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**Ecton et al.**

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(54) **METHODS AND APPARATUS TO INCREASE GLASS CORE THICKNESS**

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(51) **Int. Cl.**  
**H01L 23/538** (2006.01)  
**H01L 21/48** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01L 23/5383** (2013.01); **H01L 21/4857** (2013.01); **H01L 21/486** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01L 23/5383; H01L 21/4857; H01L 21/486; H01L 23/538; H01L 21/48

USPC ..... 174/257  
See application file for complete search history.

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\* cited by examiner

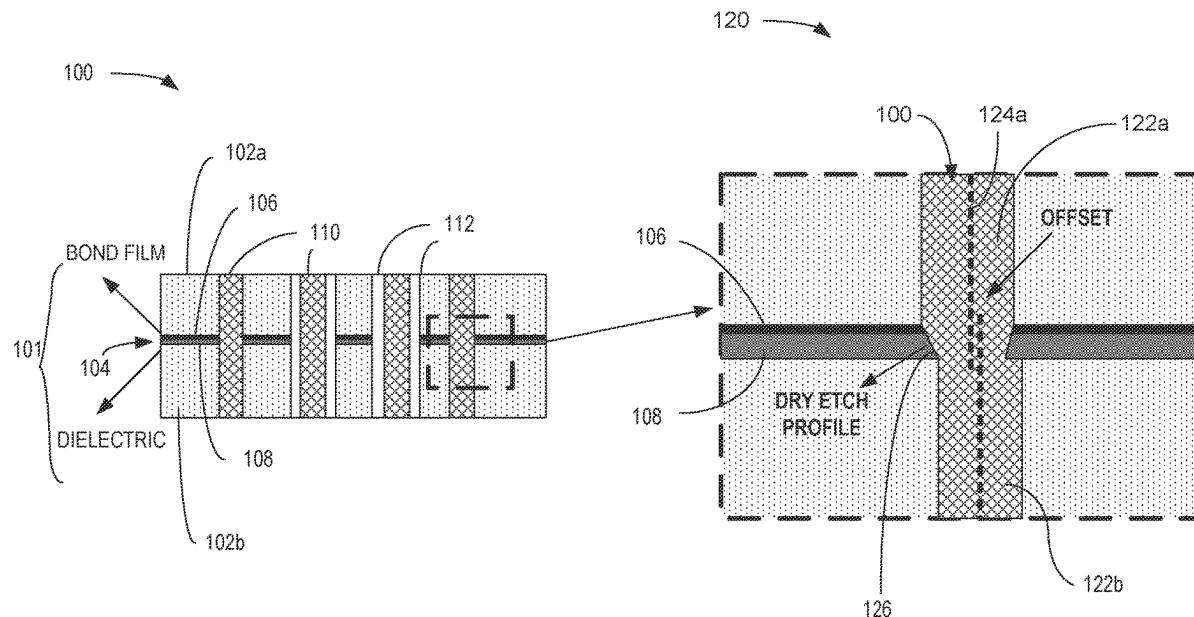
*Primary Examiner* — Tremesha W Burns

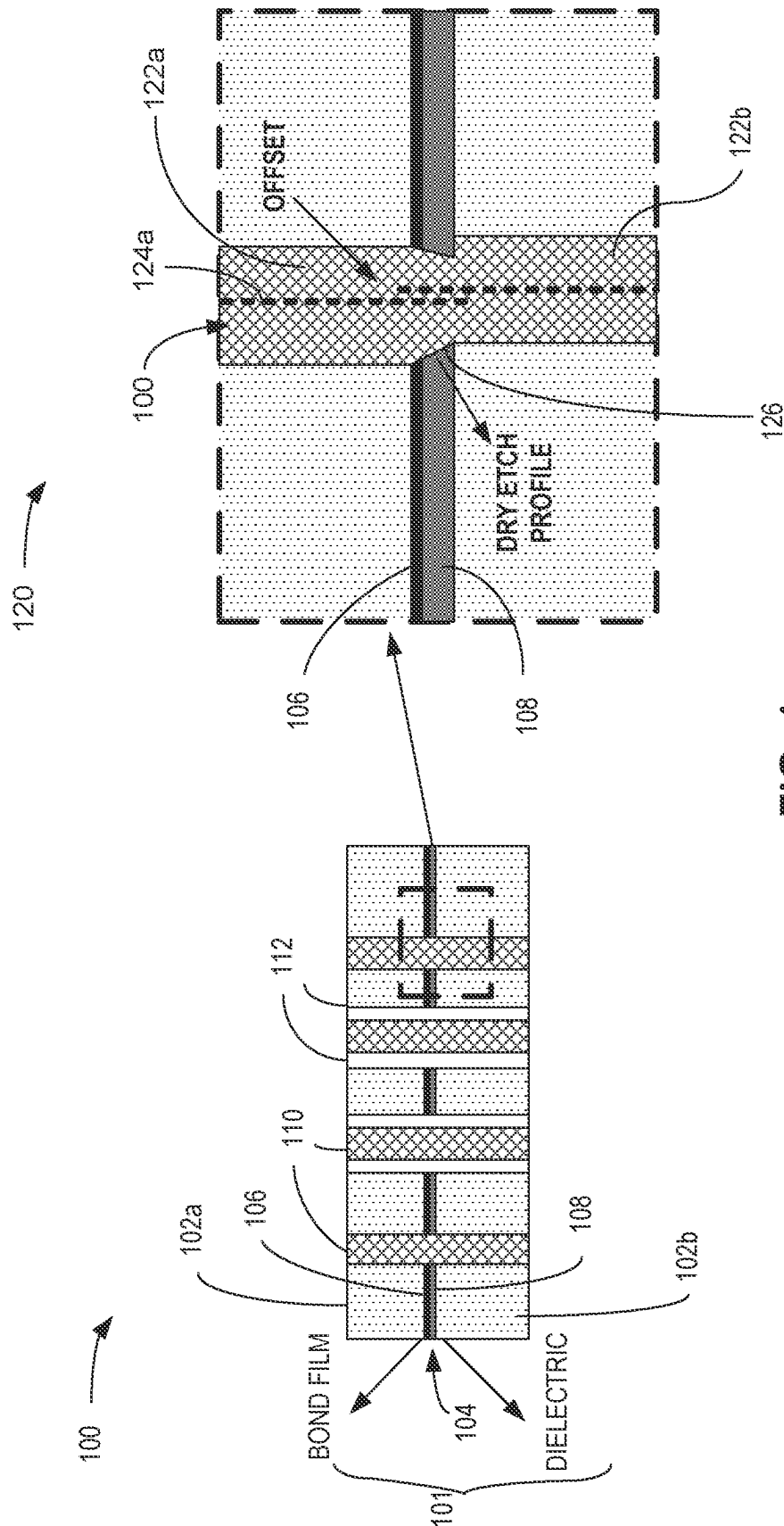
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(57) **ABSTRACT**

Methods and apparatus to increase glass core thickness are disclosed. An example apparatus includes a first glass substrate, a second glass substrate, an interface layer between the first glass substrate and the second glass substrate, the interface layer coupling the first glass substrate to the second glass substrate, and an interconnect extending through at least a portion of the first glass substrate and at least a portion of the second glass substrate.

**23 Claims, 12 Drawing Sheets**





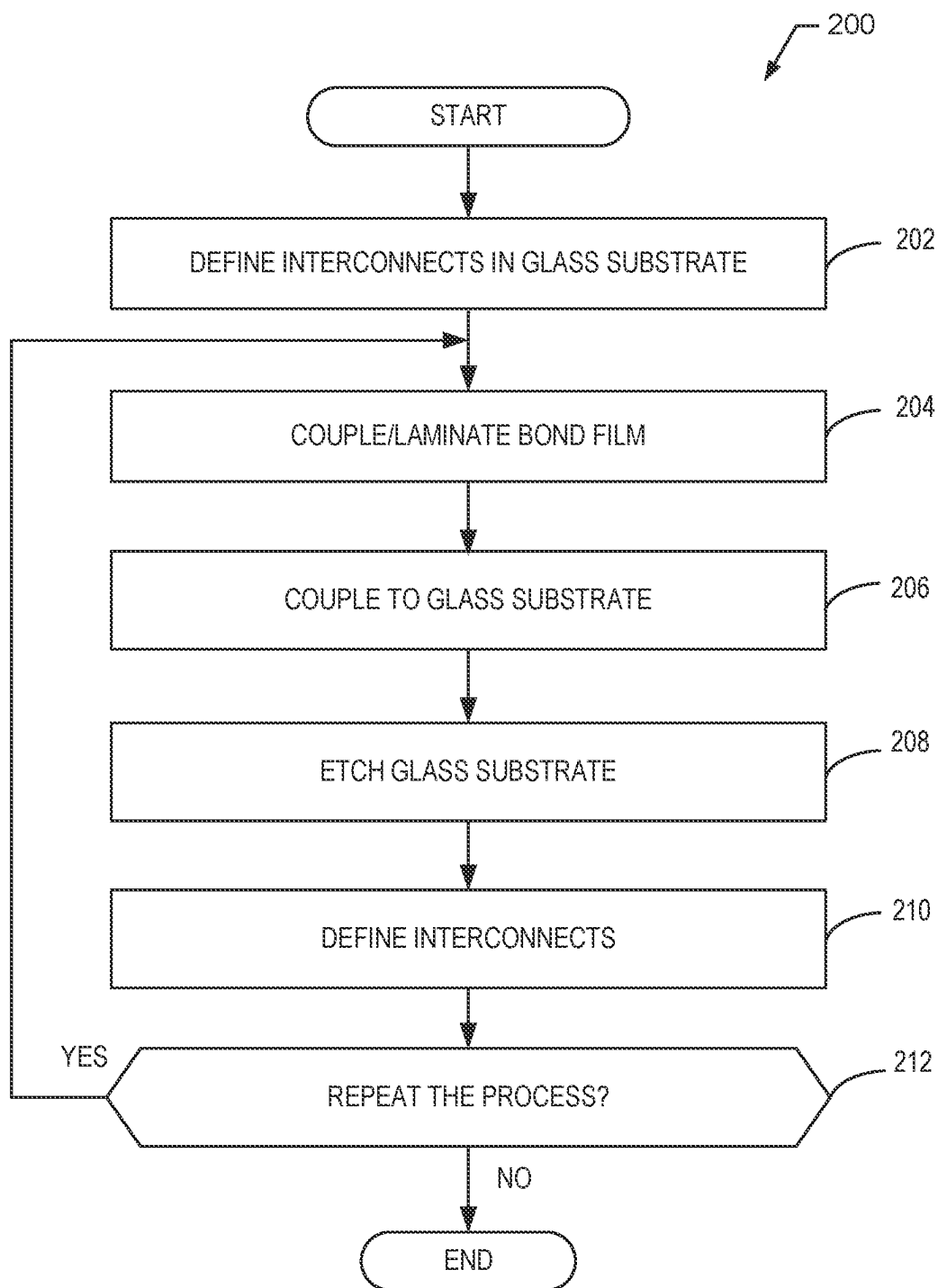


FIG. 2

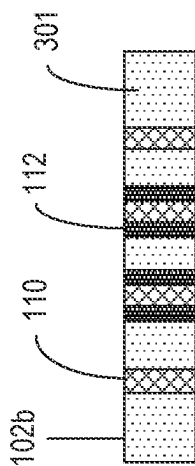


FIG. 3A

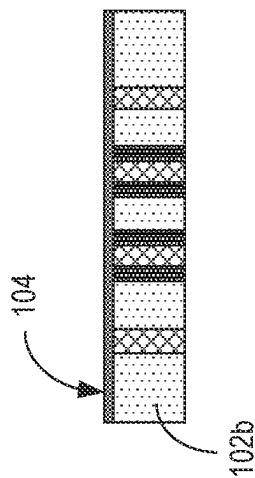


FIG. 3B

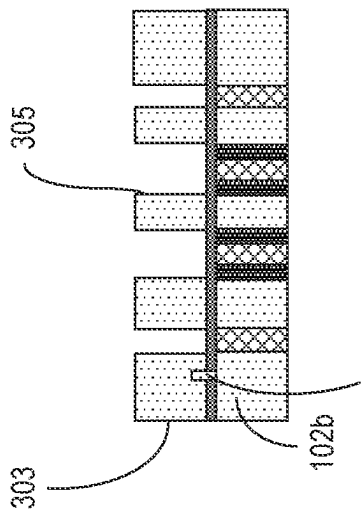


FIG. 3C

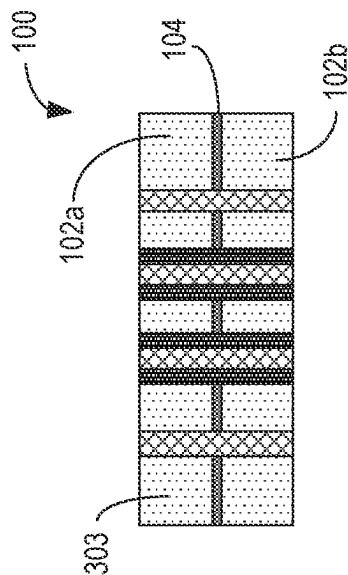


FIG. 3E

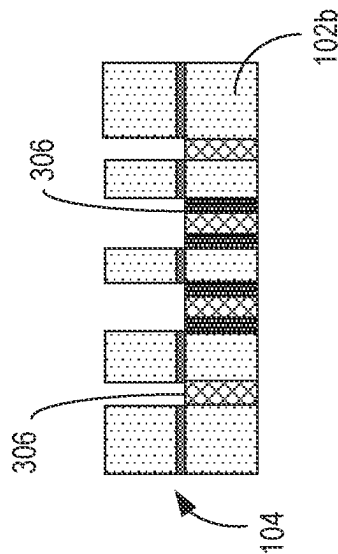


FIG. 3D

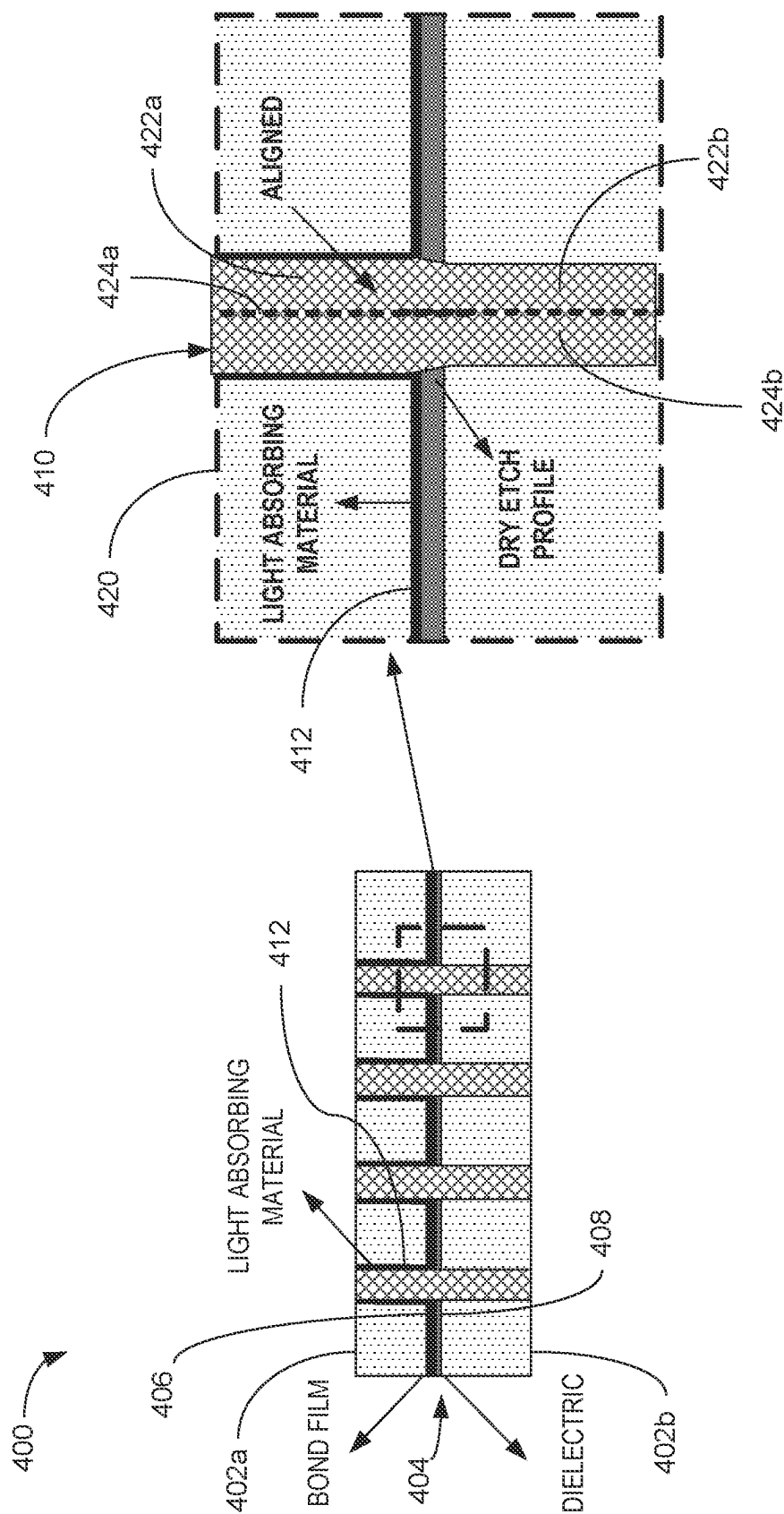


FIG. 4

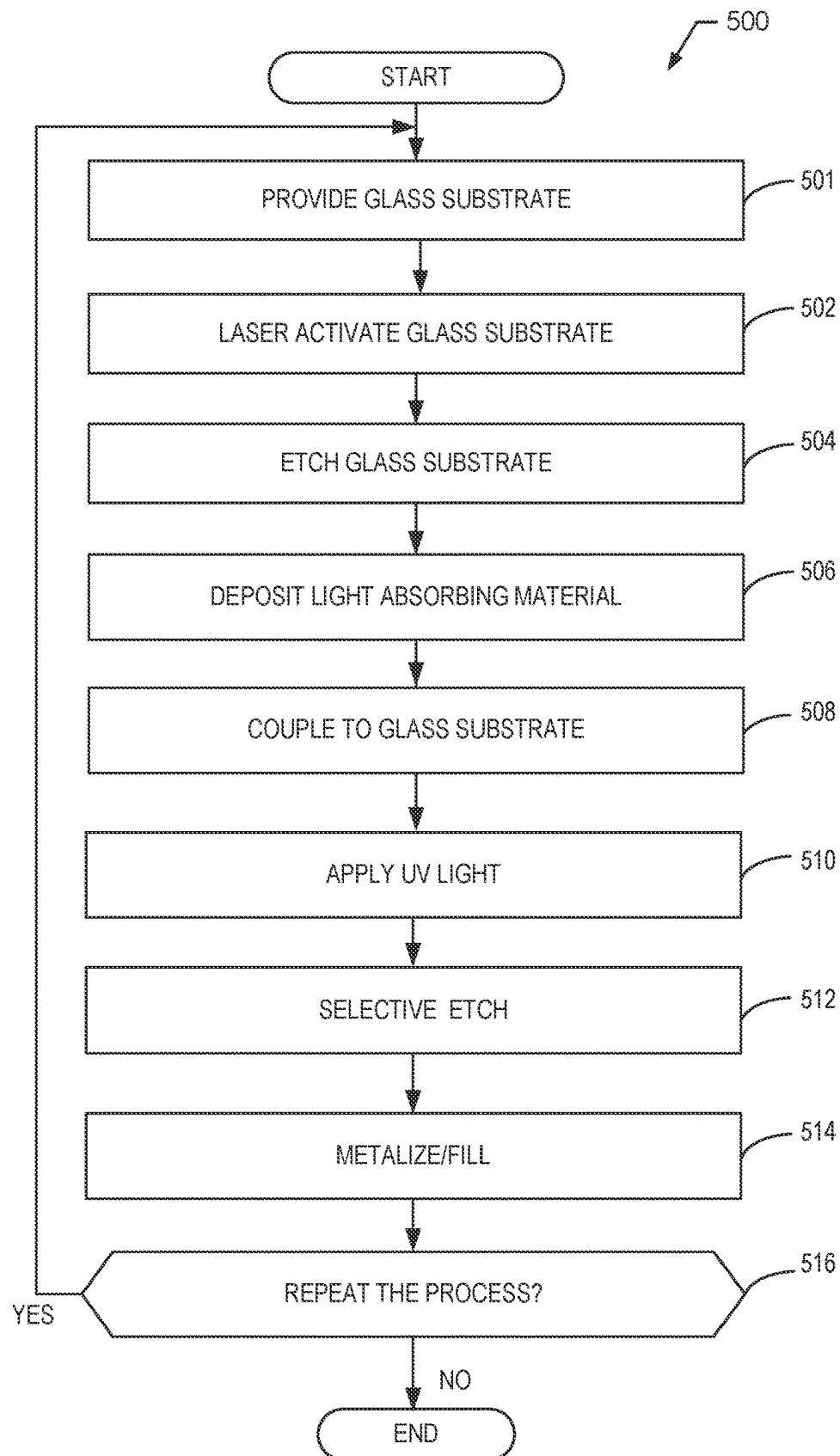


FIG. 5

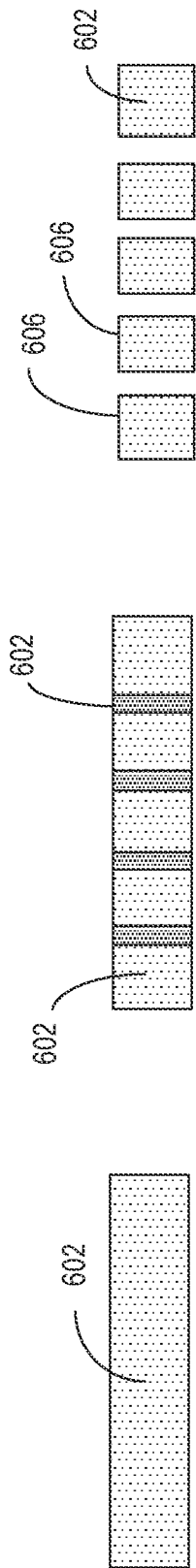


FIG. 6A

FIG. 6B

FIG. 6C

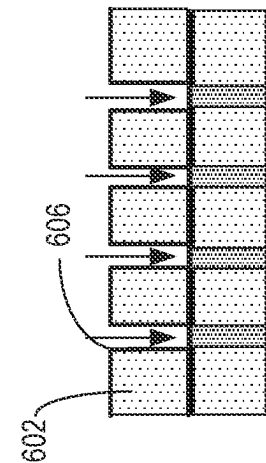
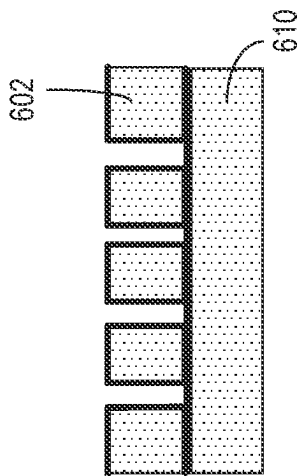
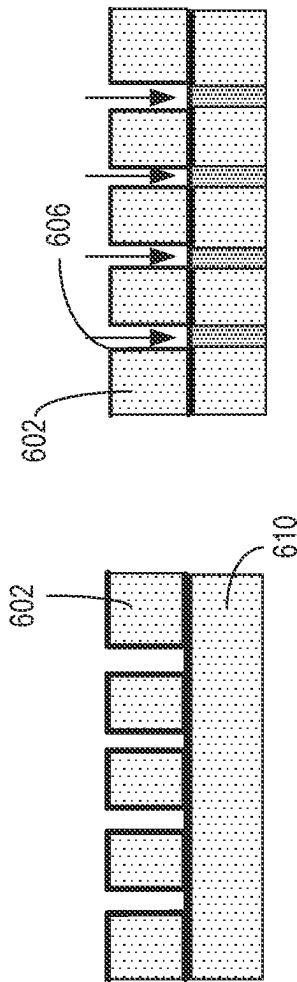


FIG. 6D

FIG. 6E

FIG. 6F

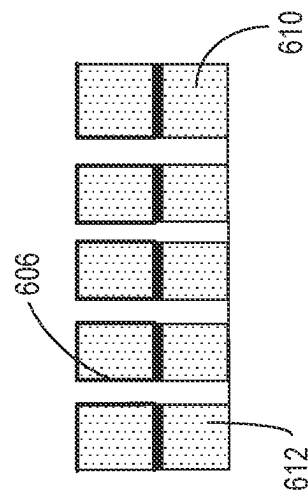


FIG. 6G

FIG. 6H

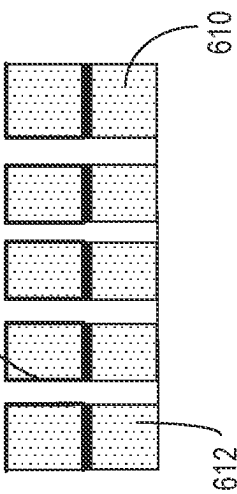
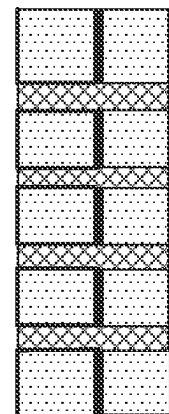
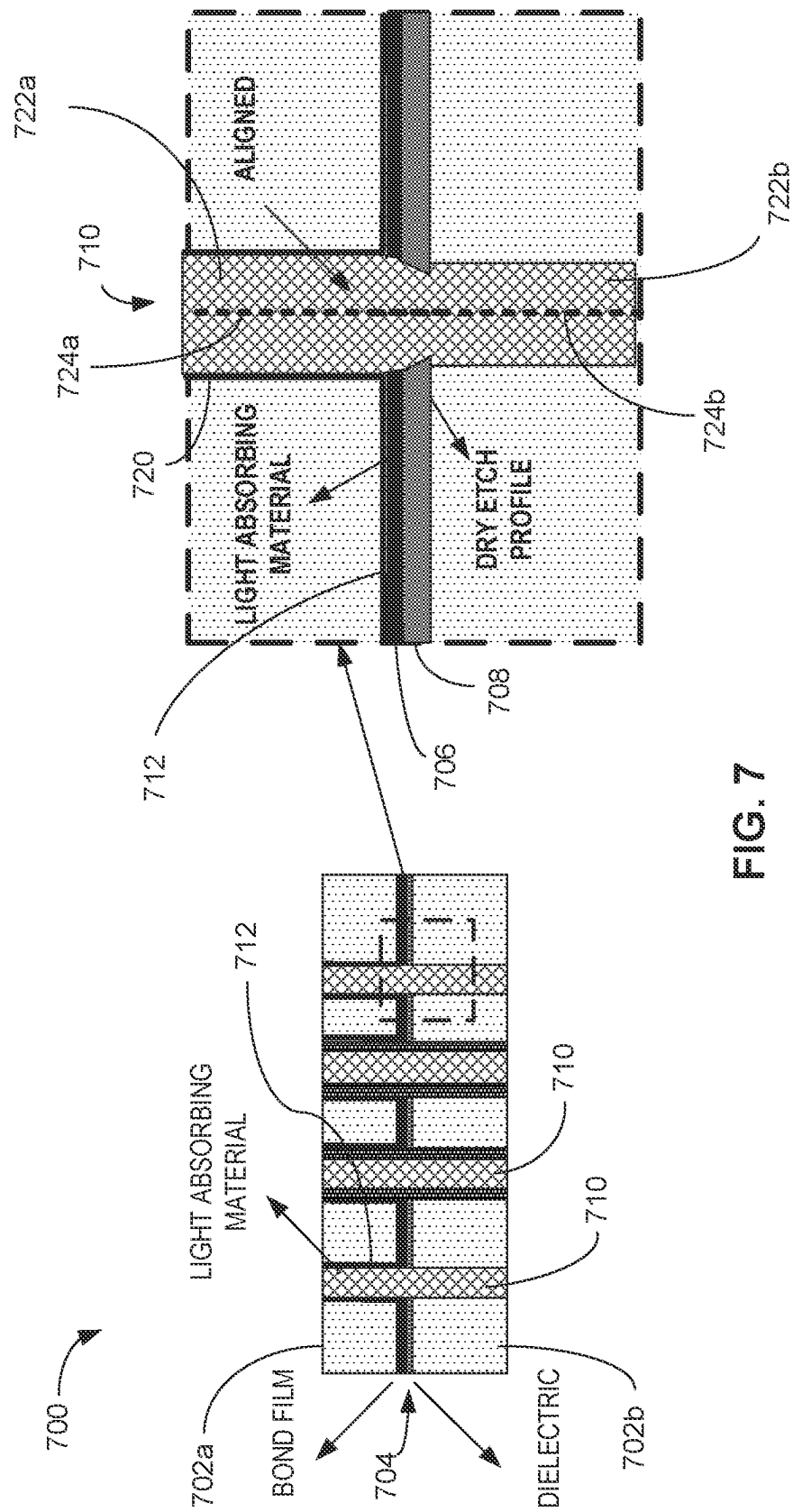


FIG. 6G

FIG. 6H



7  
G<sup>x</sup>  
L



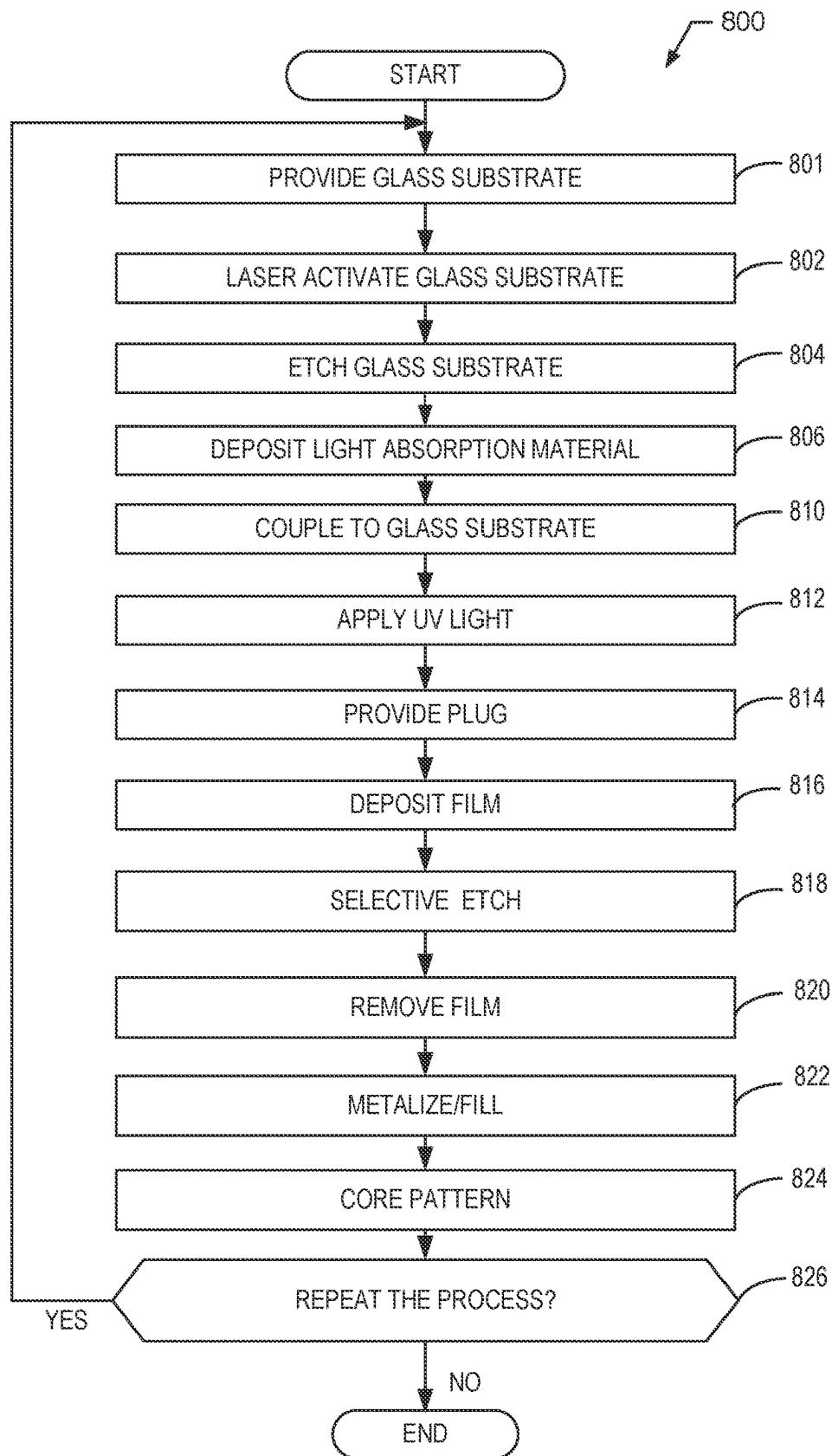


FIG. 8

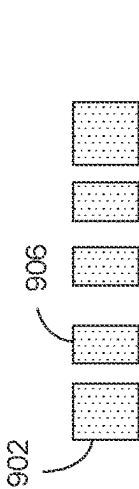


FIG. 9A

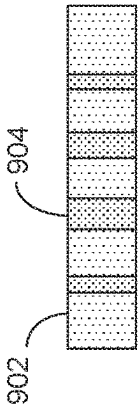


FIG. 9B

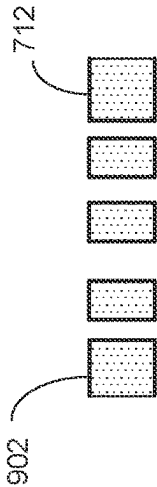


FIG. 9C

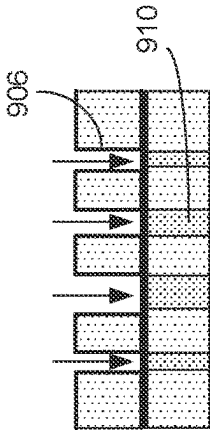


FIG. 9D

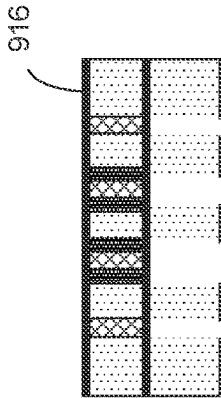


FIG. 9E

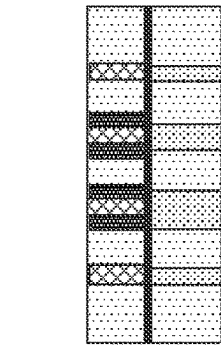


FIG. 9F

FIG. 9G

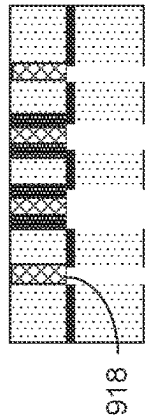


FIG. 9H

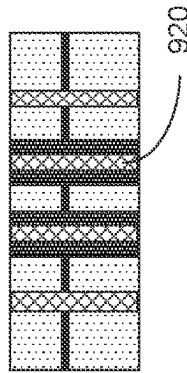


FIG. 9I

FIG. 9J

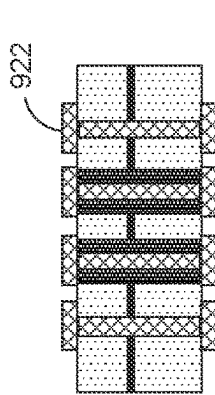
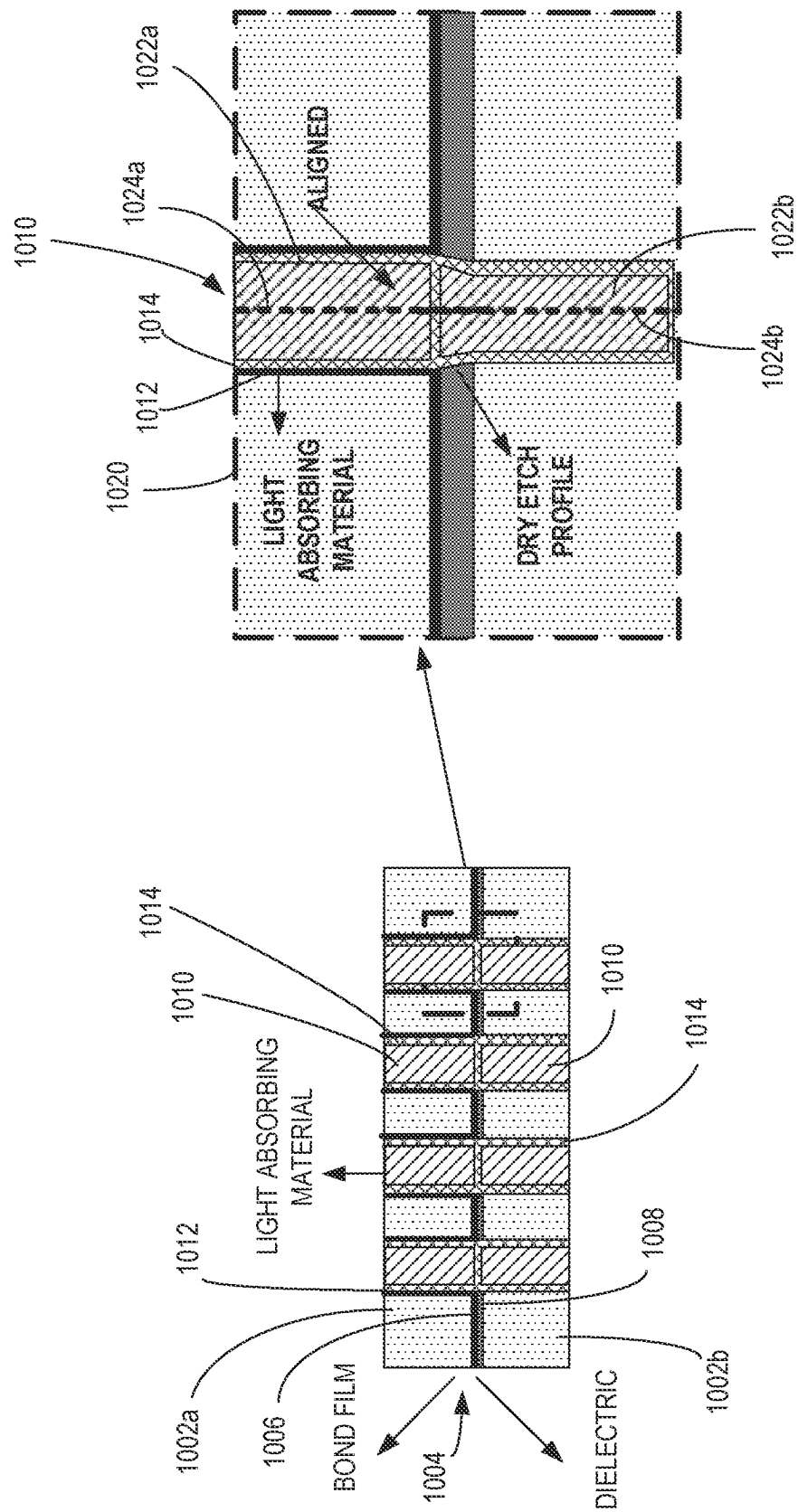


FIG. 9K

FIG. 9L



ଓଡ଼ିଶା ଗଣତନ୍ତ୍ର ପ୍ରତି

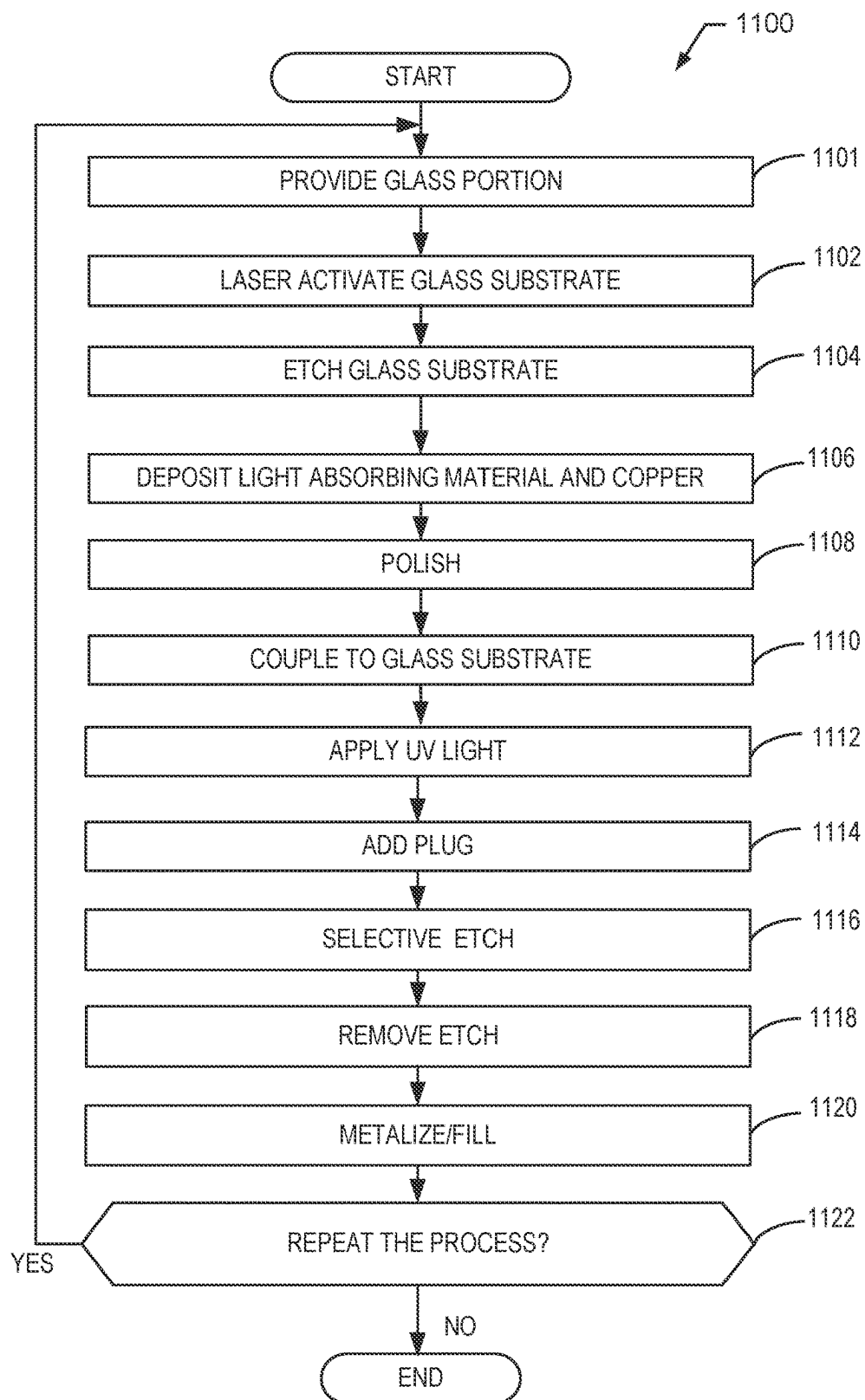


FIG. 11

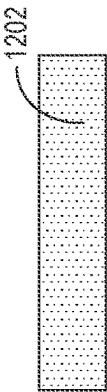


FIG. 12A

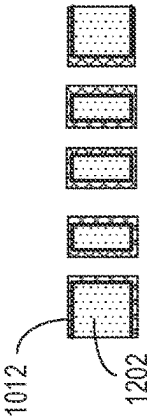


FIG. 12B

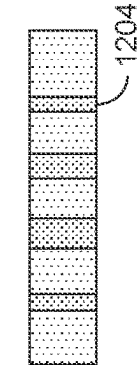


FIG. 12C

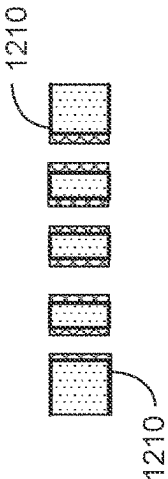


FIG. 12D

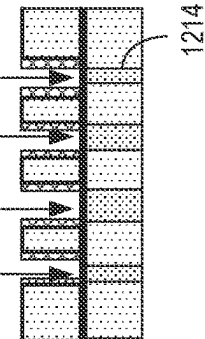


FIG. 12E

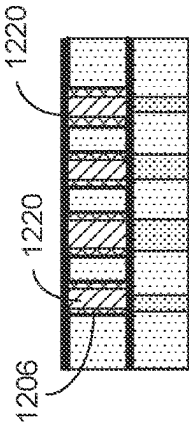


FIG. 12F

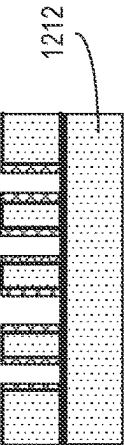


FIG. 12G

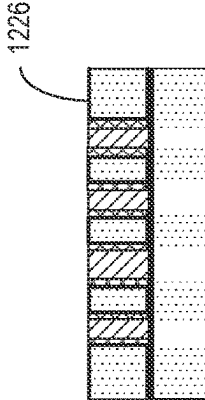


FIG. 12H

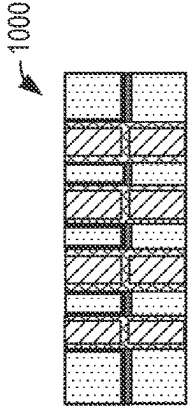


FIG. 12I

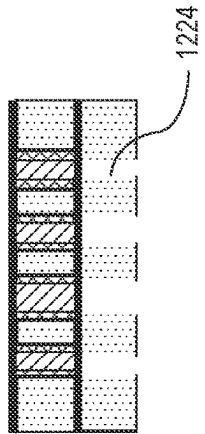


FIG. 12J

FIG. 12K

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## METHODS AND APPARATUS TO INCREASE GLASS CORE THICKNESS

### FIELD OF THE DISCLOSURE

This disclosure relates generally to glass cores in semiconductor devices and, more particularly, to methods and apparatus to increase glass core thickness.

### BACKGROUND

Glass cores can be implemented to enable relatively fine die-to-die connections in semiconductor devices. Generally, glass core implementations offer several advantages compared to implementations with conventional epoxy cores, including a higher plated through-hole (PTH) density, lower signal losses, and a lower total thickness variation.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of an example semiconductor device in accordance with teachings of this disclosure.

FIG. 2 is a flowchart representative of an example method to produce the example semiconductor device of FIG. 1.

FIGS. 3A-3E illustrate example stages in an example fabrication process to produce the example semiconductor device of FIG. 1.

FIG. 4 is a cross-sectional view of an example semiconductor device in accordance with teachings of this disclosure.

FIG. 5 is a flowchart representative of an example method to produce the example semiconductor device of FIG. 4.

FIGS. 6A-6H illustrate example stages in an example fabrication process to produce the example semiconductor device of FIG. 4.

FIG. 7 is a cross-sectional view of an example semiconductor device in accordance with teachings of this disclosure.

FIG. 8 is a flowchart representative of an example method to produce the example semiconductor device of FIG. 7.

FIGS. 9A-9L illustrate stages in an example fabrication process to produce the example semiconductor device of FIG. 7.

FIG. 10 is a cross-sectional view of an example semiconductor device in accordance with teachings of this disclosure.

FIG. 11 is a flowchart representative of an example method to produce the example semiconductor device of FIG. 10.

FIGS. 12A-12K illustrate stages in an example fabrication process to produce the example semiconductor device of FIG. 10.

The figures are not to scale. Instead, the thickness of the layers or regions may be enlarged in the drawings. Although the figures show layers and regions with clean lines and boundaries, some or all of these lines and/or boundaries may be idealized. In reality, the boundaries and/or lines may be unobservable, blended, and/or irregular. In general, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts. As used herein, unless otherwise stated, the term “above” describes the relationship of two parts relative to Earth. A first part is above a second part, if the second part has at least one part between Earth and the first part. Likewise, as used herein, a first part is “below” a second part when the first part is closer to the Earth than the second part.

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As noted above, a first part can be above or below a second part with one or more of: other parts therebetween, without other parts therebetween, with the first and second parts touching, or without the first and second parts being in direct contact with one another. Notwithstanding the foregoing, in the case of a semiconductor device, “above” is not with reference to Earth, but instead is with reference to a bulk region of a base semiconductor substrate (e.g., a semiconductor wafer) on which components of an integrated circuit are formed. Specifically, as used herein, a first component of an integrated circuit is “above” a second component when the first component is farther away from the bulk region of the semiconductor substrate than the second component. As used in this patent, stating that any part (e.g., a layer, film, area, region, or plate) is in any way on (e.g., positioned on, located on, disposed on, or formed on, etc.) another part, indicates that the referenced part is either in contact with the other part, or that the referenced part is above the other part with one or more intermediate part(s) located therebetween. As used herein, connection references (e.g., attached, coupled, connected, and joined) may include intermediate members between the elements referenced by the connection reference and/or relative movement between those elements unless otherwise indicated. As such, connection references do not necessarily infer that two elements are directly connected and/or in fixed relation to each other. As used herein, stating that any part is in “contact” with another part is defined to mean that there is no intermediate part between the two parts.

Unless specifically stated otherwise, descriptors such as “first,” “second,” “third,” etc., are used herein without imputing or otherwise indicating any meaning of priority, physical order, arrangement in a list, and/or ordering in any way, but are merely used as labels and/or arbitrary names to distinguish elements for ease of understanding the disclosed examples. In some examples, the descriptor “first” may be used to refer to an element in the detailed description, while the same element may be referred to in a claim with a different descriptor such as “second” or “third.” In such instances, it should be understood that such descriptors are used merely for identifying those elements distinctly that might, for example, otherwise share a same name. As used herein, “approximately” and “about” refer to dimensions that may not be exact due to manufacturing tolerances and/or other real world imperfections.

### DETAILED DESCRIPTION

Methods and apparatus to increase glass core thickness are disclosed. Glass cores can be implemented for relatively fine die-to-die connections for semiconductor devices. In particular, interconnects, such as vias, can be densely placed in a given area of a semiconductor device. A thicker glass core can enable improved power delivery and handling capabilities. However, for known implementations, glass cores with a relatively higher degree of thickness can have significant failure risks due to potential cracks, etc.

Examples disclosed herein enable semiconductor devices with glass cores that have a relatively high degree of thickness compared to known implementations. Further, examples disclosed herein can have increased strength, thereby reducing or eliminating requirements for special handling typically necessitated for known glass core implementations. Further, examples disclosed can also be highly resistant to cracking and/or damage, and can provide improved power performance, as well as increased plated through-hole (PTH) density.

Examples disclosed herein utilize multiple glass layers and/or cores to define a damage-resistant glass core that is significantly thicker than known glass core implementations. In other words, examples disclosed herein enable stacking of multiple glass portions, cores and/or layers. For example, examples disclosed herein can enable thicknesses of greater than 500 micrometers ( $\mu\text{m}$ ) (e.g., greater than 2,000  $\mu\text{m}$ ). Examples disclosed herein utilize an interface layer to couple first and second glass portions (e.g., first and second glass layers, first and second glass substrates, etc.) together. The interface layer can include at least one of a dielectric (e.g., a dielectric layer) or a bonding film/layer. An interconnect, such as a through-glass via (TGV) extends through first and second glass portions. In some examples, the interconnect includes a first portion that extends through at least a portion of the first glass layer and a second portion that extends through at least a portion of the second glass layer. In some examples, the first and second portions of the interconnect are substantially aligned (e.g., aligned within a distance that is approximately 20% of their nominal outer diameters or 20% of a smaller diameter between the first and second portions).

As used herein, stating that two components, assemblies and/or features are “substantially aligned” means that the two components, assemblies and/or feature are within a distance that is smaller or equal to 20% of an exterior dimension (e.g., a diameter) of a smaller component of the two components. As used herein, the term “glass core” refers to multiple glass layers, portions and/or substrates that are coupled together.

FIG. 1 is a cross-sectional view of an example semiconductor device 100 in accordance with teachings of this disclosure. The semiconductor device 100 of the illustrated example includes a glass core 101 with a first glass portion (e.g., a glass substrate, a glass layer, a glass substrate layer, etc.) 102a and a second glass portion 102b, such that the first glass portion 102a is separated from the second glass portion 102b by an interface layer 104. The example interface layer 104 is positioned between the first and second glass portions 102a, 102b, and can include at least one of a bond film 106 and a dielectric (e.g., a dielectric layer) 108. Further, interconnects 110, which are implemented as TGVs in this example, extend between and/or through at least respective portions of the first glass portion 102a and the second glass portion 102b. In the illustrated example, some of the interconnects 110 are adjacent and/or surrounded by a respective plug 112, which are comprised of materials with a relatively high magnetic permeability (e.g., the materials become magnetically charged under an electric bias) and/or polarizability to define a coaxial connector, such as a metal-inductor loop (MIL) connector, for example.

In the illustrated view of FIG. 1, a detail 120 shows a portion of the example semiconductor device 100. As can be seen in the detail 120, the interconnect 110 includes a first portion 122a with a corresponding first center axis 124a. The first portion 122a extends through the first glass portion 102a. Similarly, a second portion 122b with a corresponding second center axis 124b extends through the second glass portion 102b. In this example, the first center axis 124a and the second center axis 124b are offset based on a process by which the example semiconductor device 100 is produced, as will be discussed in greater detail below in connection with FIGS. 2 and 3.

To enable the glass core 101 to have an increased thickness compared to known implementations, the first glass portion 102a is coupled to the second glass portion 102b with the interface layer 104. In particular, the example

interface layer 104 includes at least one of the bond film 106 or the dielectric 108 to couple and/or hold the first glass portion 102a and the second glass portion 102b together. As a result, the glass core 101 can include multiple stacked glass portions to define a thickness that is significantly increased from known implementations. In other words, multiple glass portions can be stacked almost indefinitely, thereby removing thickness/height limitations seen in known glass core implementations. Further, by coupling and/or stacking the first glass portion 102a to the second glass portion 102b, an increased strength of the example glass core 101 can result in higher production yields while allowing increased power delivery and higher PTH density. In this example, the properties of the first glass portion 102a and the second glass portion 102b are generally identical. However, in other examples, the first glass portion 102a and the second glass portion 102b may have different properties (e.g., translucency, density, opacity, etc.).

As can be seen in the illustrated example of FIG. 1, a dry etch profile 126 is shown. The dry etch profile 126 defines a position of the center axis 124a. In other words, the first portion 122a of the interconnect 110 can be offset relative to the second portion 122b of the interconnect 110 based on the etching of the interface layer 104.

In some examples, at least one of the dielectric 108 and/or the bond film 106 is compressed between the first glass portion 102a and the second glass portion 102b to strengthen the adhesion therebetween. In some other examples, none of the plugs 112 are implemented. In some examples, the first glass portion 102a and the second glass portion 102b have similar or identical thicknesses. In other examples, the first glass portion 102a and the second glass portion 102b have different thicknesses.

FIG. 2 is a flowchart representative of an example method 200 to produce the example semiconductor device 100 of FIG. 1.

At block 202, interconnects, interconnect portions and/or vias are defined. In this particular example, the plugs 112 are provided, drilled and, subsequently, apertures of a glass substrate 301 (of FIG. 3), as well as apertures of the plugs 112, are metallized to define TGVs, thereby defining the second glass portion 102b.

At block 204, in some examples, the bond film 106 is laminated, deposited and/or coupled onto the glass substrate 301. Additionally or alternatively, the dielectric 108 is laminated, deposited and/or coupled to the glass substrate 301.

At block 206, in the illustrated example of FIG. 2, a glass substrate 303 of FIG. 3 (that will later define the first glass portion 102a) is attached and/or coupled to the glass substrate 301. In this example, the glass substrate 303 is patterned (e.g., pre-patterns) and/or etched prior to being coupled to the glass substrate 301. In some examples, the interface layer 104 is compressed between the glass substrate 301 and the glass substrate 303.

At block 208, in this example, at least a portion of the interface layer 104 is etched based on patterns of the substrate 303 (e.g., an entire thickness of the interface layer 104 is etched at openings of the patterns).

At block 210, interconnects, interconnect portions and/or vias are defined in the glass substrate 303, thereby defining the first glass portion 102a. In this example, the plugs 112 are provided (e.g., placed) and drilling thereof is performed prior to metallization.

At block 212, it is determined whether to repeat the process. If the process is to be repeated (block 212), control of the process returns to block 204. Otherwise, the process

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ends. The determination may be based on whether additional glass portions, cores and/or layers are to be added to the semiconductor structure **100**. The additional glass portions, cores and/or layers can be patterned or un-patterned.

FIGS. 3A-3E illustrate example stages in an example fabrication process to produce the example semiconductor device **100** of FIG. 1. Turning to FIG. 3A, the aforementioned glass substrate **301** is shown with the interconnects **110** and the plugs **112** defined therein. In this example, the interconnects **110** and the plugs **112** are defined by placing the plugs **112** that are insulative/non-conductive in this example, drilling the plugs **112**, and metallizing portions of glass substrate **301** to define the second glass portion **102b**.

FIG. 3B depicts the interface layer **104** placed onto the second glass portion **102b**. In this example, the interface layer **104** is laminated onto the second glass portion **102b**.

Turning to the FIG. 3C, the glass substrate **303** is shown coupled to the second glass portion **102b**. In this example, the glass substrate **303** is patterned (e.g., pre-patterned) prior to being coupled to the second glass portion **102b**. Patterns of the example glass substrate **303** correspond to apertures **305** shown in FIG. 3C. In some examples, the placement of the glass substrate **303** is based on aligning the apertures **305** to features and/or datums of the second glass portion **102b**. In some examples, grooves and/or protruding features **304** may be incorporated into the glass substrate **301** and/or the glass substrate **303** to substantially align the patterns of the glass substrate **303** and/or the glass substrate relative to the glass substrate **301** (e.g., align the glass substrate **303** to a substantially aligned position therebetween).

FIG. 3D depicts the example interface layer **104** being etched to expose surfaces **306** above the second glass portion **102b** (in the view of FIG. 3D).

FIG. 3E depicts the glass substrate **303** being provided with the plug **112** that has a relatively high magnetic permeability and/or polarizability. In turn, the substrate **303** is drilled and metallized to define the first glass portion **102a** that is coupled to the second glass portion **102b** via the interface layer **104**. As a result, the semiconductor device **100** shown in FIG. 1 is produced.

FIG. 4 is a cross-sectional view of an example semiconductor device **400** in accordance with teachings of this disclosure. The example semiconductor device **400** is similar to the example semiconductor device **100** shown in FIG. 1 but, instead, includes interconnect portions that are aligned between a first glass portion **402a** and a second glass portion **402b** (as opposed to being offset). Further, an example interface layer **404**, which is positioned between the first and second glass portions **402a**, **402b**, includes at least one of a bond film **406** or a dielectric **408**. In the illustrated view of FIG. 4, interconnects **410** are implemented as TGVs. In contrast to the example semiconductor device **100** of FIG. 1, light absorption material **412** is implemented.

In the illustrated view of FIG. 4, a detail **420** shows a portion of the example semiconductor device **400**. As can be seen in the detail **420**, the example interconnect **410** includes a first portion **422a** with a corresponding first center axis **424a** and, similarly, a second portion **422b** with a corresponding second center axis **424b**. In this example, the first center axis **424a** and the second center axis **424b** are substantially aligned based on a process by which the example semiconductor device **400** is produced, as will be discussed in greater detail below in connection with FIGS. 5 and 6.

FIG. 5 is a flowchart representative of an example method **500** to produce the example semiconductor device **400** of FIG. 4.

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At block **501**, a first glass substrate **602** (shown in FIG. 6A) is provided (e.g., as a raw glass substrate). In this example, the first glass substrate **602** generally exhibits a layer-like structure and/or shape.

At block **502**, the first glass substrate **602** is laser activated, for example. However, any appropriate surface activation methodology can, instead, be implemented.

At block **504**, the first glass substrate **602** is etched. The first glass substrate **602** can be photo-etched, chemical-etched or any other appropriate type of etching, machining, cutting, etc. can be performed.

At block **506**, in the illustrated example, the light absorption material **412** is deposited onto the first glass substrate **602**.

At block **508**, the first glass substrate **602** is bonded and/or coupled to a second glass substrate **610** (shown in FIG. 6E) to define a glass core, for example.

At block **510**, ultraviolet (UV) light is applied to the glass core and/or the first glass substrate **602**.

At block **512**, the glass core is selectively etched.

At block **514**, the glass core is metallized/filled. In this example, TGVs are defined in the glass core to define the example semiconductor device **400**.

At block **516**, it is determined whether to repeat the process. If the process is to be repeated (block **516**), control of the process returns to block **501**. Otherwise, the process ends. The determination may be based on whether additional glass portions, cores and/or layers are to be added to the example semiconductor device **400**.

FIGS. 6A-6H illustrate example stages in an example fabrication process to produce the example semiconductor device **400** of FIG. 4. Turning to FIG. 6A, the aforementioned glass substrate **602** is shown.

FIG. 6B depicts the example glass substrate **602** being laser activated to define activated regions **604**. In some examples, the activated regions **604** facilitate subsequent etching.

Turning to FIG. 6C, the glass substrate **602** is etched (e.g., selectively etched), thereby defining apertures **606** extending through an entire depth of the glass substrate **602**, for example.

FIG. 6D depicts the example light absorption material **412** being applied to the glass substrate **602**.

FIG. 6E depicts the glass substrate **602** of the illustrated example being coupled to the aforementioned glass substrate **610**, which is not pre-patterned in this example. The example glass substrate **602** can be bonded to the glass substrate **610** via the bond film **406**, an etch stop and/or a protective layer. In some examples, the etch stop is generally transparent to UV light by utilizing materials such as polydimethylsiloxane (PDMS) or fluorinated ethylene propylene (FEP) type polymers, for example.

In the illustrated example of FIG. 6F, UV light is applied and/or directed to the glass substrate **602** and/or toward the aforementioned apertures **606**. In some examples, an excimer laser (e.g., a highly directional flood type exposure) is utilized to provide the UV light to expose areas corresponding to the apertures **606**. Additionally or alternatively, a UV exposure process with a photo-definable glass is implemented, such as lithium silicate based glasses and the like, for example. However, any appropriate materials and/or UV exposure process can be implemented instead so long as the glass implemented is compatible with UV exposure methods and/or an amount of applied energy necessitated by pattern definition.

Turning to FIG. 6G, an example etching process causes apertures **612** to extend through the glass substrate **610**. In



the illustrated example, portions of the glass substrate **610** that are etched are based on the UV exposure process shown in FIG. 6F and, thus, the apertures **612** of the glass substrate **610** are aligned with the apertures **606**.

FIG. 6H depicts example metallization and/or fill processes that define the example semiconductor device **400**.

FIG. 7 is a cross-sectional view of an example semiconductor device **700** in accordance with teachings of this disclosure. The example semiconductor device **700** is similar to the example semiconductor device **400** of FIG. 4 in that it is self-aligning between glass layers. The semiconductor device **700** of the illustrated example includes a first glass portion **702a** and a second glass portion **702b** with an interface layer **704** positioned therebetween. In turn, the example interface layer **704** includes at least one of a bond film **706** or a dielectric **708**. In the illustrated view of FIG. 7, interconnects **710**, as well as a light absorption material **712**, are depicted.

In this example, a detail **720** shows a portion of the example semiconductor device **700**. As can be seen in the detail **720**, the interconnect **710** includes a first portion **722a** with a corresponding first center axis **724a** and, similarly, a second portion **722b** with a corresponding second center axis **724b**. In this example, the first center axis **724a** and the second center axis **724b** are substantially aligned, as will be discussed in greater detail below in connection with FIGS. 8 and 9.

FIG. 8 is a flowchart representative of an example method **800** to produce the example semiconductor device **700** of FIG. 7.

At block **801**, a first glass substrate **902** (shown in FIG. 9A) is provided (e.g., as a raw glass substrate). In this example, the first glass substrate **902** is positioned for subsequent coupling to at least one other additional glass substrate.

At block **802**, the first glass substrate **902** of the illustrated example is laser activated, for example. However, any other appropriate surface activation methodology can instead be implemented.

At block **804**, in this example, the first glass substrate **902** is etched. The example first glass substrate **902** can be photo-etched, chemical-etched or any other appropriate type of etching process can be employed.

At block **806**, in the illustrated example, the light absorption material **712** is deposited onto the first glass substrate **902**.

At block **810**, the example first glass substrate **902** is bonded and/or coupled to a second glass substrate **908** (shown in FIG. 9E) to define a glass core.

At block **812**, UV light is applied. In this example, the UV light is directed toward the aforementioned apertures of the first glass substrate **902** and/or the glass core.

At block **814**, at least one plug is added and/or provided. In this example, at least one plug with a relatively high magnetic permeability is provided to the glass core.

At block **816**, in some examples, a protective film is deposited over a surface defined by the at least one plug.

At block **818**, the glass core is selectively etched.

At block **820**, the aforementioned protective film is removed. Additionally or alternatively, the protective film is etched and/or dissolved in a solution applied thereto.

At block **822**, the glass core is metallized/filled. As a result, TGVs are defined in the glass core, for example.

At block **824**, the glass core is patterned. For example, traces and/or interconnects are patterned onto surfaces of the glass core.

At block **826**, it is determined whether to repeat the process. If the process is to be repeated (block **826**), control of the process returns to block **801**. Otherwise, the process ends. The determination may be based on whether additional glass portions, cores and/or layers are to be added to the example semiconductor device **700**.

FIGS. 9A-9L illustrate example stages in an example fabrication process to produce the example semiconductor device **700** of FIG. 7. Turning to FIG. 9A, the aforementioned example first glass portion **902**, which is a raw glass substrate in this example, is provided.

In the illustrated example of FIG. 9B, a laser activation process is performed to define activated zones **904**.

Turning to FIG. 9C, the example glass substrate **902** is etched to define apertures **906**.

FIG. 9D depicts the example light absorption material **712** being applied to the glass substrate **902**. The light absorption material **712** can be electrically non-conductive, for example.

FIG. 9E depicts the glass substrate **902** of the illustrated example being coupled to the glass substrate **908**, which is not pre-patterned in this example. The glass substrate **902** and the glass substrate **908** can be coupled via at least one of a bond film, a protective film, an etch stop and/or a dielectric. In some examples, a protective film or etch stop material can include materials generally transparent to UV light, such as PDMS or FEP type polymers, for example.

In the illustrated example of FIG. 9F, UV light is applied to the aforementioned apertures **906** to define activated regions **910**. In this example, the application of the UV light through and/or toward the apertures **906** enables alignment of interconnects and/or interconnect portions between different glass layers of the example semiconductor device **700**.

FIG. 9G depicts example plugs (e.g., magnetic plugs) **912** being placed into ones of the apertures **906**.

FIG. 9H depicts metallization and/or fill processes that include drilling to define a central aperture for each interconnect. In particular, a mechanical drill or a laser drill can be utilized. In examples where a laser drill is utilized, a "soft" etch may be advantageous after the example stage shown in FIG. 9J. The "soft" etch can be applied for mechanical or laser drilling processes. In some examples, a laser stop material is implemented for improved control of drill processes.

In the illustrated example of FIG. 9I, a protective film **916** is placed onto the glass core while a selective etching process is performed on a side opposite to that of the protective film **916**.

Turning to FIG. 9J, the protective film **916** of FIG. 9I is at least partially removed and etching is performed to expose surfaces **918**, for example.

FIG. 9K depicts plugging with an insulative plug, drilling the plug, seed deposition (e.g., copper seed deposition), plating (e.g., copper plating) and grinding to define coaxial interconnects **920**.

In the illustrated example of FIG. 9L, patterning of traces **922** is performed onto the glass core. Accordingly, the traces **922** can be electrically coupled to other components or interconnects.

FIG. 10 is a cross-sectional view of an example semiconductor device **1000** in accordance with teachings of this disclosure. The semiconductor device **1000** of the illustrated example includes a first glass portion **1002a** and a second glass portion **1002b**. Further, an example interface layer **1004**, which is positioned between the first glass portion **1002a** and the second glass portion **1002b**, includes at least one of a bond film **1006** or a dielectric **1008**. Example

interconnects **1010** and a light absorption material **1012** are also shown. Further, the example semiconductor device **1000** also includes a copper layer **1014**.

In the illustrated view of FIG. **10**, a detail **1020** shows a portion of the example semiconductor device **1000**. As can be seen in the detail **1020**, the interconnect **1010** includes a first portion **1022a** with a corresponding first center axis **1024a** and, similarly, a second portion **1022b** with a corresponding second center axis **1024b**. In this example, the first center axis **1024a** and the second center axis **1024b** are substantially aligned.

FIG. **11** is a flowchart representative of an example method **1100** to produce the example semiconductor device of FIG. **10**.

At block **1101**, a first glass substrate **1202** (shown in FIG. **12A**) is provided.

At block **1102**, portions and/or regions of the example first glass substrate **1202** are laser activated for subsequent laser etching. However, any appropriate surface activation methodology can instead be implemented.

At block **1104**, in this example, the first glass substrate **1202** is etched. The first glass substrate **1202** can be photo-etched, chemical-etched or any other appropriate type of etching may be utilized.

At block **1106**, in the illustrated example, the light absorption material **1012** and the copper layer **1014** are deposited and/or provided onto the first glass substrate **1202** with the copper layer **1014** surrounding the light absorption material **1012**.

At block **1108**, a polishing process is performed on the first glass substrate **1202** (e.g., on a first side of the first glass substrate **1202** and on a second side of the first glass substrate **1202** that is opposite the first side). In this example, portions of the copper layer **1014** are polished (e.g., removed).

At block **1110**, the first glass substrate **1202** is bonded and/or coupled to a second glass portion **1212** (shown in FIG. **12F**) to define a glass core. In some examples, the first glass substrate **1202** is bonded to the second glass substrate **1212** with a bond film, an etch stop material and/or a protective film.

At block **1112**, UV light is applied. In this example, the UV light is directed toward the first glass substrate **1202** and/or the glass core.

At block **1114**, at least one plug is provided and/or added to the glass core. In some examples, a protective film is deposited over a surface defined by the at least one plug.

At block **1116**, the glass core is selectively etched.

At block **1118**, the aforementioned protective film and/or an etch is removed.

At block **1120**, the glass core is metallized/filled. In this example, TGVs are defined in the glass core to define the example semiconductor device **1000**.

At block **1122**, it is determined whether to repeat the process. If the process is to be repeated (block **1122**), control of the process returns to block **1101**. Otherwise, the process ends. The determination may be based on whether additional glass portions, cores and/or layers are to be added to the example semiconductor device **1000**.

FIGS. **12A-12K** illustrate stages in an example fabrication process to produce the example semiconductor device **1000** of FIG. **10**. Turning to FIG. **12A**, the aforementioned first glass substrate **1202**, which is a raw glass substrate in this example, is provided.

In the illustrated example of FIG. **12B**, a laser activation process is performed to define activated zones **1204**.

Turning to FIG. **12C**, the glass substrate **1202** is etched to define apertures **1206**.

FIG. **12D** depicts the example light absorption material **1012** and the copper layer **1014** being applied and/or deposited to the glass substrate **1202**. In this example, the copper layer **1014** is deposited to surround the light absorption material **1012**. Further, the copper layer **1014** extends along a length of corresponding TGVs in this example.

FIG. **12E** depicts a surface **1208** and a surface **1210** being polished (e.g., copper polished). In some examples, copper from the copper deposition is at least partially removed (e.g., fully removed) from the surface **1208** and the surface **1210**.

FIG. **12F** depicts the glass substrate **1202** of the illustrated example being coupled to the aforementioned glass substrate **1212**, which is not patterned in this example. The glass substrate **1202** and the glass substrate **1212** can be coupled together via at least one of a bond film, a protective film, an etch stop and/or a dielectric. In some examples, protective film or etch stop material that is generally transparent to UV light can be implemented, such as materials including PDMS or FEP type polymers, for example.

In the illustrated example of FIG. **12G**, UV light is applied to the aforementioned apertures **1206** (e.g., from a UV light source, a laser, etc.) to define activated regions **1214** that are utilized in subsequent etching to align apertures between the glass substrate **1202** and the glass substrate **1212**.

Turning to FIG. **12H**, example plugs (e.g., magnetic plugs) **1216** are depicted being placed into ones of the apertures **1206**. Additionally or alternatively, a protective film **1220** is applied.

FIG. **12I** depicts a selective etch process defining apertures **1224**.

FIG. **12J** depicts removal of the example protective film **1220** shown in FIGS. **12H** and **12I**. As a result, an exposed surface **1226** is formed.

FIG. **12K** depicts metallization and/or fill processes that include drilling to define the example semiconductor device **1000**. In particular, a mechanical drill or a laser drill can be utilized.

Any of the aspects, features, components and/or process methodology described above in connection with the examples of FIGS. **1-12K** can be combined with any other aspects, features, components and/or process methodology of other examples.

Further examples and combinations thereof include the following: Example 1 includes an apparatus comprising a first glass substrate, a second glass substrate, an interface layer between the first glass substrate and the second glass substrate, the interface layer coupling the first glass substrate to the second glass substrate, and an interconnect extending through at least a portion of the first glass substrate and at least a portion of the second glass substrate.

Example 2 includes the apparatus as defined in example 1, wherein the interface layer includes a dielectric layer.

Example 3 includes the apparatus as defined in example 1, wherein the interface layer includes a bonding film.

Example 4 includes the apparatus as defined in example 1, wherein the interconnect includes a first portion extending through the first glass substrate and a second portion extending through the second glass substrate, and wherein the first portion of the interconnect and the second portion of the interconnect are substantially aligned.

Example 5 includes the apparatus as defined in example 1, wherein the interconnect includes a through-glass via (TGV).

Example 6 includes the apparatus as defined in example 5, further including a plug surrounding the TGV.

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Example 7 includes the apparatus as defined in example 6, further including light absorption material surrounding at least a portion of the plug.

Example 8 includes the apparatus as defined in example 5, further including light absorption material surrounding at least a portion of the TGV.

Example 9 includes the apparatus as defined in example 1, further including light absorption material surrounding at least a portion of at least one of the first glass substrate or the second glass substrate.

Example 10 includes a glass core for use with a semiconductor device, the glass core comprising a first glass substrate layer, a second glass substrate layer, and an interface layer between the first glass substrate layer and the second glass substrate layer, the interface layer including at least one of a dielectric layer or a bonding film, the interface layer coupling the first glass substrate layer and the second glass substrate layer together.

Example 11 includes the glass core as defined in example 10, further including a through-glass via (TGV) extending through at least a portion of the glass core.

Example 12 includes the glass core as defined in example 11, wherein the TGV includes a first portion extending through the first glass substrate layer, and a second portion extending through the second glass substrate layer, wherein the first portion of the TGV and the second portion of the TGV are substantially aligned.

Example 13 includes the glass core as defined in example 11, wherein TGV is at least partially surrounded by light absorption material.

Example 14 includes the glass core as defined in example 13, wherein the light absorption material extends through the first glass substrate layer or the second glass substrate layer.

Example 15 includes the glass core as defined in example 13, further including a copper layer, the light absorption material between the copper layer and at least one of the first glass substrate layer or the second glass substrate layer.

Example 16 includes the glass core as defined in example 10, wherein the first glass substrate layer or the second glass substrate layer includes a protrusion to be received by a groove of another of the first glass substrate layer or the second glass substrate layer.

Example 17 includes a method comprising coupling a first glass substrate to a second glass substrate with an interface layer positioned therebetween, the interface layer including at least one of a bonding film or a dielectric layer, and defining an interconnect that extends through at least a portion of the first glass substrate and at least a portion of the second glass substrate.

Example 18 includes the method as defined in example 17, further including providing a plug to at least one of the first glass substrate or the second glass substrate, drilling the plug to define a central aperture thereof, and metalizing the central aperture to define the interconnect.

Example 19 includes the method as defined in example 17, wherein at least one of the first glass substrate or the second glass substrate is patterned with a pattern prior to being coupled to another of the first glass substrate or the second glass substrate.

Example 20 includes the method as defined in example 19, further including activating at least one of the first glass substrate or the second glass substrate to define an activated region thereof by directing UV light toward the pattern.

Example 21 includes the method as defined in example 20, further including etching the activated region to define an aperture that corresponds to the interconnect.

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Example 22 includes the method as defined in example 17, wherein the coupling of the first glass substrate to the second glass substrate includes compressing the interface layer between the first glass substrate and the second glass substrate.

Example 23 includes the method as defined in example 17, wherein the coupling of the first glass substrate to the second glass substrate includes aligning a protrusion of the first glass substrate or the second glass substrate to a groove of another of the first glass substrate or the second glass substrate.

From the foregoing, it will be appreciated that example systems, methods, apparatus, and articles of manufacture have been disclosed that enable semiconductor devices with glass structures and/or cores that are highly resistant to damage. Further, examples disclosed herein enable glass structures to be relatively thick compared to known implementations. In other words, examples disclosed herein enable stacking of glass portions (e.g., glass layers, glass cores, glass core layers, etc.).

Although certain example systems, methods, apparatus, and articles of manufacture have been disclosed herein, the scope of coverage of this patent is not limited thereto. On the contrary, this patent covers all systems, methods, apparatus, and articles of manufacture fairly falling within the scope of the claims of this patent.

The following claims are hereby incorporated into this Detailed Description by this reference, with each claim standing on its own as a separate embodiment of the present disclosure.

What is claimed is:

1. An apparatus comprising:

a first glass substrate;

a second glass substrate;

an interface layer between the first glass substrate and the second glass substrate, the interface layer coupling the first glass substrate to the second glass substrate; and an interconnect extending through at least a portion of the first glass substrate and at least a portion of the second glass substrate, wherein the interconnect includes a first portion extending through the first glass substrate and a second portion extending through the second glass substrate, and wherein the first portion of the interconnect and the second portion of the interconnect are offset along a lateral direction.

2. The apparatus as defined in claim 1, wherein the interface layer includes a dielectric layer.

3. The apparatus as defined in claim 1, wherein the interface layer includes a bonding film.

4. The apparatus as defined in claim 1, wherein the interconnect includes a through-glass via (TGV).

5. The apparatus as defined in claim 4, further including a plug surrounding the TGV.

6. The apparatus as defined in claim 5, further including light absorption material surrounding at least a portion of the plug.

7. The apparatus as defined in claim 4, further including light absorption material surrounding at least a portion of the TGV.

8. The apparatus as defined in claim 1, further including light absorption material surrounding at least a portion of at least one of the first glass substrate or the second glass substrate.

9. A glass core for use with a semiconductor device, the glass core comprising:

a first glass substrate layer;

a second glass substrate layer;

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an interface layer between the first glass substrate layer and the second glass substrate layer, the interface layer including at least one of a dielectric layer or a bonding film, the interface layer coupling the first glass substrate layer and the second glass substrate layer together; and

an interconnect extending through at least a portion of the first glass substrate layer and at least a portion of the second glass substrate layer, wherein the interconnect includes a first portion extending through the first glass substrate layer and a second portion extending through the second glass substrate layer, and wherein the first portion of the interconnect and the second portion of the interconnect are offset along a lateral direction.

10. The glass core as defined in claim 9, wherein the interconnect includes a through-glass via (TGV) extending through at least a portion of the glass core.

11. The glass core as defined in claim 10, wherein TGV is at least partially surrounded by light absorption material.

12. The glass core as defined in claim 11, wherein the light absorption material extends through the first glass substrate layer or the second glass substrate layer.

13. The glass core as defined in claim 11, further including a copper layer, the light absorption material between the copper layer and at least one of the first glass substrate layer or the second glass substrate layer.

14. The glass core as defined in claim 9, wherein the first glass substrate layer or the second glass substrate layer includes a protrusion to be received by a groove of another of the first glass substrate layer or the second glass substrate layer.

15. A method comprising:

coupling a first glass substrate to a second glass substrate with an interface layer positioned therebetween, the interface layer including at least one of a bonding film or a dielectric layer; and

defining an interconnect that extends through at least a portion of the first glass substrate and at least a portion of the second glass substrate, wherein the interconnect

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includes a first portion extending through the first glass substrate and a second portion extending through the second glass substrate, and wherein the first portion of the interconnect and the second portion of the interconnect are offset along a lateral direction.

16. The method as defined in claim 15, further including: providing a plug to at least one of the first glass substrate or the second glass substrate;

drilling the plug to define a central aperture thereof; and metalizing the central aperture to define the interconnect.

17. The method as defined in claim 15, wherein at least one of the first glass substrate or the second glass substrate is patterned with a pattern prior to being coupled to another of the first glass substrate or the second glass substrate.

18. The method as defined in claim 17, further including activating at least one of the first glass substrate or the second glass substrate to define an activated region thereof by directing UV light toward the pattern.

19. The method as defined in claim 18, further including etching the activated region to define an aperture that corresponds to the interconnect.

20. The method as defined in claim 15, wherein the coupling of the first glass substrate to the second glass substrate includes compressing the interface layer between the first glass substrate and the second glass substrate.

21. The method as defined in claim 15, wherein the coupling of the first glass substrate to the second glass substrate includes aligning a protrusion of the first glass substrate or the second glass substrate to a groove of another of the first glass substrate or the second glass substrate.

22. The apparatus as defined in claim 1, wherein the first portion of the interconnect and the second portion of the interconnect partially intersect along the lateral direction.

23. The apparatus as defined in claim 22, wherein a region of the interface layer between the first portion of the interconnect and the second portion of the interconnect includes an angled edge.

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