**. After the bus bar pad expose operation is performed, bus bars are applied as provided by module **625** described with respect to **Figure 5A**. Then, the first flexible substrate **3102**, having a plurality of EC devices thereon, is laminated with the second flexible substrate **3104** fed into the lamination line. The first flexible substrate **3102** and the second flexible substrate **3104** are laminated via appropriate application of lamination adhesive and rollers **630** described with respect to **Figure 5B**. The newly formed EC laminate is cut, e.g. via laser, see **635**, to form individual flexible EC laminates, which can pass along conveyer **477** for further processing. As described above, the second flexible substrate **3104** "mate lite" may be patterned with apertures to accommodate the bus bars, or ablated to reveal TCO and the bus bars (process **625**) added after lamination, either before or after cutting into individual laminated EC lites. The optional low emissivity layer **3108** may be prefabricated on the first flexible substrate **3102** or may be deposited on the inboard surface during the fabrication process. The apparatus for performing the fabrication may be in any orientation, but in one embodiment, the flexible substrate is in a vertical orientation.

[0164] The configuration shown in **Figure 9A** is more light weight and flexible, but perhaps more susceptible to damage, than the configurations shown in **Figures 18-19**, however, certain fusion glass products have high damage resistance and thus the light weight and flexible EC laminate may meet certain building codes. From a manufacturability standpoint, the configuration in **Figure 9A** might be more difficult to manufacture than the configuration shown in **Figure 8A** since the fabrication process coats both surfaces of the first flexible substrate **3102**; though this substrate may be commercially available pre-coated with, for example, coating **3109**.

[0165] ***- EC Flexible Substrate (e.g., EXG) Inboard with IR reflective material outboard***

[0166] **Figure 9B** is a drawing of a cross-sectional view through a portion of a laminate **3130** of a monolithic EC window, according to an embodiment. The laminate **3130** includes a first flexible substrate **3132** with an EC device **3136** thereon, a second flexible substrate **3134** with an IR reflective material layer **3139**, and a laminate adhesive **3138** at the interface between the first flexible substrate **3132** and the second flexible substrate **3134**. As illustrated by the depicted eye located inboard and looking outboard, the laminate **3130** is oriented so that the second flexible substrate **3134** is located outboard of the first flexible substrate **3132**. The configuration shown in **Figure 9B** may be more desirable for controlling heat load than the configuration in **Figure 9A** since the IR reflective material layer **3139** not only reflects solar radiation away from the monolithic EC window, but also prevents solar radiation from impinging the EC device since it is outboard of the EC device. The support substrate, **3132**, if an alkali based glass for example, may include a barrier layer to prevent alkali ion diffusion into the EC device coating **3136**.

[0167] To fabricate the laminate **3130** of the monolithic EC window shown in **Figure 9B**, similar operations described with respect to similar layers in the laminate **3100** shown in **Figure 9A** can be used. However, an additional operation will be needed to deposit the IR reflective material layer **3139** on the second flexible substrate **3134**. In one case, the IR reflective material layer **3139** may be deposited onto the second flexible substrate **3134** prior to lamination with the first flexible substrate **3132**. In another case, the IR reflective material may be incorporated into the lamination adhesive layer **3068**.

[0168] ***- EC Flexible Substrate (e.g., EXG) Inboard***

[0169] **Figure 9C** is a cross-sectional view through a portion of a laminate **3200** of a monolithic EC window, according to an embodiment. The laminate **3200** includes a first flexible substrate **3202**, a second flexible substrate **3204** with an EC device **3206** thereon, and a laminate adhesive **3208** at the interface between the first flexible substrate **3202** and the second flexible substrate **3204**. As illustrated by the depicted eye located inboard and looking outboard, the laminate **3200** is oriented so that the second flexible substrate **3204** is located outboard of the first flexible substrate **3202**. Optionally, the laminate **3200** may also have a low emissivity layer **3018** at the inboard surface of the monolithic EC window. The support substrate, **3204**, if an alkali based glass for example, may include a barrier layer to prevent alkali ion diffusion into the EC device coating **3206**.

[0170] To fabricate the laminate **3200** of the monolithic EC window shown in **Figure 9C**, certain similar operations to those described with respect to the fabrication process shown in **Figure 5B**. Although the first flexible substrate **3202** and/or the second flexible substrate **3204** are shown as provided in roll form, the flexible substrates may be prefabricated in sheets. In some cases, one or both flexible substrates **3202**, **3204** may be prefabricated with a diffusion barrier and/or a first TCO layer (e.g., an ITO coating). The second flexible substrate **3204** is fed into an edge deletion module such as, for example, described with respect to edge deletion module, **605** of **Figure 5A**. The second flexible substrate **3204** may be optionally cleaned of any contaminants resulting from the first edge delete. Also, if the second flexible substrate **3204** is prefabricated with a first TCO layer, the TCO layer may optionally be given an edge taper and/or polishing process. Next, the second flexible substrate **3204** enters a coater e.g., coater **610** shown in **Figure 5A**, where the layers of EC devices are deposited. In the example shown with respect to **Figure 5A**, the EC device layers are deposited using a vacuum integrated all-PVD sputter apparatus. Such an apparatus is described in U.S. Patent No. 8,243,357, titled “Fabrication of Low Defectivity Electrochromic Devices,” filed on May 11, 2011. After the second flexible substrate **3204** is coated with the EC device **3206**, a second edge delete may be carried out such as, for example, provided by module **615** described with respect to **Figure 5A**. Optionally, edge deletion may be followed by edge taper. Next, a bus bar pad expose operation is performed such as, for example, provided by module **620** described with respect to **Figure 5A**. After the bus bar pad expose operation is performed, bus bars are applied as provided by module **625** described with respect to **Figure 5A**. Then, second flexible substrate **3204**, having a plurality of EC devices thereon, is laminated with the first flexible substrate **3202** fed into the lamination line. The first flexible substrate **3202** and the second flexible substrate **3204** are laminated via appropriate application of lamination adhesive **3206** and rollers **630** described with respect to **Figure 5B**. The newly formed EC laminate is cut, e.g. via laser, see

635, to form individual flexible EC laminates, which can pass along conveyer **477** for further processing. As described above, the first flexible substrate **3202** “mate lite” may be patterned with apertures to accommodate the bus bars, or ablated to reveal TCO and the bus bars (process **625**) added after lamination, either before or after cutting into individual laminated EC lites. The optional low emissivity layer **3208** may be prefabricated on the first flexible substrate **3202** or may be deposited on the inboard surface during the fabrication process. The apparatus for performing the fabrication may be in any orientation, but in one embodiment, the flexible substrate is in a vertical orientation.

[0171] The configuration shown in **Figure 9C** is more light weight and flexible, but more fragile, than the configurations shown in **Figures 7-8**, however, certain fusion glass products have high damage resistance and thus the light weight and flexible EC laminate may meet certain building codes. From a manufacturability standpoint, the configuration in **Figure 9C** might be more difficult to manufacture than the configuration shown in **Figure 9B**since the fabrication process coats both surfaces of the first flexible substrate **3202**; though this substrate may be commercially available pre-coated with, for example, coating **3209**.

[0172] The laminates **Figures 7A, 7B, 7C, 8A, 8B, 8C, 9A, 9B** and **9C** are described as monolithic EC windows; however, these laminates can be a lite in an IGU, e.g., of other embodiments described herein. In certain embodiments, where the thicker support substrate faces the outside, the flexible substrate may face the interior volume of an IGU, where the other pane (mate lite) of the IGU is also a thicker substrate, e.g. a tempered lite or heat strengthened lite or annealed lite. The mate lite in an IGU construct may be colored to compliment the EC laminates color properties, and/or may have low E, IR reflective or other coatings as well.

[0173] Although the foregoing embodiments have been described in some detail to facilitate understanding, the described embodiments are to be considered illustrative and not limiting. It will be apparent to one of ordinary skill in the art that certain changes and modifications can be practiced within the scope of the above description and the appended claims.

CLAIMS

We claim:

1. An electrochromic laminate, comprising:

a first substrate;

a second substrate laminated to the first substrate, wherein the second substrate is a thin flexible substrate;

a lamination adhesive between the first substrate and the second substrate; and

an EC device at a lamination interface between the first and the second substrates.

2. The electrochromic laminate of claim 1, wherein the EC device is disposed on the second substrate.

3. The electrochromic laminate of claim 2,

wherein the first substrate has an infrared radiation reflective material layer disposed thereon, and

wherein the infrared radiation reflective material layer is located outboard of the EC device.

4. The electrochromic laminate of claim 3, wherein the first substrate is a thick support substrate located outboard of the second substrate.

5. The electrochromic laminate of claim 2, wherein a low emissivity coating is disposed on the inboard surface of the second substrate.

6. The electrochromic laminate of claim 2,

wherein the first substrate is a thick support substrate located inboard of the second substrate; and

wherein a low emissivity coating is disposed on an inboard surface of the first substrate.

7. The electrochromic laminate of claim 2, wherein the first substrate is a thin, flexible substrate.

8. The electrochromic laminate of claim 7, wherein a low emissivity coating is disposed on the inboard surface of the first substrate.

9. The electrochromic laminate of claim 1, wherein the EC device is disposed on the first substrate.

10. The electrochromic laminate of claim 9, wherein a low emissivity coating is disposed on an inboard surface of the second flexible substrate.

11. The electrochromic laminate of claim 10, wherein the first substrate is a thick support substrate located outboard of the second substrate.

12. The electrochromic laminate of claim 9,

wherein the first substrate is a thick support substrate located inboard of the second substrate; and

wherein a low emissivity coating is disposed on an inboard surface of the first substrate.

13. The electrochromic laminate of claim 9,

wherein the second flexible substrate has an infrared radiation reflective material layer disposed thereon, and

wherein the infrared radiation reflective material layer is located outboard of the EC device.

14. The electrochromic laminate of claim 9, wherein the first substrate is a thin, flexible substrate.

15. The electrochromic laminate of claim 9,

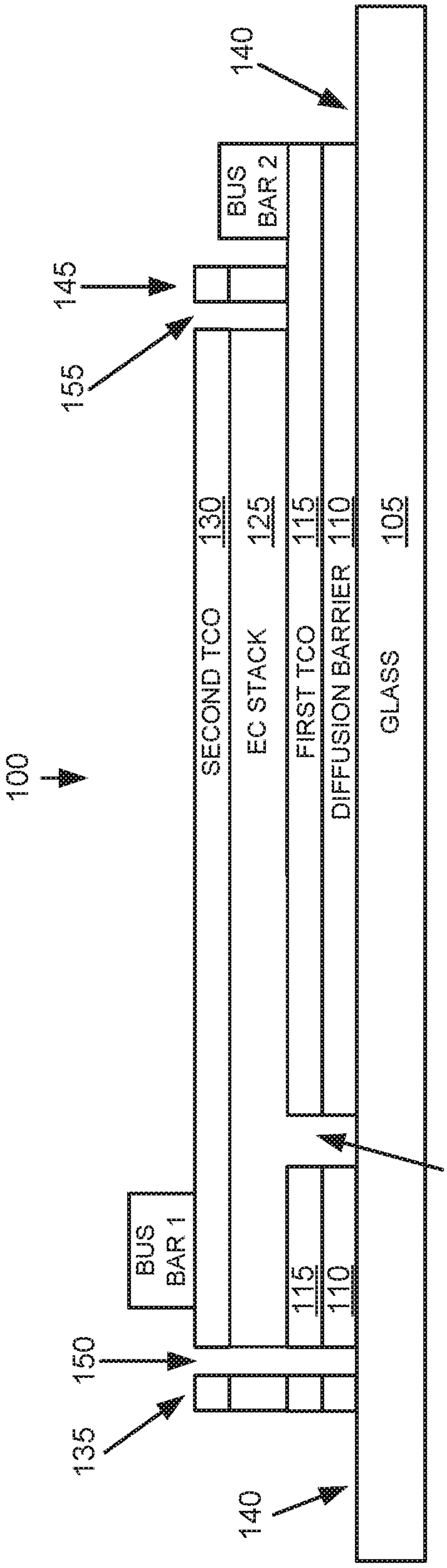
wherein the second substrate has an infrared radiation reflective material layer disposed thereon, and wherein the infrared radiation reflective material layer is located outboard of the EC device.

16. The electrochromic laminate of claim 1, wherein the second substrate has a thickness of about 0.7mm.

17. The electrochromic laminate of claim 1, wherein the second substrate has a thickness of between about 0.5mm to about 1.6mm.

18. The electrochromic laminate of claim 1, wherein the second substrate has a thickness of about 0.05mm.

19. The electrochromic laminate of claim 1, wherein at least one of the first and second substrates is in a prefabricated roll format.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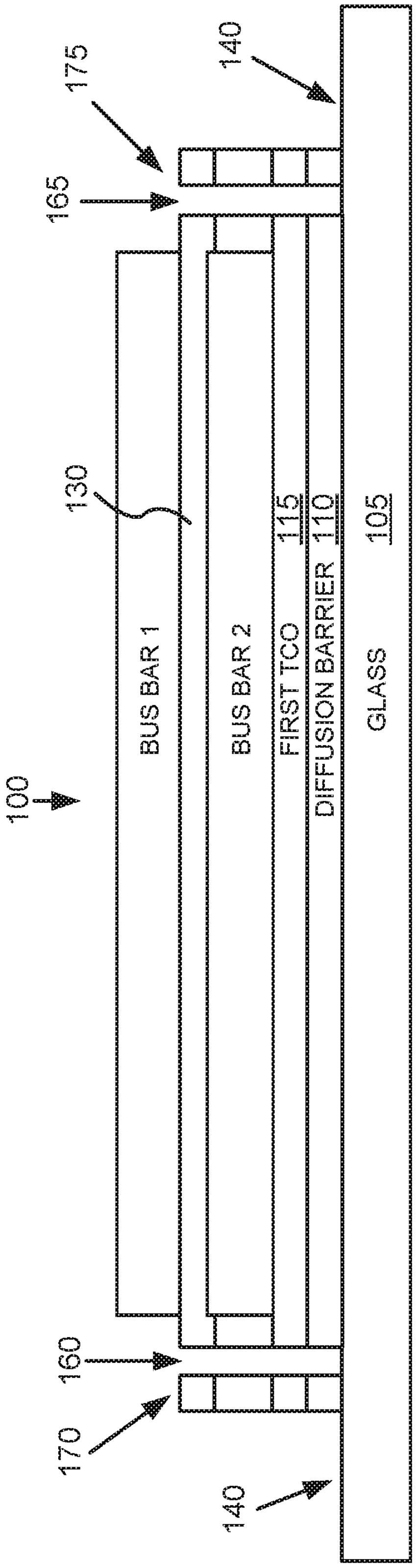
140
BUS BAR 2
145
155
SECOND TCO 130
EC STACK 125
FIRST TCO 115
DIFFUSION BARRIER 110
GLASS 105
120
BUS BAR 1
115
110
150
135
140

Fig. 1A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140
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130
BUS BAR 1
BUS BAR 2
FIRST TCO 115
DIFFUSION BARRIER 110
GLASS 105
160
170
140

Fig. 1B

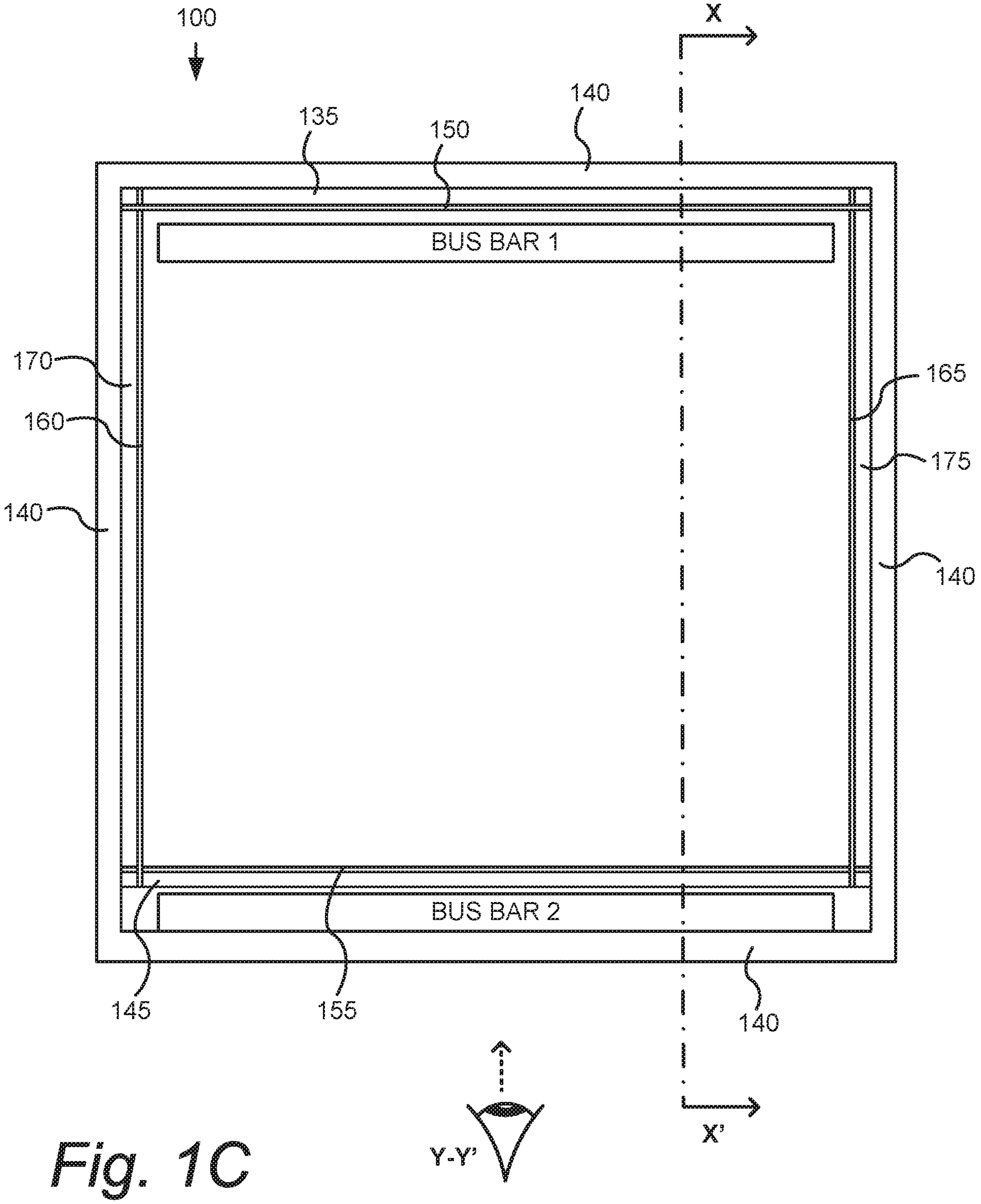
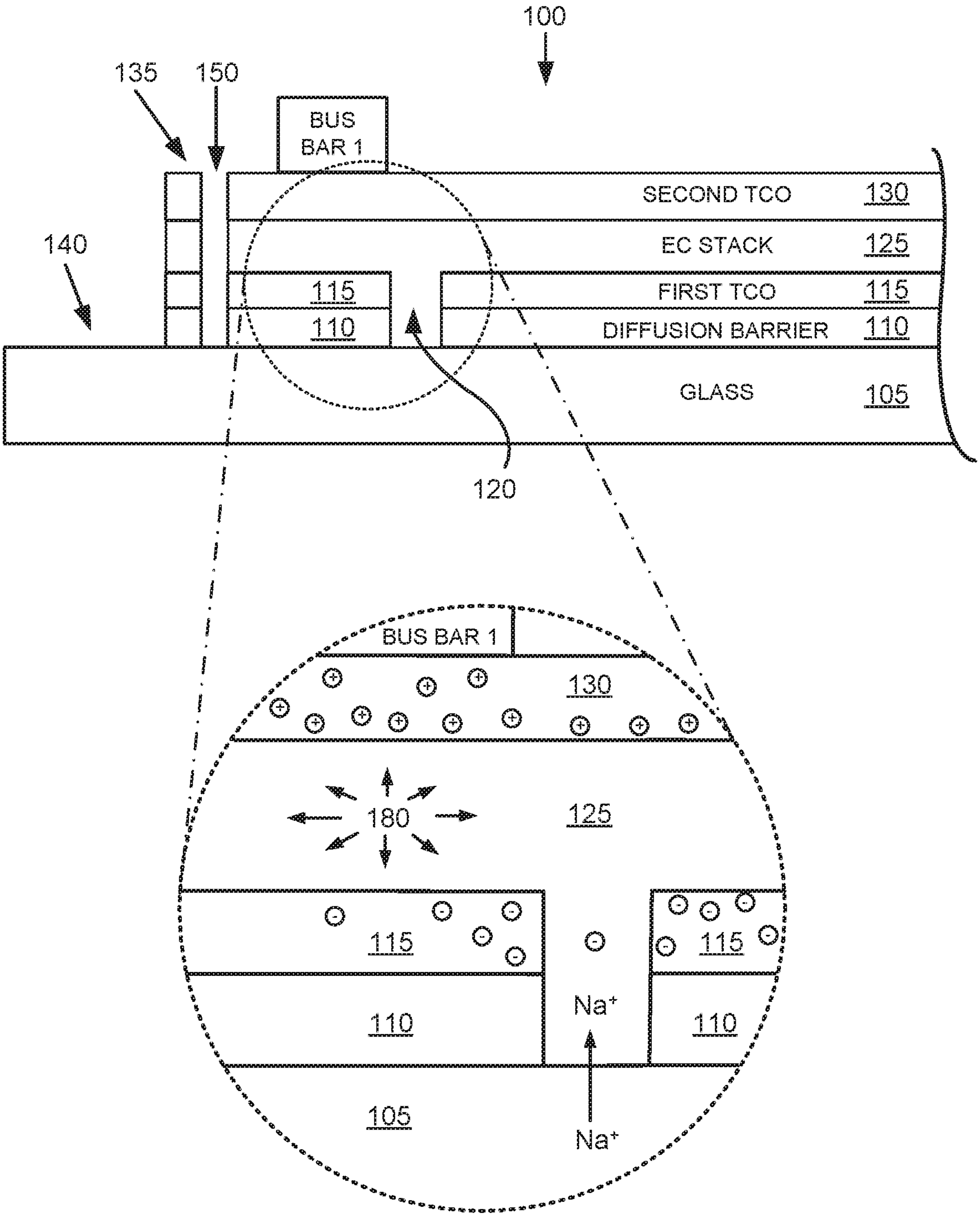

100
X
140
135
150
BUS BAR 1
170
160
140
165
175
140
BUS BAR 2
145
155
140
Y-Y'
X'

Fig. 1C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135
150
BUS BAR 1
SECOND TCO 130
EC STACK 125
140
115
FIRST TCO 115
110
DIFFUSION BARRIER 110
GLASS 105
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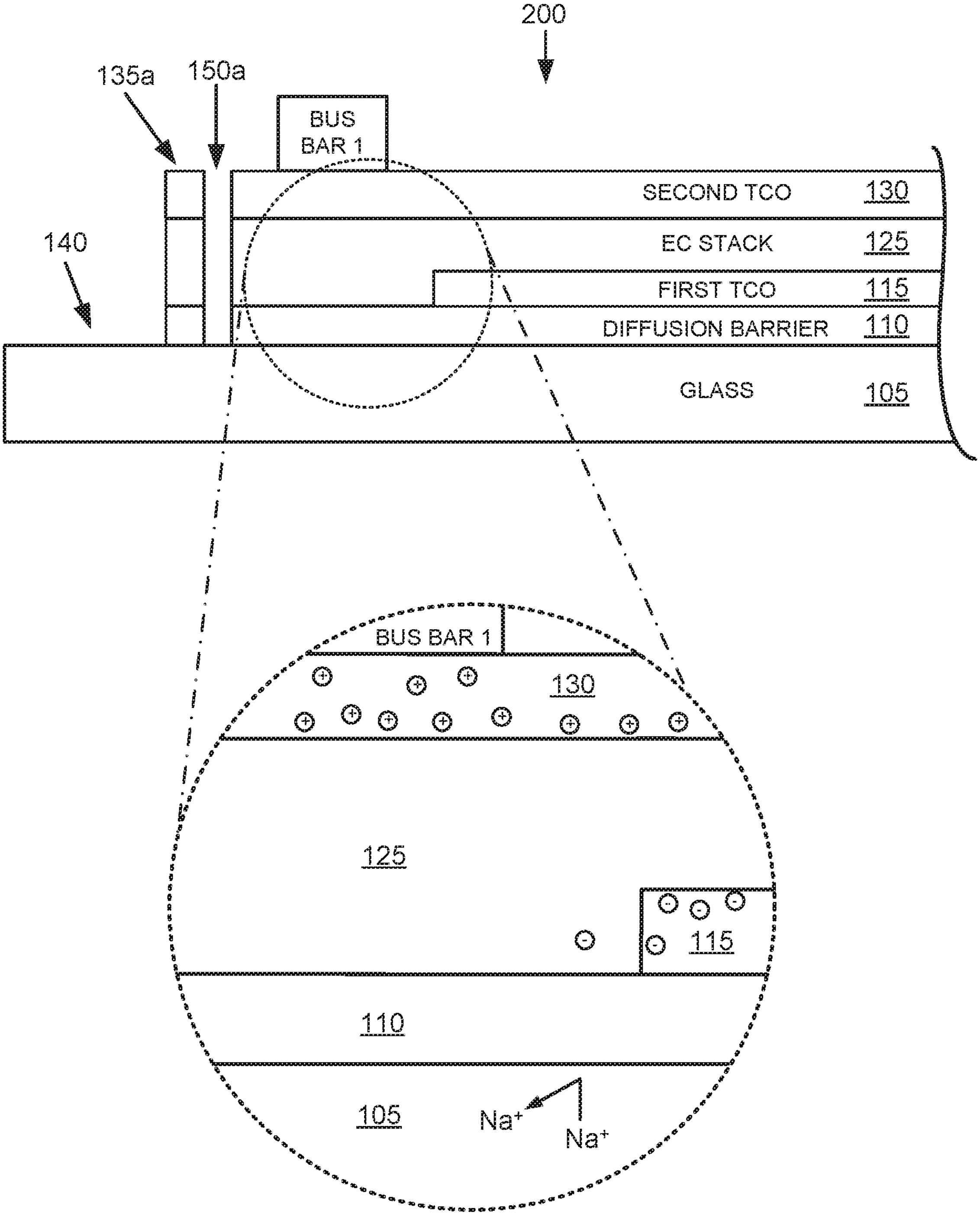
110
110
105
Na+

Fig. 1D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135a
150a
BUS BAR 1
140
SECOND TCO
130
EC STACK
125
FIRST TCO
115
DIFFUSION BARRIER
110
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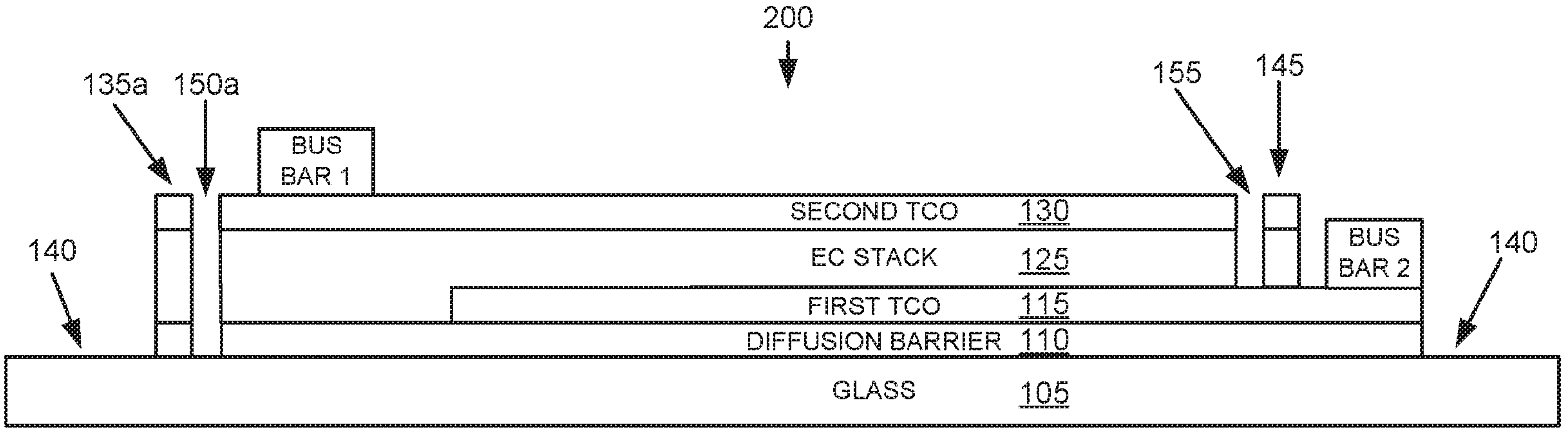
115
110
105
Na+
Na+

Fig. 2A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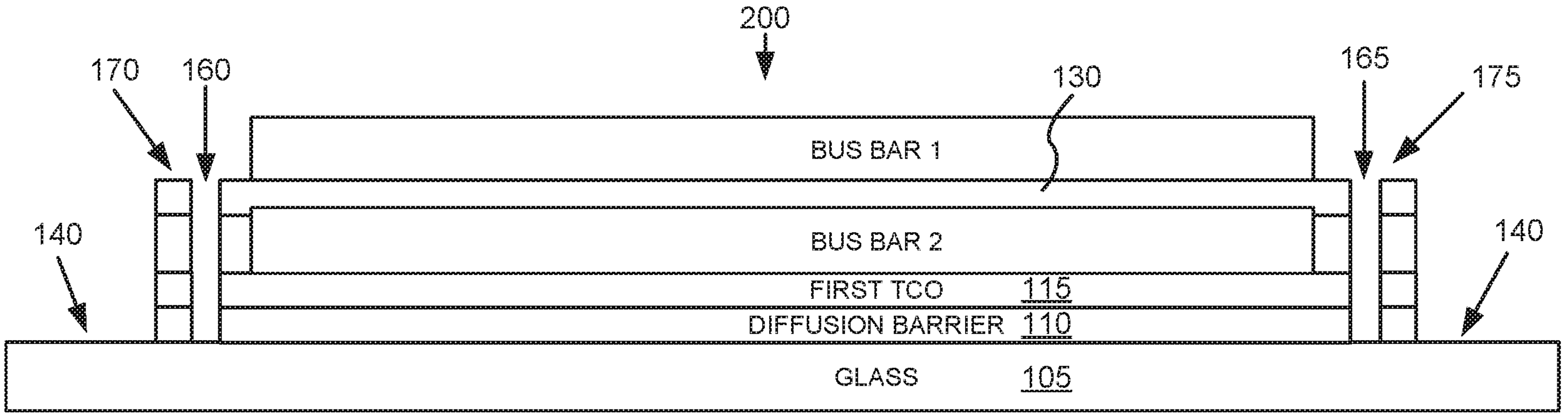
135a
150a
BUS BAR 1
155
145
BUS BAR 2
140
140
SECOND TCO 130
EC STACK 125
FIRST TCO 115
DIFFUSION BARRIER 110
GLASS 105

Fig. 2B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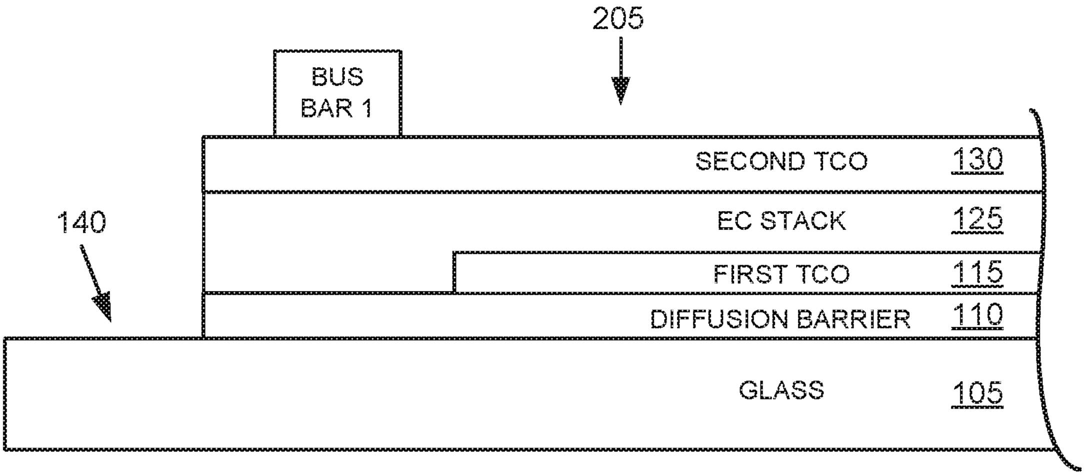
170
160
130
165
175
140
140
BUS BAR 1
BUS BAR 2
FIRST TCO 115
DIFFUSION BARRIER 110
GLASS 105

Fig. 2C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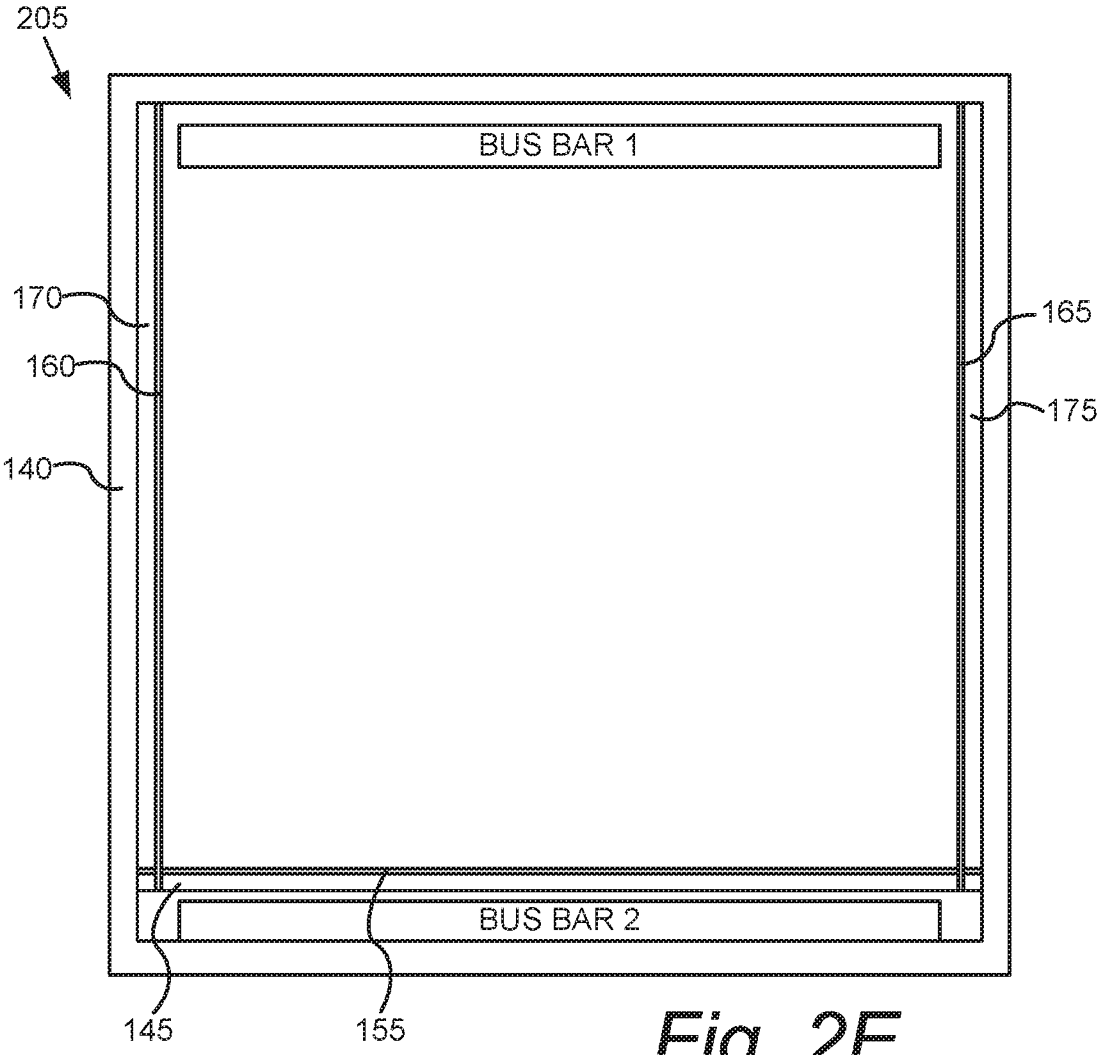
140
SECOND TCO 130
EC STACK 125
FIRST TCO 115
DIFFUSION BARRIER 110
GLASS 105

Fig. 2D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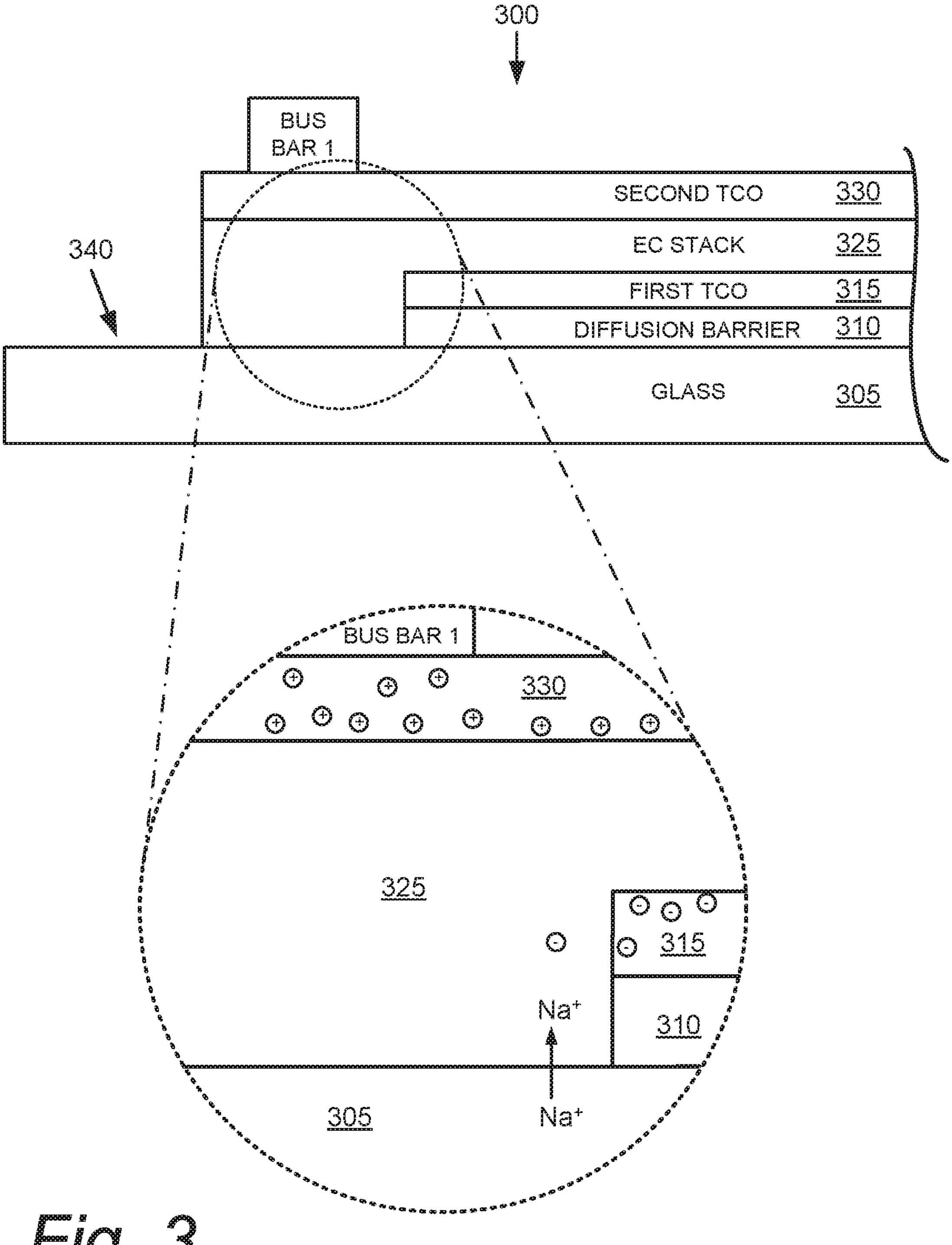
170
160
140
165
175
BUS BAR 2
145
155

Fig. 2E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BUS BAR 1
SECOND TCO 330
EC STACK 325
340
FIRST TCO 315
DIFFUSION BARRIER 310
GLASS 305
BUS BAR 1
330
325
315
310
Na+
Na+
305

Fig. 3

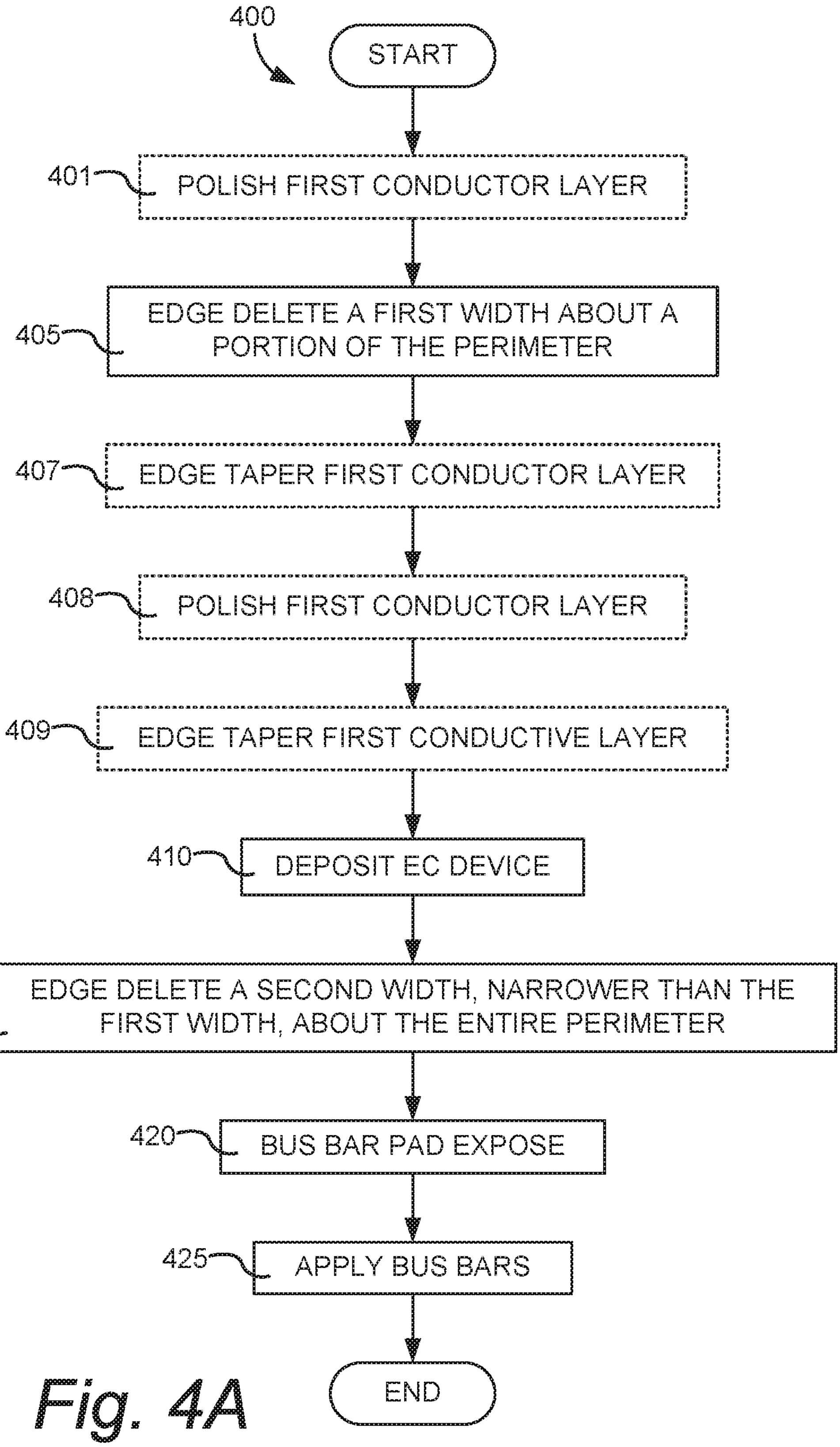

400
START
401
POLISH FIRST CONDUCTOR LAYER
405
EDGE DELETE A FIRST WIDTH ABOUT A PORTION OF THE PERIMETER
407
EDGE TAPER FIRST CONDUCTOR LAYER
408
POLISH FIRST CONDUCTOR LAYER
409
EDGE TAPER FIRST CONDUCTIVE LAYER
410
DEPOSIT EC DEVICE
415
EDGE DELETE A SECOND WIDTH, NARROWER THAN THE FIRST WIDTH, ABOUT THE ENTIRE PERIMETER
420
BUS BAR PAD EXPOSE
425
APPLY BUS BARS
END

Fig. 4A

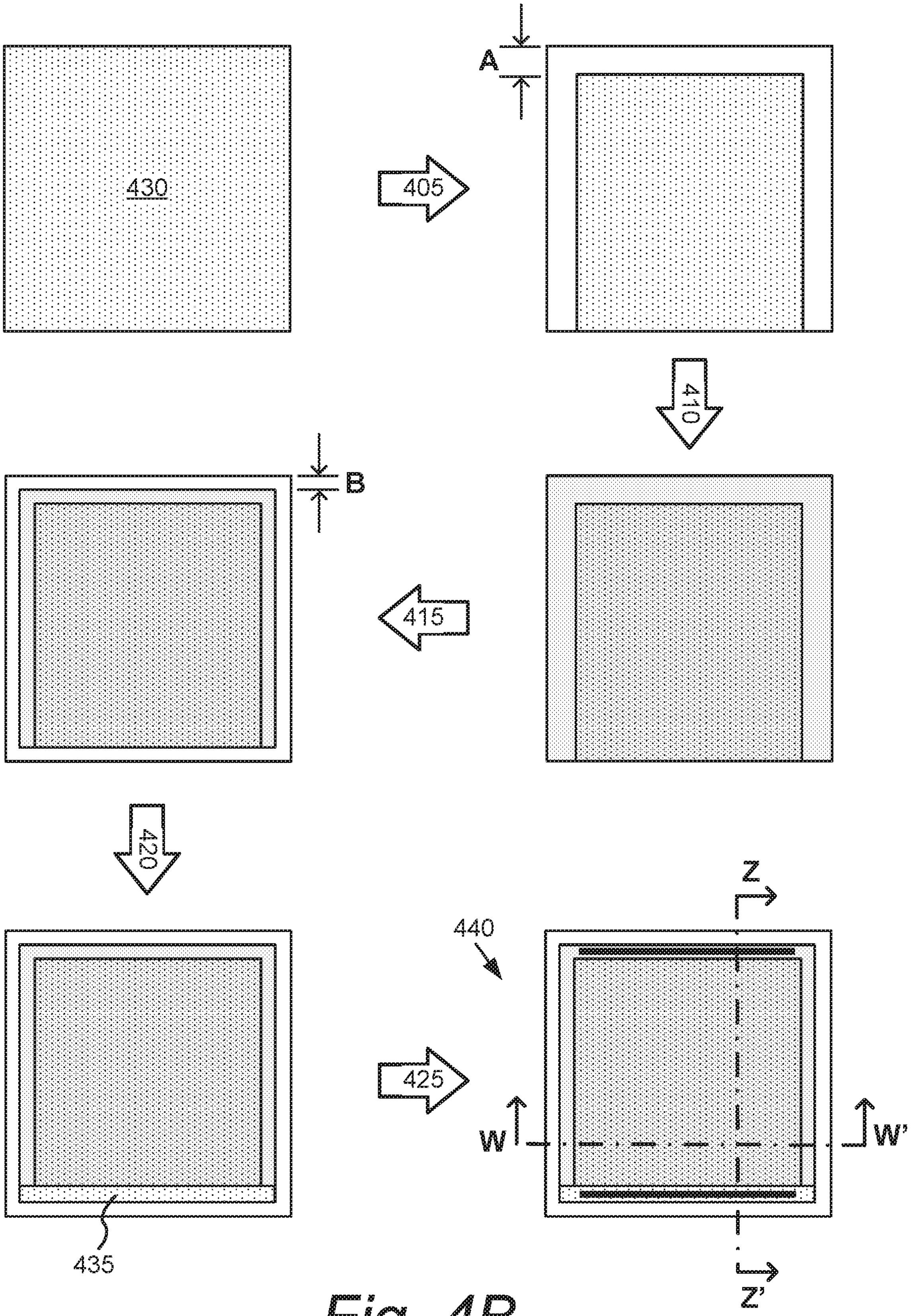
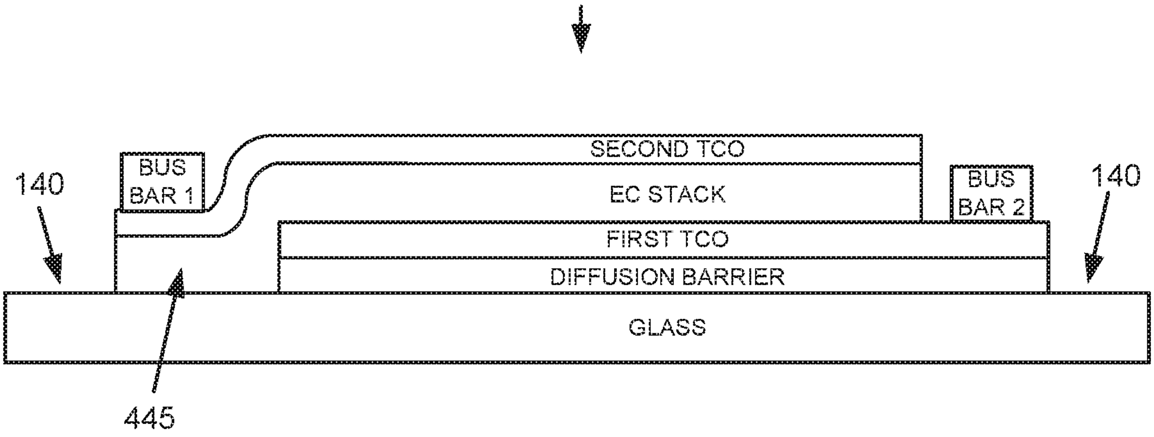


Fig. 4B

Section **Z-Z'** of device 440



Section **W-W'** of device 440

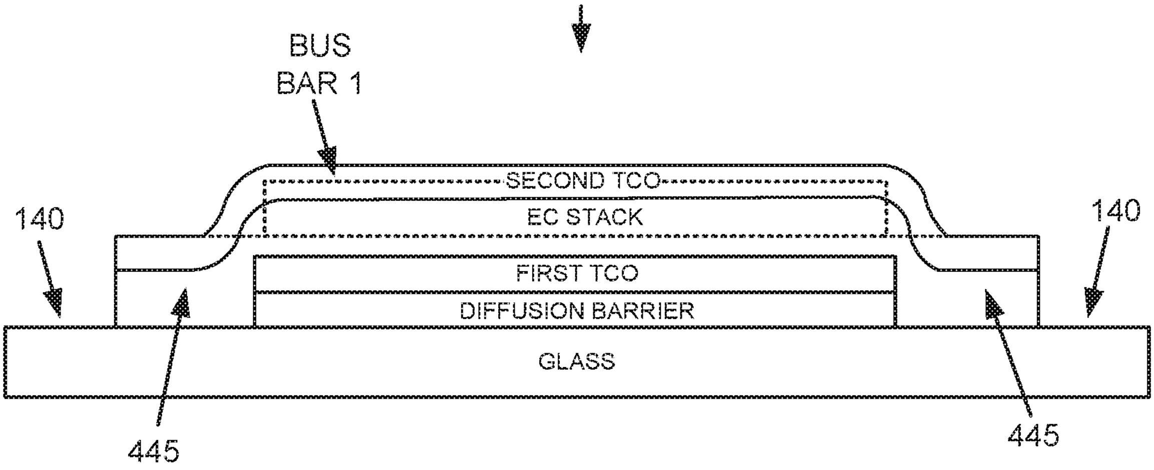


Fig. 4C

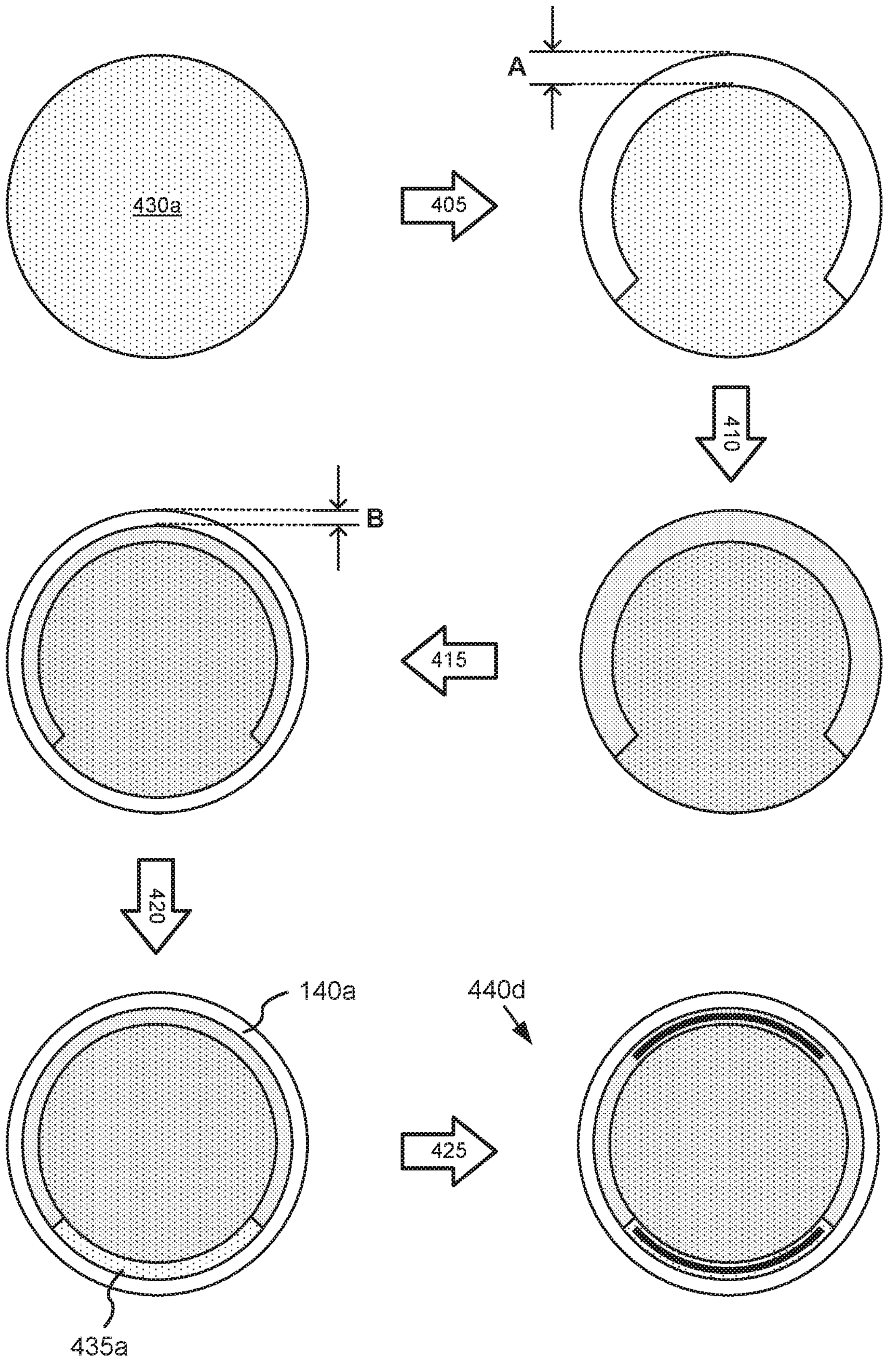


Fig. 4D

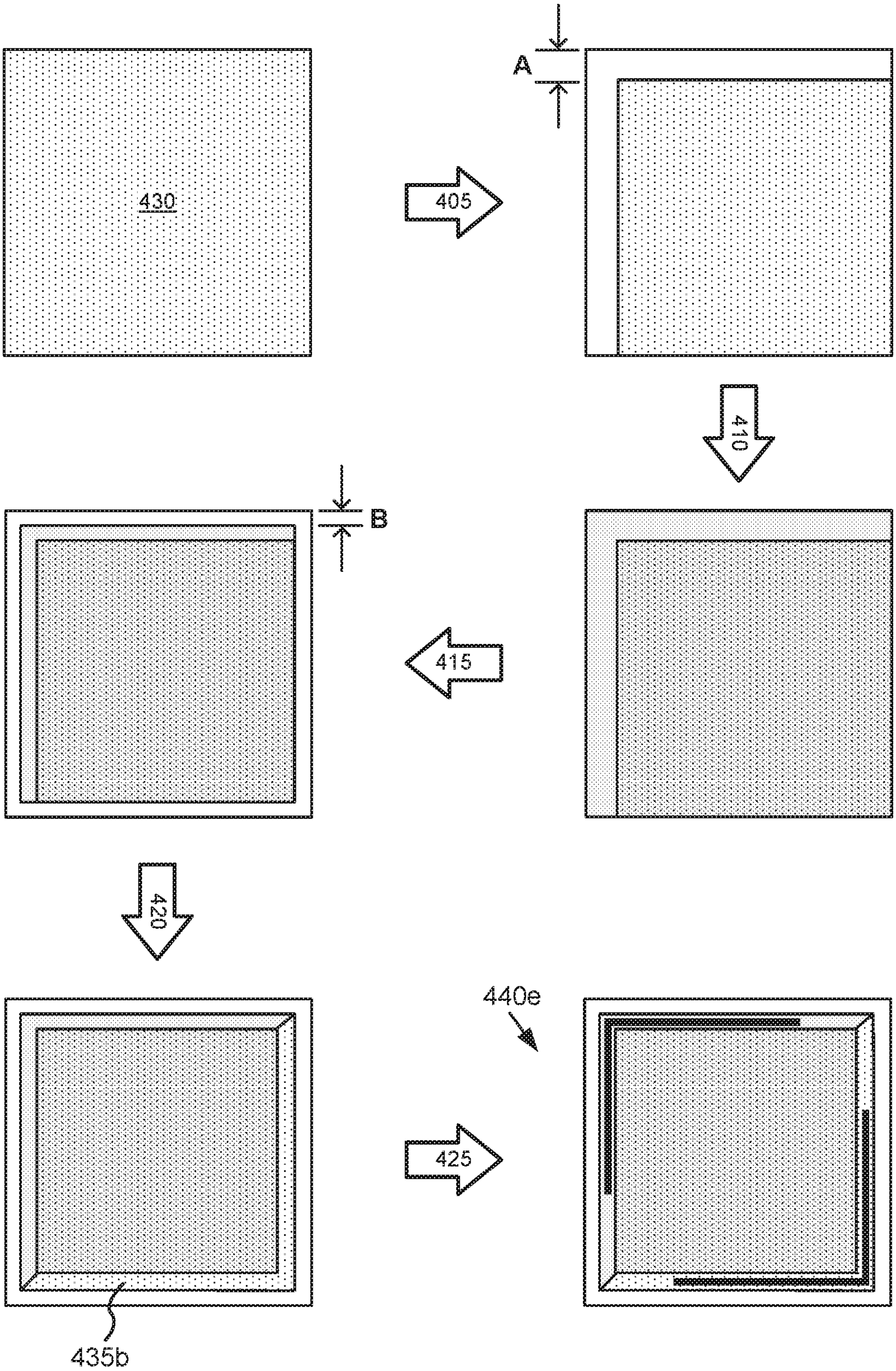


Fig. 4E

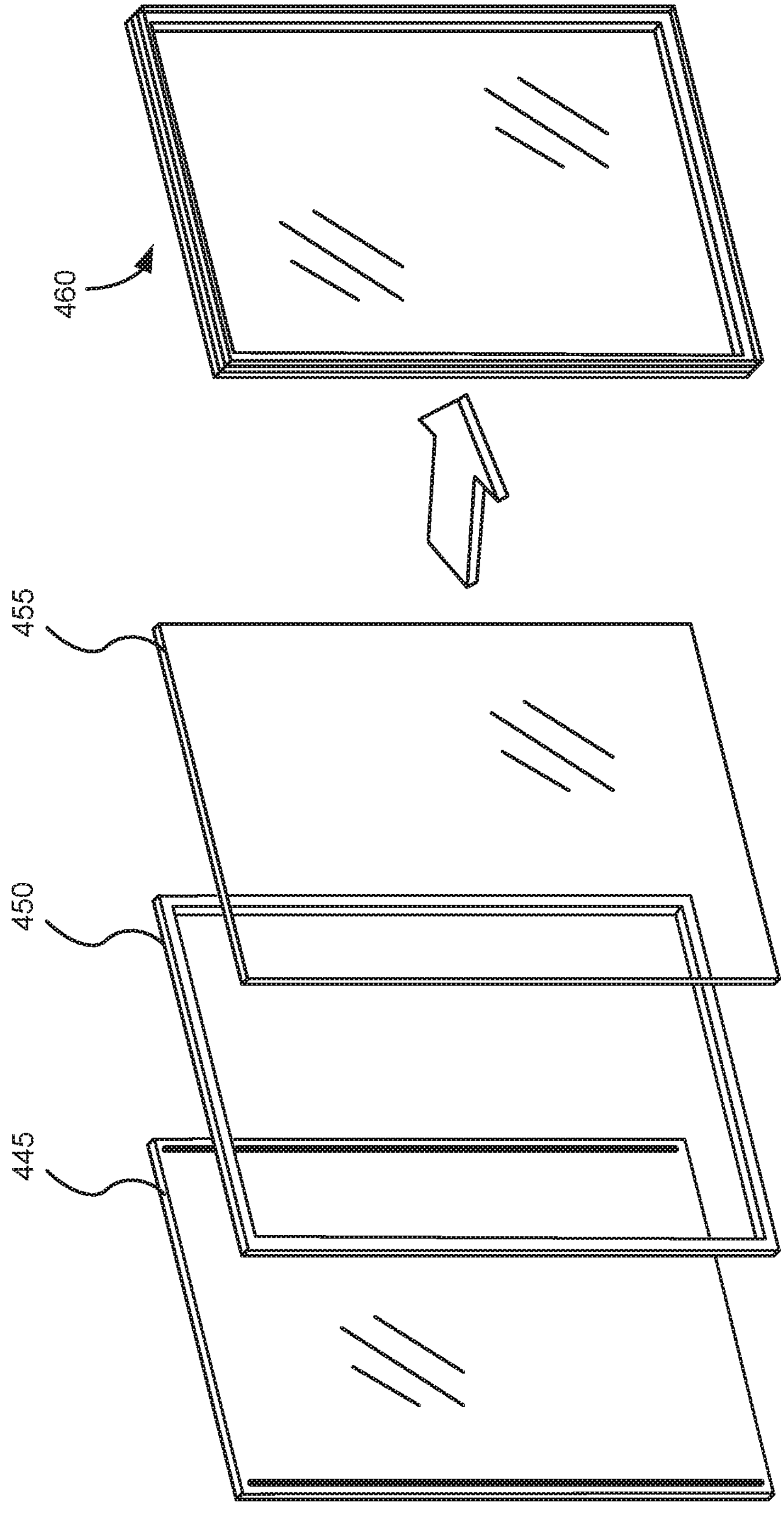


Fig. 4F

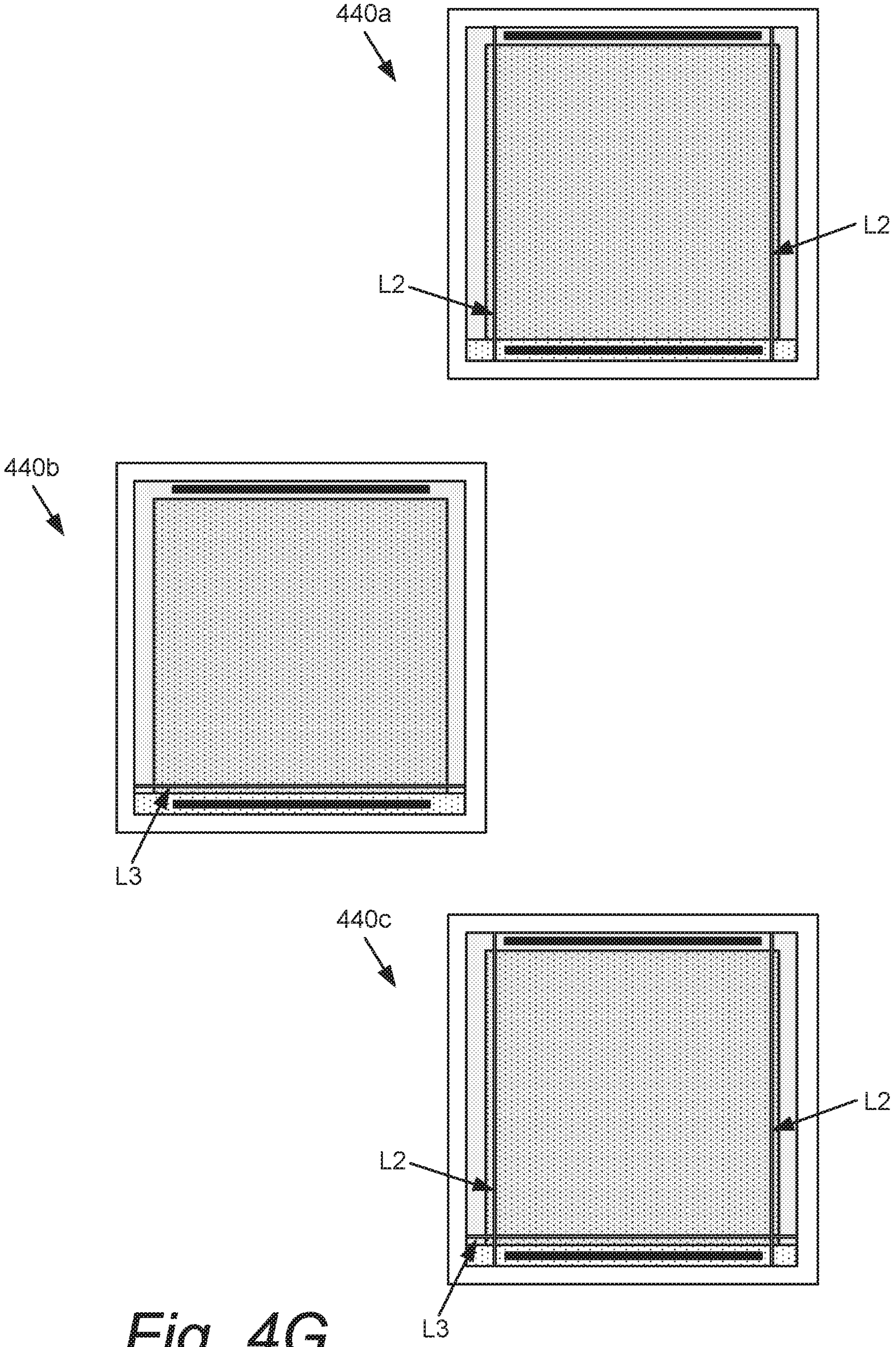


Fig. 4G

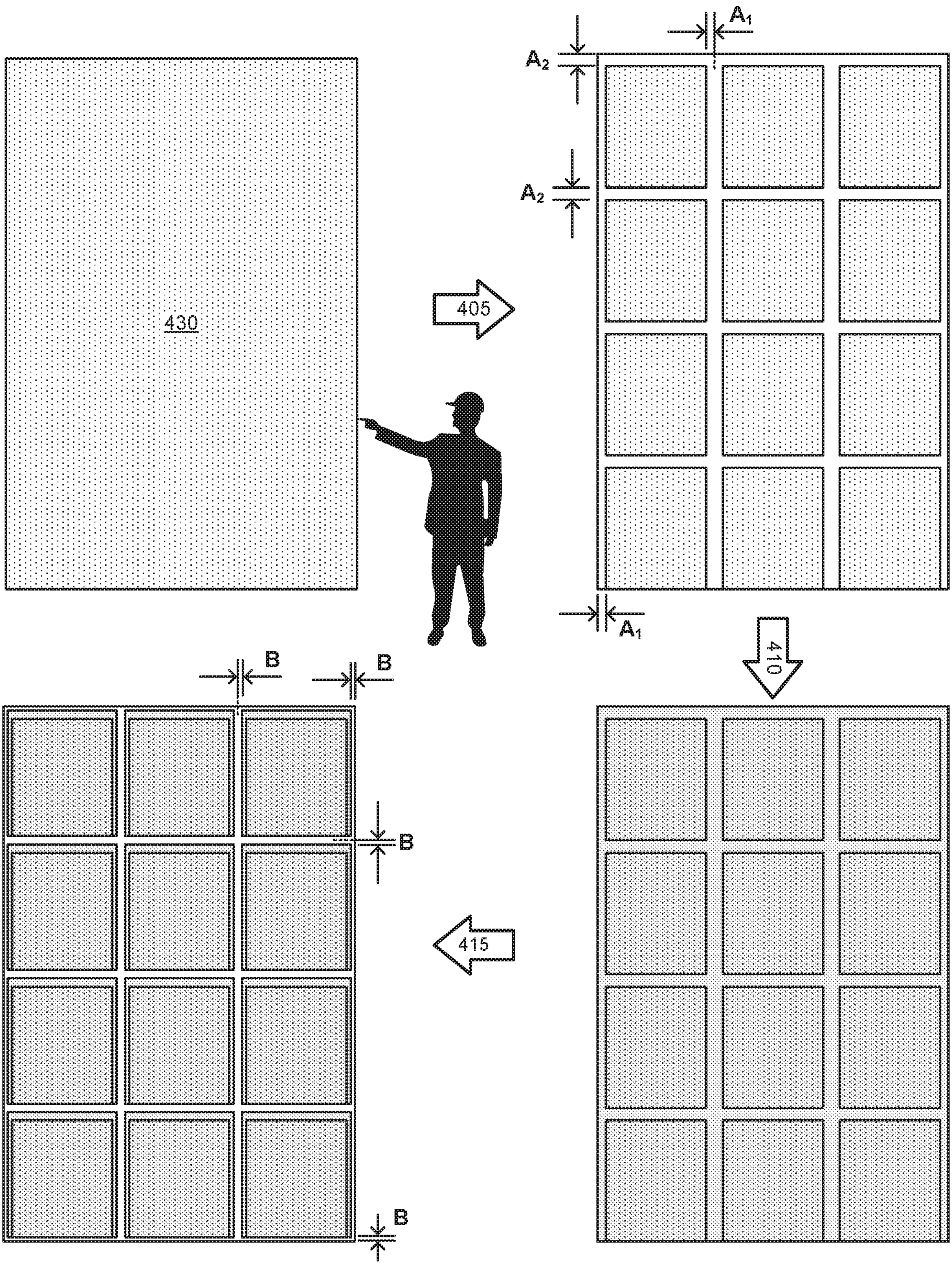


Fig. 4H

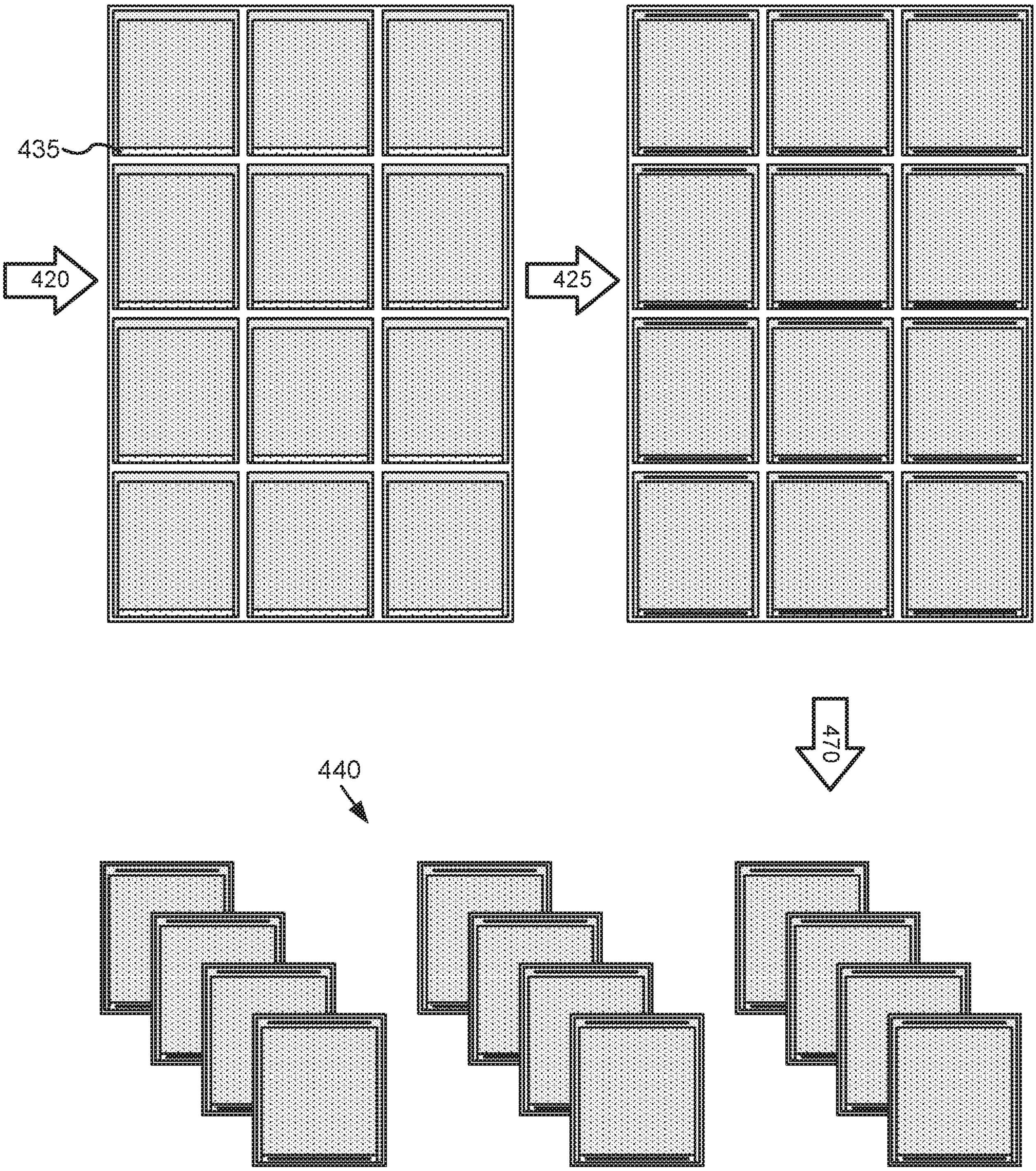


Fig. 4I

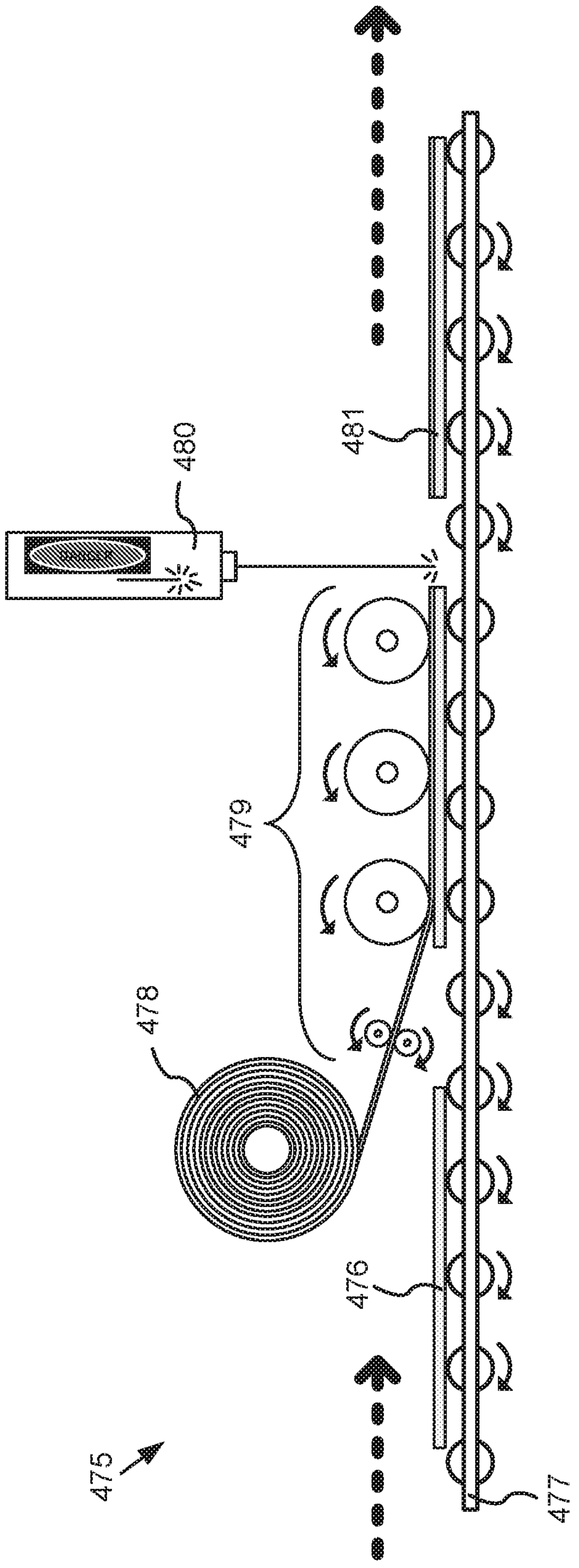


Fig. 4J

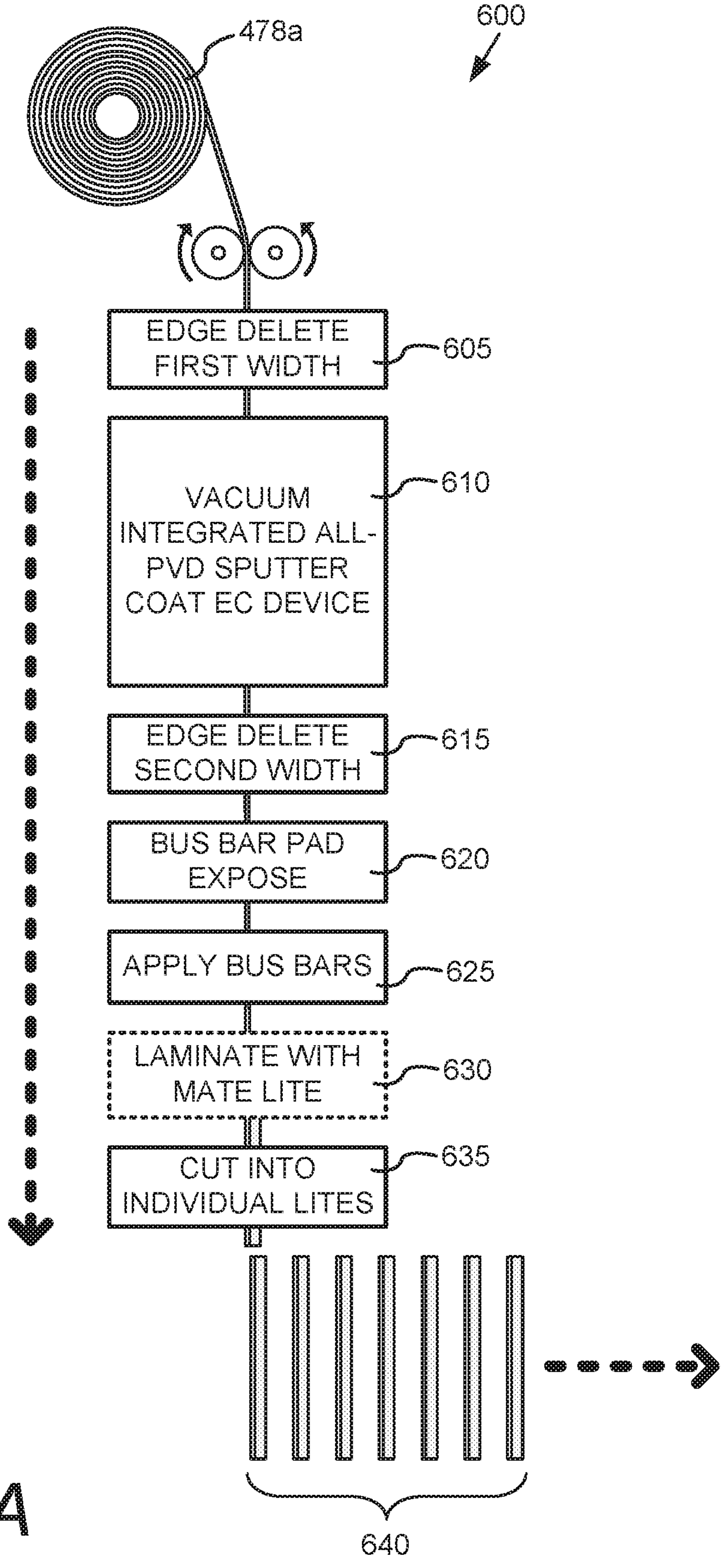

478a
600
EDGE DELETE FIRST WIDTH
605
VACUUM INTEGRATED ALL-PVD SPUTTER COAT EC DEVICE
610
EDGE DELETE SECOND WIDTH
615
BUS BAR PAD EXPOSE
620
APPLY BUS BARS
625
LAMINATE WITH MATE LITE
630
CUT INTO INDIVIDUAL LITES
635
640

Fig. 5A

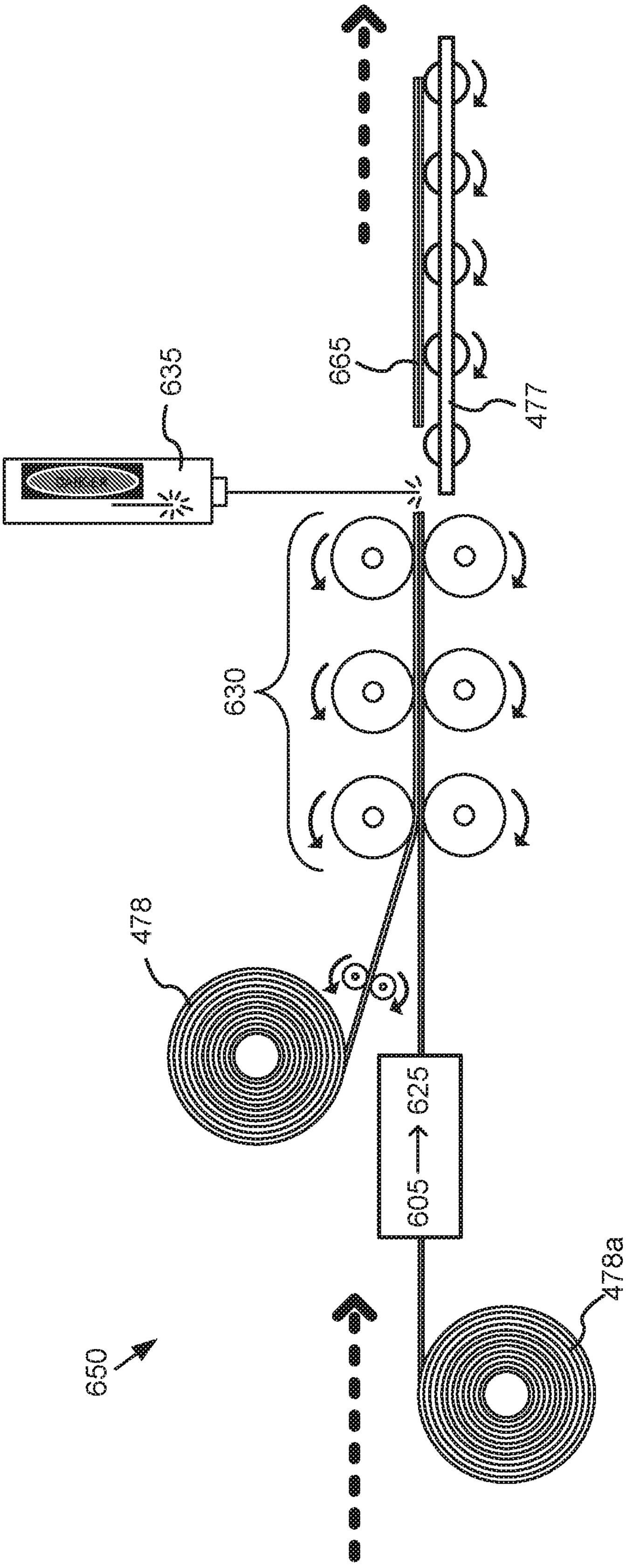


Fig. 5B

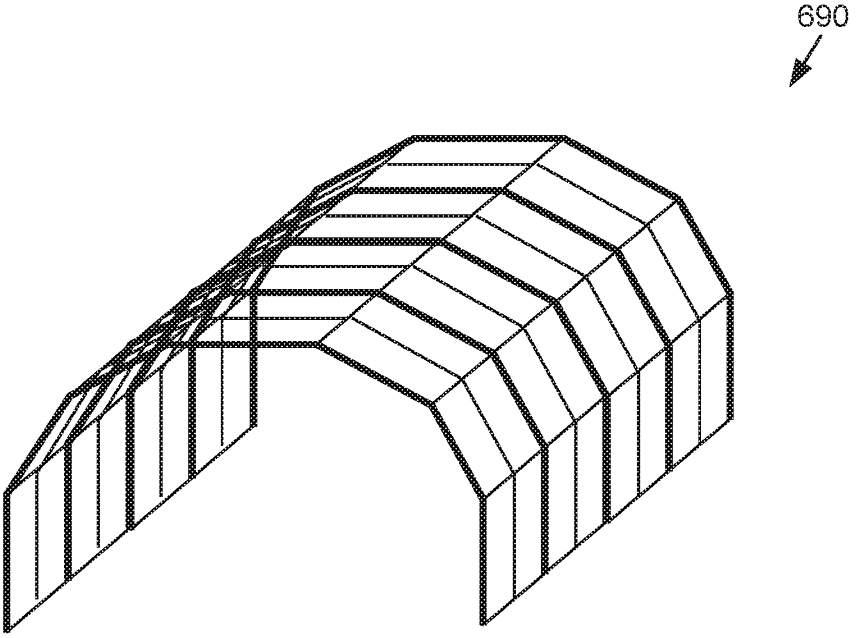


Fig. 6A

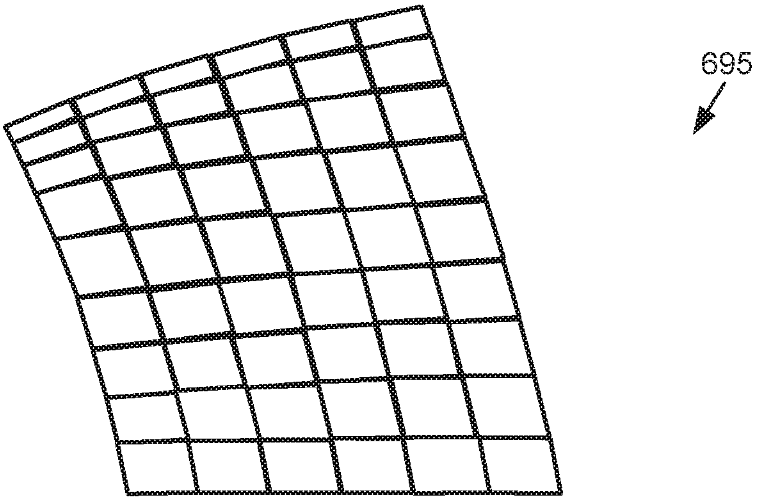


Fig. 6B

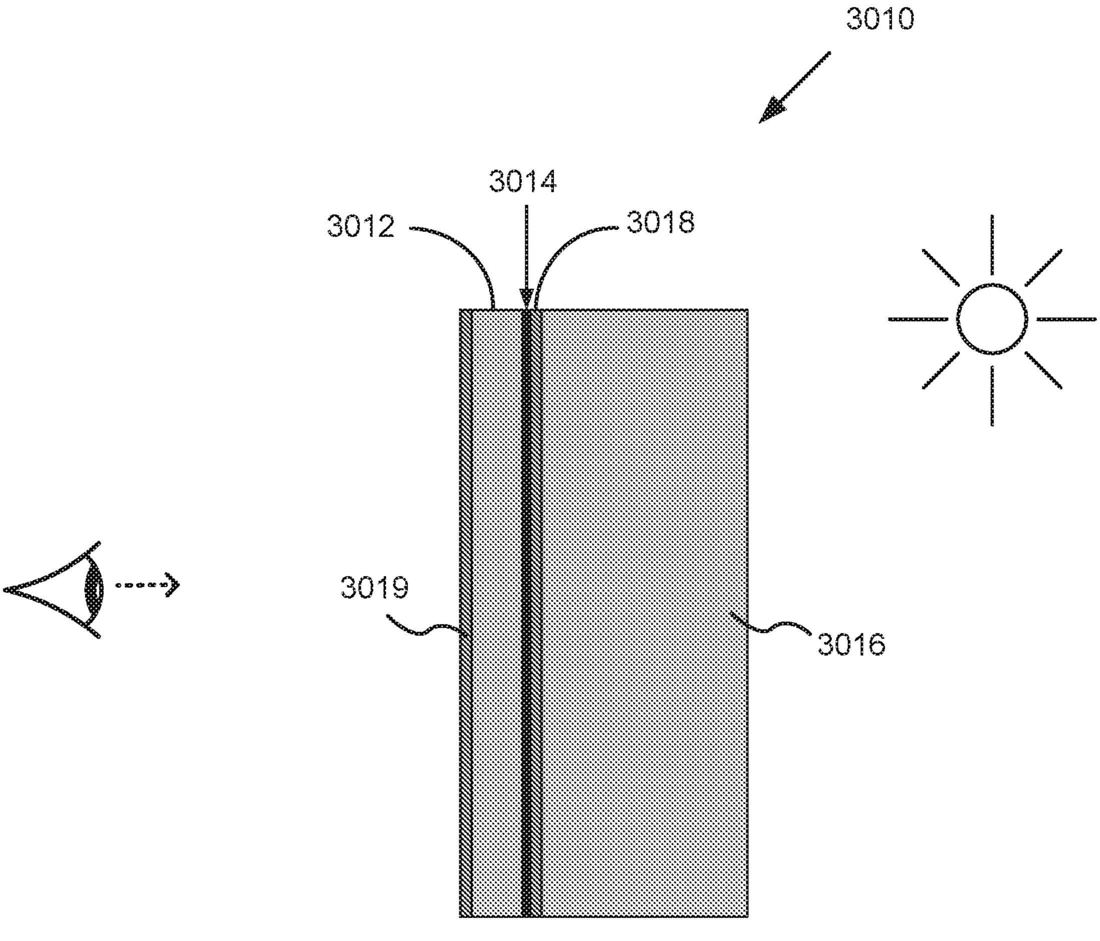


Fig. 7A

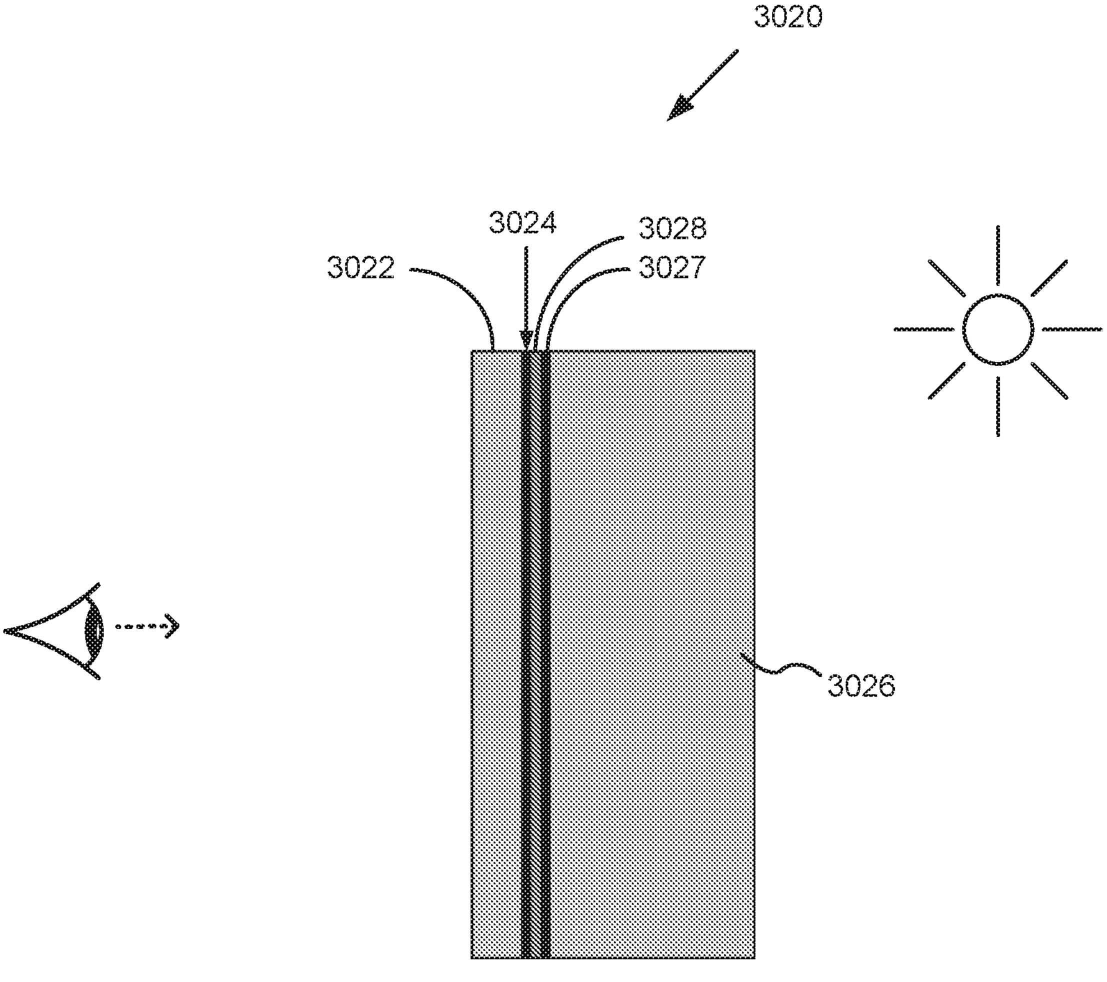


Fig. 7B

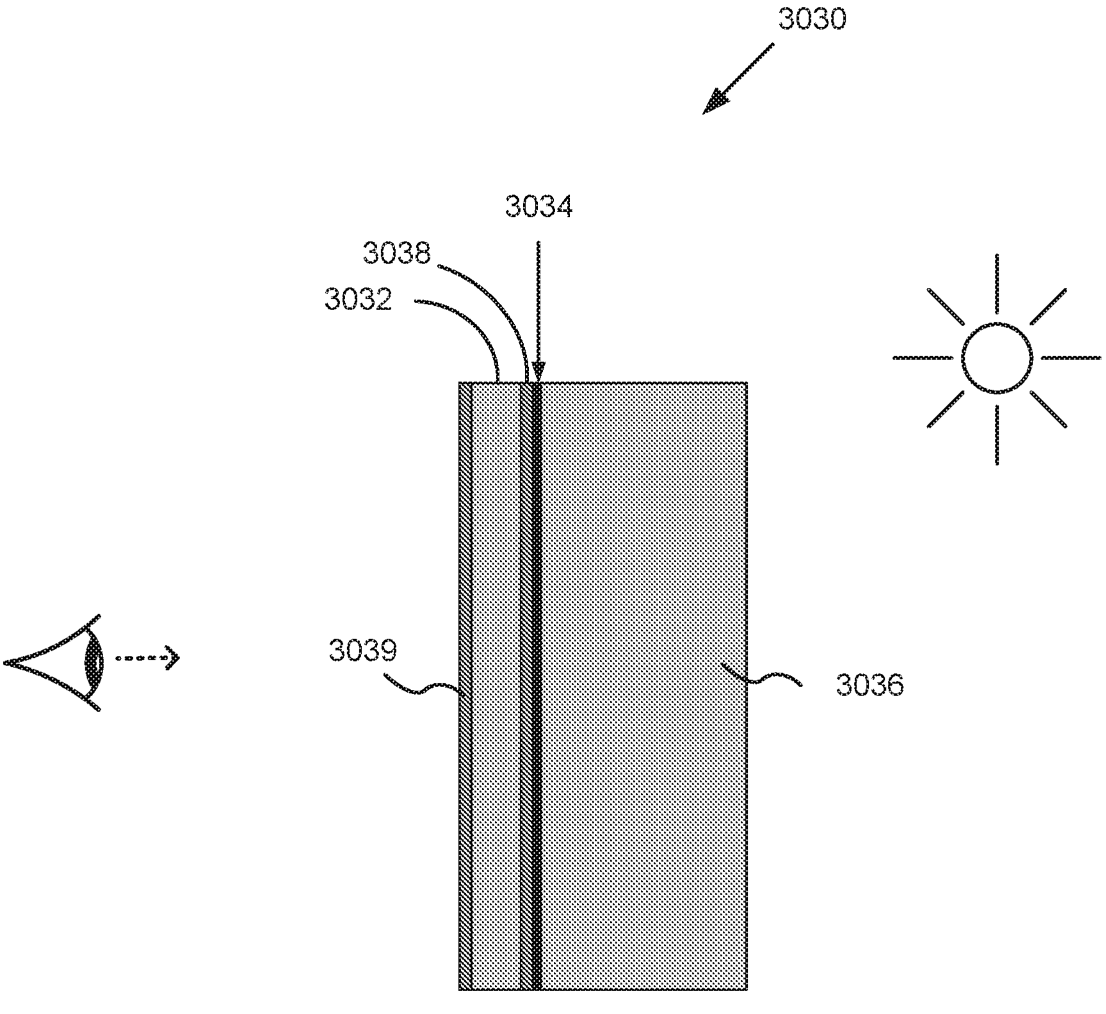


Fig. 7C

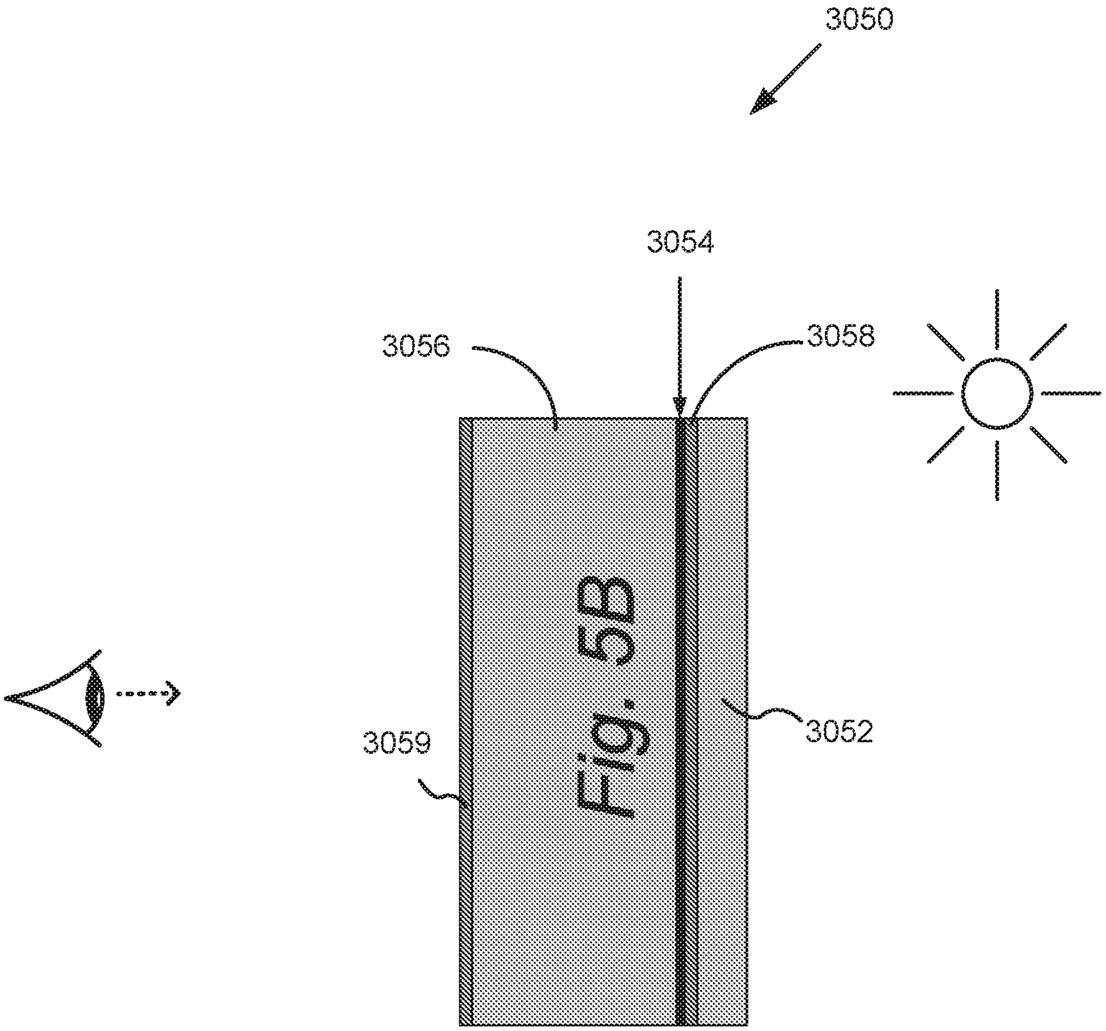


Fig. 8A

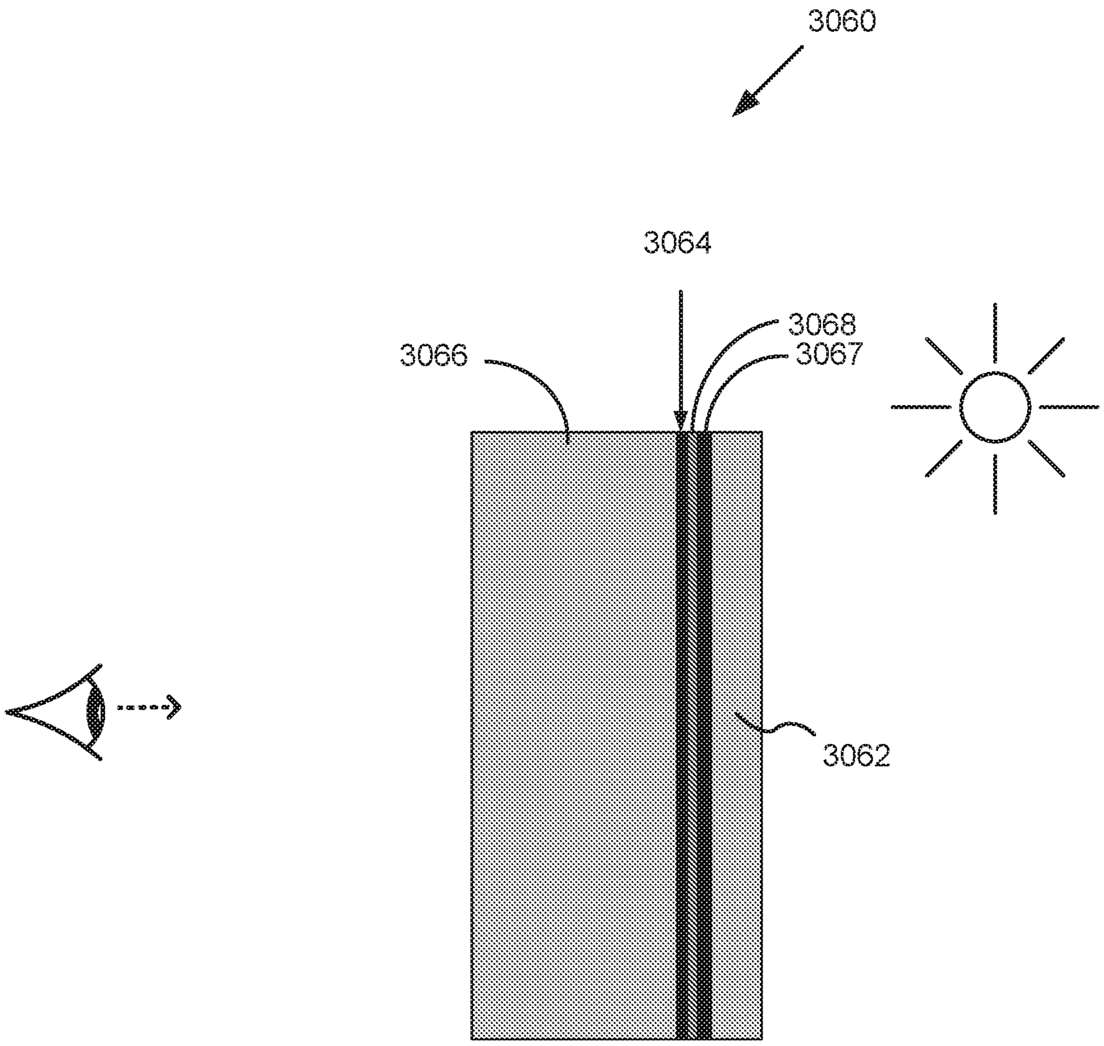


Fig. 8B

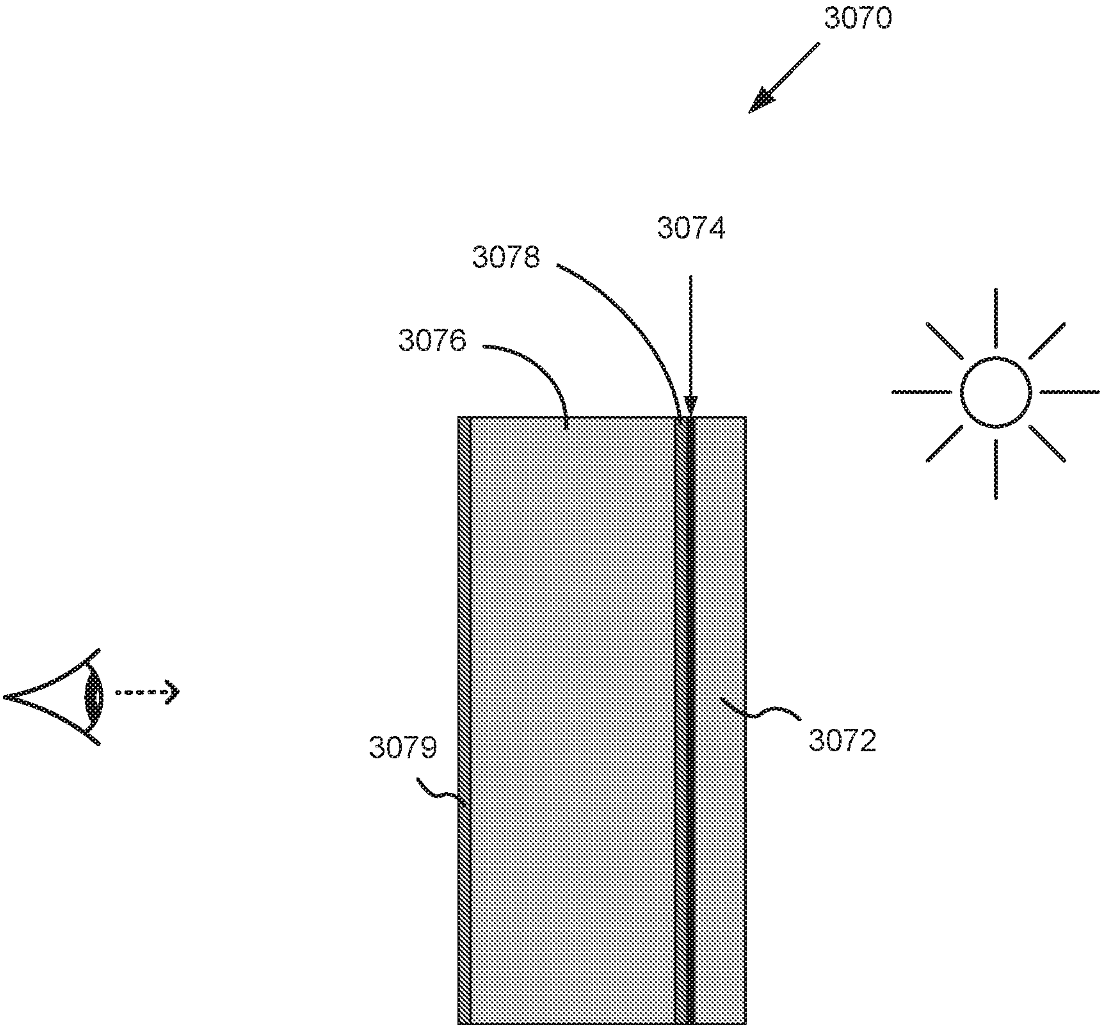


Fig. 8C

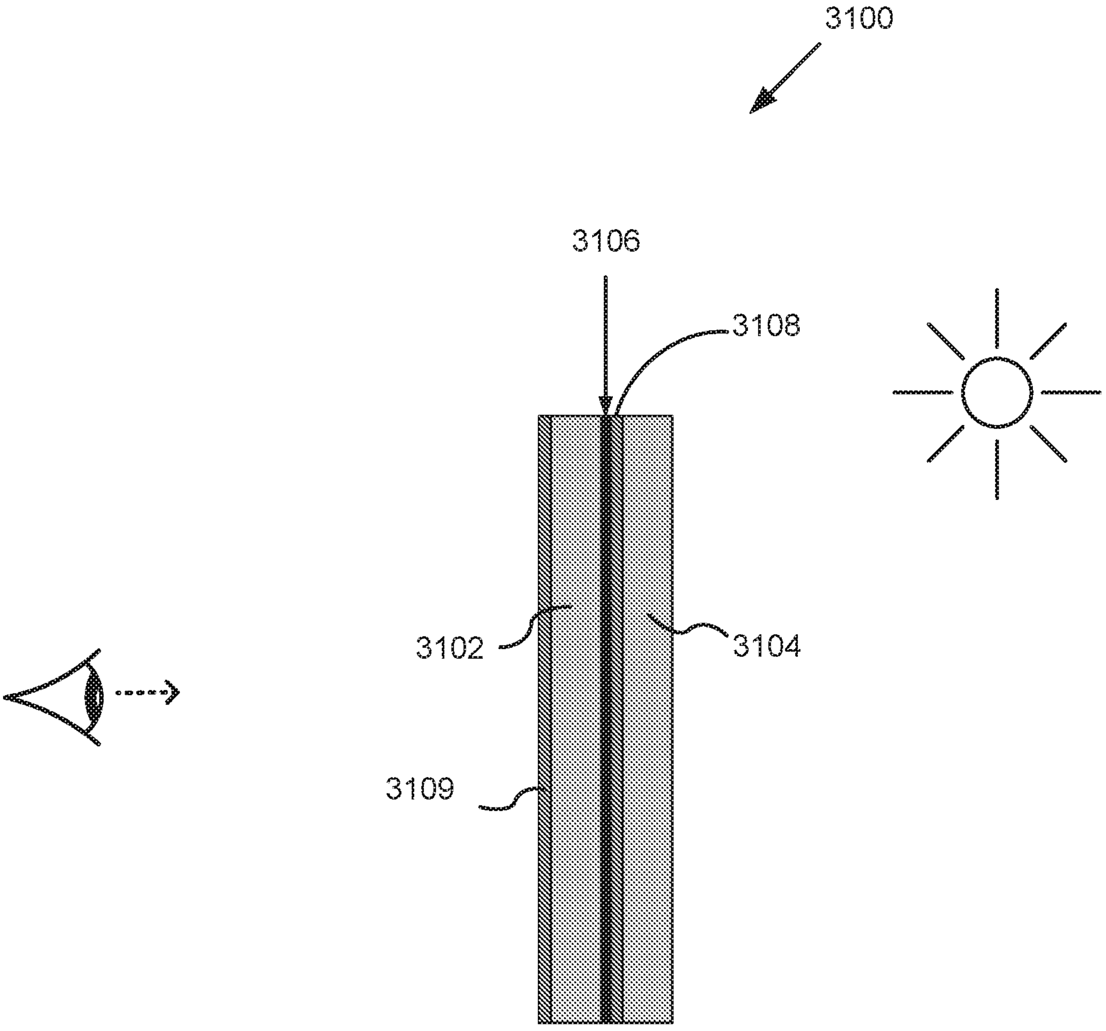


Fig. 9A

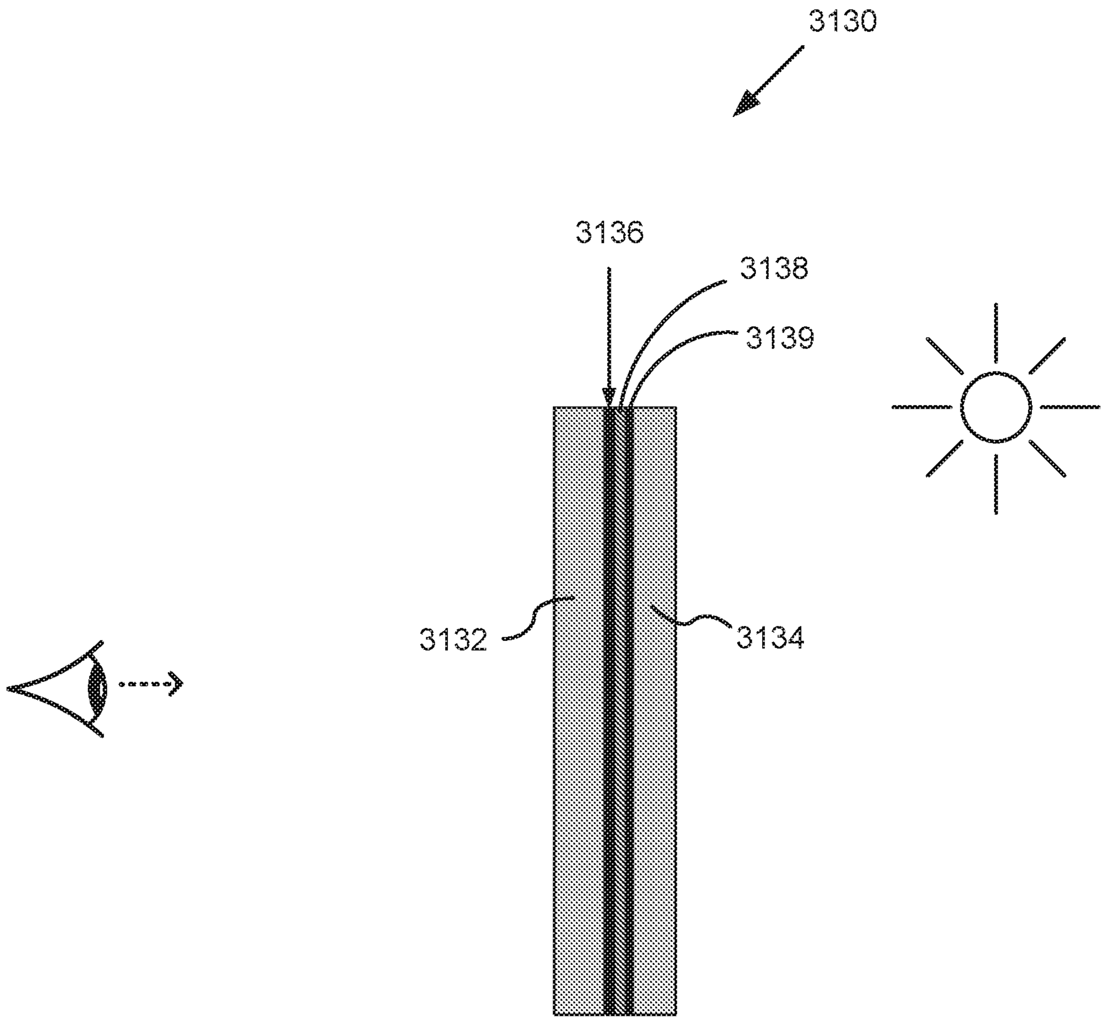


Fig. 9B

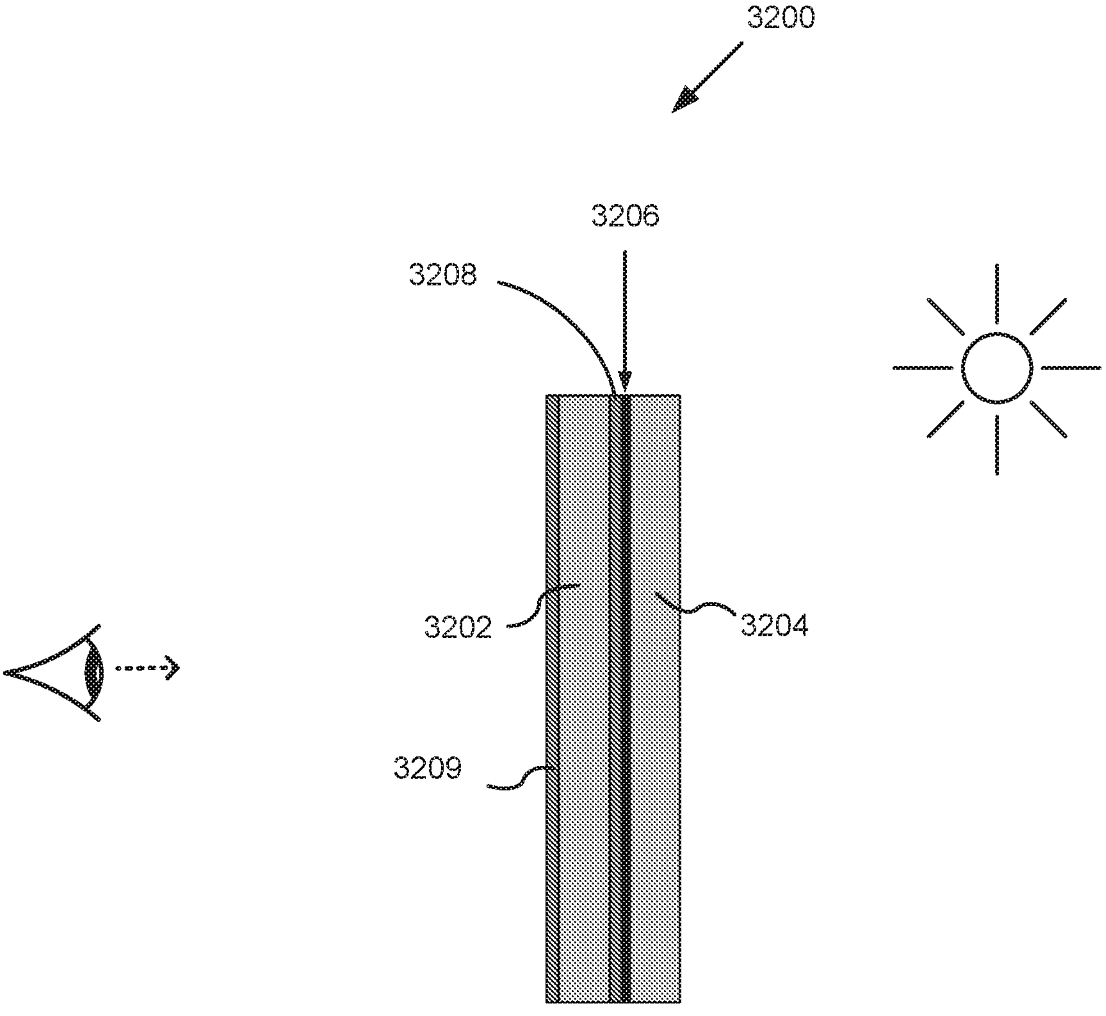


Fig. 9C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/041624

A. CLASSIFICATION OF SUBJECT MATTER

G02F 1/155(2006.01)i, C23C 14/08(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 1/155; B05D 5/12; G02F 1/153; H01M 618; G02F 1/15; G03B 13/00; B32B 38/00; G02F 115; C23C 14/08

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: electrochromic, lamination, TCO, edge cutting, fabrication

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012-0182593 A1 (MARK A. COLLINS et al.) 19 July 2012 See paragraphs [0023], [0030], [0062]; claim 1; and figures 4A-4B.	1-2,5-12,14,16-19
A		3-4,13,15
Y	US 2010-0245973 A1 (ZHONGCHUN WANG et al.) 30 September 2010 See paragraph [0044]; and figuere 6A.	1-2,5-12,14,16-19
Y	WO 2014-170241 A2 (CHROMOGENICS AB) 23 October 2014 See page 3, lines 4-23, page 17, line 28 - page 18, line 12; and figures 2B, 8A.	19
A	US 6822778 B2 (RAYMOND T. WESTFALL et al.) 23 November 2004 See columns 6-8; and figures 3-22.	1-19
A	US 7777933 B2 (FABIENNE PIROUX et al.) 17 August 2010 See columns 7-9; and claim 1.	1-19

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"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
13 October 2016 (13.10.2016)

Date of mailing of the international search report
17 October 2016 (17.10.2016)

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Information on patent family members

International application No.
PCT/US2016/041624

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