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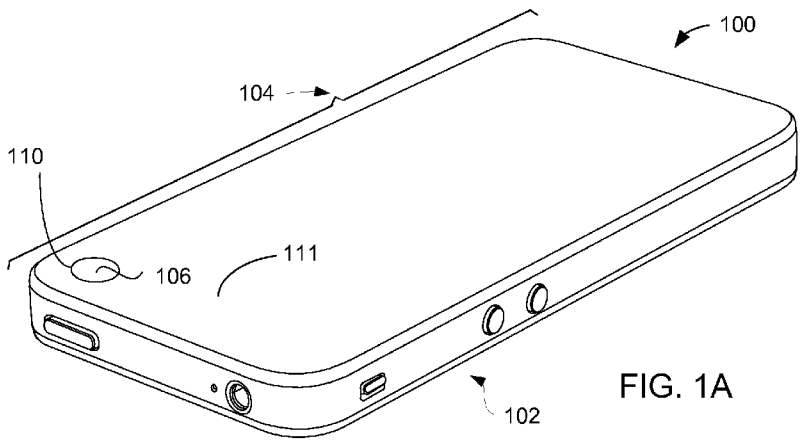


FIG. 1A

(57) Abstract: Apparatus, systems and methods for camera integration with cover glass and for processing cover glass to provide a camera window for an electronic device are disclosed. A camera window can be integrated into the cover glass. The apparatus, systems and methods are especially suitable for cover glasses, or displays (e.g., LCD displays), assembled in small form factor electronic devices such as handheld electronic devices (e.g., mobile phones, media players, personal digital assistants, remote controls, etc.). The apparatus, systems and methods can also be used for cover glasses or displays for other relatively larger form factor electronic devices (e.g., portable computers, tablet computers, displays, monitors, televisions, etc.).

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INTEGRATED CAMERA WINDOW

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to processing glass. More particularly, the present invention relates to processing cover glass used in portable electronic devices.

[0002] Conventionally, small form factor devices, such as handheld electronic devices, have a display arrangement that includes various layers. The various layers include at least a display technology layer, and may additionally include a sensing arrangement and/or a cover window disposed over the display technology layer. By way of example, the display technology layer may include or pertain to a Liquid Crystal Display (LCD) that includes a Liquid Crystal Module (LCM). The LCM generally includes an upper glass sheet and a lower glass sheet that sandwich a liquid crystal layer therebetween. The sensing arrangement may be a touch sensing arrangement such as those used to create a touch screen. For example, a capacitive sensing touch screen can include substantially transparent sensing points or nodes dispersed about a sheet of glass (or plastic). In addition, the cover window, which is typically designed as the outer protective barrier, may be glass or plastic. However, glass tends to provide a better protective barrier given its strength and scratch resistance.

[0003] Further, rapid improvements in size and cost of digital camera technology have lead to integration of one or more digital cameras into various portable electronic devices. While such integration provides convenience in having camera functionality available, often quality of images or video captured by such integrated cameras suffers. Moreover, although images or video of dark scenes could benefit from a flash or other illumination, for various reasons including integration difficulties, flash or other illumination are often omitted from portable electronic devices.

[0004] Thus, in electronic devices there is a continuing need for improved approaches for camera integration with glass cover arrangements.

SUMMARY

[0005] Apparatus, systems and methods for camera integration with cover glass and for processing cover glass to provide a camera window for an electronic device are disclosed. A camera window can be integrated into the cover glass. The apparatus, systems and methods are especially suitable for cover glasses, or displays (e.g., LCD displays), assembled in small form factor electronic devices such as handheld electronic devices (e.g., mobile phones, media players, personal digital assistants, remote controls, etc.). The apparatus, systems and methods can also be used for cover glasses or displays for other relatively larger form factor electronic devices (e.g., portable computers, tablet computers, displays, monitors, televisions, etc.).

[0006] The invention can be implemented in numerous ways, including as a method, system, device or apparatus. Several embodiments of the invention are discussed below.

[0007] As a consumer electronic product, one embodiment can include at least a housing and electrical components disposed at least partially internal to the housing, wherein the electrical components including at least a camera. A cover glass can be coupled to the housing. The cover glass can have a substantially smooth exterior surface comprising a transparent region substantially encircled by an optical barrier perimeter. The camera can being arranged adjacent to the transparent region and within the optical barrier perimeter so that the transparent region of the cover glass is substantially transparent to the camera. The optical barrier perimeter can be interposed within the cover glass between the camera and an adjacent region of the cover glass for reducing glare at the camera via the cover glass.

[0008] As a consumer electronic product, another embodiment can include at least a housing and electrical components disposed at least partially internal to the housing, wherein the electrical components include at least a camera. A cover glass can be coupled to the housing. The cover glass can comprise a chemically strengthened glass camera window and an optical barrier. The camera can be arranged adjacent to the chemically strengthened glass camera window. The optical barrier can be interposed within the cover glass between the camera and an adjacent region of the cover glass for reducing glare at the camera via the cover glass.

[0009] As consumer electronic product, another embodiment can include at least a housing and electrical components disposed at least partially internal to the housing, wherein the electrical components include at least a camera. A cover glass can be coupled to the housing. The cover glass can comprise a transparent camera window and an adjacent glass region that is dark or opaque. The camera can be arranged adjacent to the transparent camera window. The adjacent glass region can be sufficiently dark or opaque for substantially reducing glare at the camera via the cover glass.

[0010] As consumer electronic product, still another embodiment can include at least a housing and electrical components disposed at least partially internal to the housing, wherein the electrical components include at least a camera. A cover glass can be coupled to the housing. The cover glass can comprise a camera window and an optical barrier. The camera can be arranged adjacent to the camera window. The optical barrier can comprise an optical barrier perimeter substantially encircling the camera window, and the optical barrier perimeter can comprise a layer of material applied by physical vapor deposition.

[0011] As a method for assembling an electronic product, one embodiment includes at least the acts of: forming an aperture in a cover glass, disposing a transparent camera window in the cover glass, and lapping the transparent camera window and an adjacent glass region of the cover glass into a planar exterior surface

of the cover glass. Additionally, if desired, the method can further include the acts of disposing the transparent camera window adjacent to a camera, and subsequently attaching the cover glass to a housing for the electronic product.

[0012] Other aspects and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The invention will be readily understood by the following detailed description in conjunction with the accompanying drawings, wherein like reference numerals designate like structural elements, and in which:

[0014] FIGs. 1A-1E show views of one or more embodiments of a consumer electronic product.

[0015] FIGs. 2A-2B show cover glass processing according to one embodiment.

[0016] FIG. 3A shows a perspective view of processed cover glass after an aperture has been formed according to one embodiment.

[0017] FIG. 3B shows a detailed view of the peripheral region of processed cover glass illustrated in FIG. 3A according to one embodiment.

[0018] FIG. 4A shows a perspective view of a further processed cover glass after an optical barrier perimeter has been disposed in an aperture formed in the cover glass, according to one embodiment.

[0019] FIG. 4B shows a detailed view of the peripheral region of further the processed cover glass illustrated in FIG. 3A, according to one embodiment.

[0020] FIG. 5A shows a perspective view of a further processed cover glass after a transparent camera window has been disposed within optical barrier perimeter, and within an aperture extending through the cover glass, according to one embodiment.

[0021] FIG. 5B shows a detailed view of the peripheral region of further the processed cover glass illustrated in FIG. 5A, according to one embodiment.

[0022] FIGs. 6A-6D are simplified cross sectional views illustrating cover glass processing according to one embodiment.

[0023] FIGs. 7A-7C are simplified cross sectional views illustrating cover glass processing according to another embodiment.

[0024] FIGs. 8A-8C are simplified cross sectional views illustrating cover glass processing according to another embodiment.

[0025] FIG. 8D is a simplified view of another embodiment of a consumer electronic product.

[0026] FIG. 9 is a diagram showing a detailed partial cross sectional view of chemical strengthening of exposed surface portions of cover glass.

[0027] FIGs. 10A and 10B are simplified cross sectional views illustrating chemical strengthening of cover glass according to one embodiment.

[0028] FIG. 10C is a simplified view of another embodiment of a consumer electronic product.

[0029] FIG. 11 is a flow diagram showing an assembly process according to one embodiment.

[0030] It should be noted that FIGs. 1-11 are not necessarily drawn to scale. Instead, these figures are enlarged so that features are more readily visible.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0031] Apparatus, systems and methods for camera integration with cover glass and for processing cover glass to provide a camera window for an electronic device are disclosed. A camera window can be integrated into the cover glass. The apparatus, systems and methods are especially suitable for cover glasses, or

displays (e.g., LCD displays), assembled in small form factor electronic devices such as handheld electronic devices (e.g., mobile phones, media players, personal digital assistants, remote controls, etc.). The apparatus, systems and methods can also be used for cover glasses or displays for other relatively larger form factor electronic devices (e.g., portable computers, tablet computers, displays, monitors, televisions, etc.).

[0032] Since handheld electronic devices and portable electronic devices are mobile, they are potentially subjected to various different impact events and stresses that stationary devices are not subjected to. As such, the invention is well suited for implementation of displays for handheld electronic device or a portable electronic device that are designed to be thin.

[0033] In one embodiment, the size of the glass cover depends on the size of the associated electronic device. For example, with handheld electronic devices, the glass cover is often not more than five (5) inches diagonal. As another example, for portable electronic devices, such as smaller portable computers or tablet computers, the glass cover is often between four (4) to twelve (12) inches diagonal. As still another example, for portable electronic devices, such as full size portable computers, displays or monitors, the glass cover is often between ten (10) to twenty (20) inches diagonal or even larger.

[0034] However, it should be appreciated that with larger screen sizes, the thickness of the glass layers may need to be greater. The thickness of the glass layers may need to be increased to maintain planarity of the larger glass layers. While the displays can still remain relatively thin, the minimum thickness can increase with increasing screen size. For example, the minimum thickness of the glass cover can correspond to about 0.4 mm for small handheld electronic devices, about 0.6 mm for smaller portable computers or tablet computers, about 1.0 mm or more for full size portable computers, displays or monitors, again depending on the size of the screen. The thickness of the glass cover depends on the application and/or the size of electronic device. While the current trend is to accommodate

thinner and thinner devices, some examples for thicknesses of the glass cover can correspond to about 1 mm for small handheld electronic devices, about 2 mm for smaller portable computers or tablet computers, about 3 mm or more for full size portable computers, displays or monitors, again depending on the size of the screen.

[0035] Embodiments of the invention are discussed below with reference to FIGs. 1A-11. However, those skilled in the art will readily appreciate that the detailed description given herein with respect to these figures is for explanatory purposes as the invention extends beyond these limited embodiments.

[0036] FIGs. 1A-1E show views of one or more embodiments of a consumer electronic product. The electronic device 100 may, for example, be embodied as portable or handheld electronic device having a thin form factor (or low profile). The electronic device 100 can, for example, correspond to a media player, a media storage device, a Portable Digital Assistant (PDA), a tablet PCs, a computer, a cellular phone, a smart phone, a GPS unit, a remote control, and the like.

[0037] FIG. 1A shows a perspective view of electronic device 100 according to one embodiment. FIG. 1B shows a detailed view of the electronic device 100. The electronic device 100 may include a housing 102 that serves as part of an outer surface for the electronic device 100. Electrical components (not shown in FIGs. 1A and 1B) may be disposed within the housing 102. The electrical components may include, but are not limited to, a controller (or processor), memory, battery, display, camera, and illuminator such as a flash.

[0038] Additionally, glass may be used in covering front and/or back surfaces of the electronic device 100. The electronic device 100 may have at least one cover glass 104. The cover glass 104 may serve as an external surface, i.e., front or back surface, for the electronic device 100. The cover glass 104 may also resist scratching and therefore may provide a substantially scratch-resistance surface for the front or back surface of the housing 102 for the electronic device 100. The cover glass 104 may be coupled to the housing 102, for example, using an adhesive.

[0039] The cover glass 104 may be provided over a camera area. The cover glass 104 may comprise a transparent camera window 106 at or adjacent the camera area. In one example, the camera area may comprise at least a camera such as a digital camera for capturing images or video. At or adjacent the camera area, the transparent camera window 106 of the cover glass 104 may be substantially transparent to the camera, for capturing images or video through the cover glass 104. The camera area may extend within the housing 102 of the electronic device 100. A minority region of cover glass 104 adjacent to the camera may extend over the camera area. The minority region of cover glass 104 adjacent to the camera may comprise the transparent camera window 106. The cover glass 104, and more particularly the transparent camera window 106 can substantially overlap the camera, In one embodiment, a peripheral region of the cover glass 104 (more particularly the transparent camera window 106) may be adjacent to the camera and may extend over the camera area.

[0040] Similarly, the cover glass 104 may be provided over an illuminator area. In one example, the illuminator area may comprise at least an illuminator such as a light emitting diode (LED) or electronic flash tube for illuminating dark scenes. At the illuminator area, the cover glass 106 may be substantially transparent to the illuminator and arranged so that illumination may project outwardly from the cover glass 104. The illuminator area may be disposed within the housing 102 of the electronic device 100.

[0041] Additionally, in some embodiments the cover glass 104 may be provided over a display area. In some embodiments the cover glass 104 may be substantially transparent so that the display area can be viewed through the cover glass 104. In some embodiments, the display area may be disposed within the housing 102 of the electronic device 100. In some embodiments, the electronic device 100 may include a full view or substantially full view display area that consumes a majority of the front surface of the electronic device 100. The display area may be embodied in a variety of ways. In one example, the display area may comprise at least a display such as a flat panel display and more particularly an LCD display.

[0042] The display area may alternatively or additionally include a touch sensing device positioned over a display screen. For example, the display area may include one or more glass layers having capacitive sensing points distributed thereon. Each of these components may be separate layers or they may be integrated into one or more stacks. In one embodiment, the cover glass 104 may act as the outer most layer of the display area.

[0043] In some embodiments, the electronic device 100 may include a display region (e.g., the display area) that includes various layers. The various layers may include at least a display, and may additionally include a sensing arrangement disposed over the display. In some cases, the layers may be stacked and adjacent one another, and may even be laminated thereby forming a single unit. In other cases, at least some of the layers are spatially separated and not directly adjacent.

[0044] For example, the sensing arrangement may be disposed above the display such that there is a gap therebetween. By way of example, the display may include a Liquid Crystal Display (LCD) that includes a Liquid Crystal Module (LCM). The LCM generally includes at least an upper glass sheet and a lower glass sheet that at least partially sandwich a liquid crystal layer therebetween. The sensing arrangement may be a touch sensing arrangement such as those used to create a touch screen.

[0045] For example, a capacitive sensing touch screen may include substantially transparent sensing points or nodes dispersed about cover glass. The cover glass 104 may serve as an outer protective barrier for the display region. Typically, the cover glass 104 may be adjacent to the display region. However, the cover glass 104 may also be integrated with the display region, such as another layer (outer protective layer) for the display region.

[0046] The cover glass 104 may extend across the entire top surface of the housing 102. In such a case, the edges of the cover glass 104 may be aligned, or substantially aligned, with the sides of the housing 102.

[0047] Given that the thickness of the cover glass 104 may be rather thin (i.e., typically less than a few millimeters), the cover glass 104 if not carefully arranged can be susceptible to cracking or breaking if a significant force is imposed thereon, such as by a drop event where the electronic device 100 is accidentally dropped.

[0048] The glass material for the cover glass 104 can be selected from available glass that is stronger. For example, alumino silicate glass (e.g., DVTS from Corning) is one suitable choice for the glass material for the cover glass 104. Other examples of glass materials include, but are not limited to including, sodalime, borosilicate, and the like.

[0049] Transparent camera window 106 can be integrated into the cover glass 104. Transparent camera window 106 can likewise comprise glass. However, in some embodiments, transparent camera window can comprise plastic.

[0050] The edges of the cover glass pieces can be configured to correspond to a particular predetermined geometry. By machining the edges of the cover glass 104 to correspond to the particular predetermined geometry, the cover glass 104 can become stronger and thus less susceptible to damage.

[0051] Moreover, as will be discussed in greater detail subsequently herein, the cover glass 104 can be selectively chemically treated for further strengthening. One suitable chemical treatment is to selectively expose one or more surface portions of the cover glass in a chemical bath containing potassium (e.g., KNO3) for a period of time (e.g., several hours) at an elevated temperature. The selective chemical treatment can desirably result in higher compression stresses at the selectively exposed surface portions of the cover glass. The higher compression stresses may be the result ion exchange wherein K+ ions effectively replacing some Na+ ions at or near the selectively exposed surface portions of the cover glass 104.

[0052] In addition to such selective strengthening, reducing veiling glare may improve quality of images or video captured by the camera through transparent camera window 106. Optical features such as an optical barrier region 110 may be

disposed in the cover glass 104. The optical barrier region 110 may substantially reduce veiling glare, substantially inhibiting such diffuse stray light from reaching the image plane of the camera. Veiling glare might otherwise reduce contrast and resolution of images or video captured by the camera.

[0053] As shown in the figures (and as particularly shown in detailed view in FIG. 1B), the cover glass 104 can have a substantially smooth exterior surface comprising the transparent camera window 106 substantially encircled by the optical barrier perimeter 110. The exterior surface of the cover glass 104 can be lapped to be planar over the transparent camera window 106, the optical barrier perimeter 110 and the adjacent region 111 of the cover glass 104. As discussed in greater detail subsequently herein the optical barrier perimeter 110 may comprise metal.

[0054] The camera can be arranged adjacent to the transparent camera window 106 and within the optical barrier perimeter 110. The optical barrier perimeter 110 can be interposed within the cover glass 104 between the camera and an adjacent region 111 of the cover glass for reducing glare at the camera via the cover glass. More particularly, the optical barrier perimeter 110 can be interposed within the cover glass 104 between the transparent camera window 106 and an adjacent region 111 of the cover glass for reducing glare at the camera via the cover glass. As shown in the figures, the adjacent region 111 of the cover glass may comprise a majority region of the cover glass.

[0055] Similarly, the optical barrier perimeter 110 may be disposed within the cover glass 104 between the camera associated with transparent camera window 106 and the illuminator of the illuminator area. The optical barrier perimeter 110 may serve to substantially reduce light from the illuminator from coupling into the camera by way of the cover glass 104. More specifically, the optical barrier perimeter 110 may serve to substantially reduce veiling glare from the illuminator from coupling into the camera by way of the cover glass 104.

[0056] As shown in simplified cross sectional view in FIG. 1C, the electronic device 100 may include housing 102 (shown greatly simplified in FIG. 1C). Electrical

components 103 may be disposed within housing 102. As mentioned previously herein the electrical components may include, but are not limited to, a controller (or processor), memory, battery, display, camera, and illuminator such as a flash. The cover glass 104 may be coupled to the housing 102, for example, using adhesive 105. For ease of illustration, in cross sectional views relative thickness of cover glass 104 is shown as greatly exaggerated. Similarly, for ease of illustration, layer thickness of optical barrier perimeter 110 is show as greatly exaggerated. The optical barrier perimeter 110 is highlighted in the figures using hatching.

[0057] As shown in cross sectional view in FIG. 1C, the cover glass 104 can have a substantially smooth exterior surface comprising the transparent camera window 106 substantially encircled by optical barrier perimeter 110. The optical barrier perimeter 110 can be interposed within the cover glass 104 between the transparent camera window 106 and adjacent region 111 of the cover glass, for reducing glare at the camera via the cover glass. The adjacent region 111 of the cover glass may comprise the majority region of the cover glass 104.

[0058] In FIG. 1D, a portion of the electronic device 100 is shown further simplified in cross sectional view, so as to illustrate operation of optical barrier perimeter 110 in reducing veiling glare at camera 107 of the electronics of device 100. Veiling glare propagating in cover glass 104 is depicted in FIG. 1D by notional dashed line arrows. The optical barrier perimeter 110 may substantially reduce veiling glare, substantially inhibiting such diffuse stray light from reaching the image plane of the camera 107. Accordingly, the optically barrier perimeter 110 is shown in FIG. 1D as blocking the notional dashed line arrows, so as to depict such substantial reduction in veiling glare.

[0059] As shown in FIG. 1D the camera 107 can be arranged adjacent to the transparent camera window 106 and within the optical barrier perimeter 110. The optical barrier perimeter 110 can be interposed within the cover glass 104 between camera 107 and adjacent region 111 of the cover glass for reducing glare at the camera 107 via the cover glass 104. More particularly, the optical barrier perimeter

110 can be interposed within the cover glass 104 between the transparent camera window 106 and an adjacent region 111 of the cover glass for reducing glare at the camera 107 via the cover glass 104. As shown in FIG. 1D, the adjacent region 111 of the cover glass 104 may comprise the majority region of the cover glass 104.

[0060] In FIG. 1E, a portion of the electronic device 100 is shown simplified in cross sectional view, so as to illustrate operation of optical barrier perimeter 110 in reducing veiling glare at camera 107 from illuminator 109 of the electronics of device 100. Veiling glare propagating in cover glass 104 from illuminator 109 is depicted in FIG. 1E by notional dashed line arrows. The optical barrier perimeter 110 may substantially reduce veiling glare from illuminator 109, substantially inhibiting such diffuse stray light of the illuminator from reaching the image plane of the camera 107. Accordingly, the optical barrier perimeter 110 is shown in FIG. 1E as blocking the notional dashed line arrows, so as to depict such substantial reduction in veiling glare from illuminator 109.

[0061] As shown in FIG. 1E the camera 107 can be being arranged adjacent to the transparent camera window 106 and within the optical barrier perimeter 110. The optical barrier perimeter 110 can be interposed within the cover glass 104 between camera 107 and adjacent region 111 (or illuminator area of illuminator 109) for reducing glare at the camera 107 via the cover glass. More particularly, the optical barrier perimeter 110 can be interposed within the cover glass 104 between the transparent camera window 106 and an adjacent region 111 (or illuminator area of illuminator 109) for reducing glare at the camera via the cover glass 104.

[0062] FIGs. 2A-2B show cover glass processing according to one embodiment.

[0063] FIG. 2A shows a perspective view of cover glass 204, which may be singulated from sheet glass. FIG. 2B shows a detailed view of the peripheral region of cover glass 204.

[0064] FIG. 3A shows a perspective view of processed cover glass 304 after an aperture 312 has been formed in the cover glass 304. The aperture 312 may be

formed in various ways, for example by drilling. FIG. 3B shows a detailed view of the peripheral region of processed cover glass 304 with the aperture 312.

[0065] FIG. 4A shows a perspective view of a further processed cover glass 404 after an optical barrier perimeter 410 has been disposed in an aperture 412 formed in the cover glass 404. Optical barrier perimeter 410 can be metal, which may be selected to have a relatively high melting temperature, for example tungsten or molybdenum.

[0066] Layer thickness of the optical barrier perimeter 410 may be relatively thin, for example on the order of approximately hundreds of nanometers, or on the order of approximately a micron or microns. Layer thickness of the optical barrier perimeter 410 may be selected depending on the material (e.g. metal) and based on effectiveness for reducing veiling glare.

[0067] Various ways may be used for disposing the optical barrier perimeter 410 in the aperture 412 formed in the cover glass 404. For example, a process of Physical Vapor Deposition may be used. PVD allows for forming a thin layer of material (e.g., metal) in the aperture 412 which can serve as the optical barrier perimeter 410. As shown in FIG. 4A, the thin layer of material applied by a PVD process can be provided on the exposed sides within the aperture 412 of the cover glass.

[0068] FIG. 4B shows a detailed view of the peripheral region of further the processed cover glass 404. Optical barrier perimeter 410 is highlighted in FIGs. 4A and 4B using hatching.

[0069] FIG. 5A shows a perspective view of a further processed cover glass 504 after a transparent camera window 514 has been disposed within optical barrier perimeter 510, and within an aperture 506 extending through the cover glass 504. The transparent camera window 514 can be formed as a suitably sized glass plug or peg, and can be hot pressed in place at a suitable temperature, for example approximately six hundred (600) to approximately seven hundred (700) degrees Celsius (ºC).

[0070] As particularly shown in detailed view in FIG. 5B, the cover glass 504 can have a substantially smooth exterior surface comprising the transparent camera window 514 substantially encircled by the optical barrier perimeter 510. The exterior surface (e.g., front or rear surface) of the cover glass 504 can be lapped to be planar over the transparent camera window 514, the optical barrier perimeter 510 and the adjacent region 511 of the cover glass 504.

[0071] FIGs. 6A-6D are simplified cross sectional views illustrating cover glass processing according to one embodiment. FIG. 6A shows a cross sectional view of processed cover glass 604 after an aperture 612 has been formed in the cover glass 604. As mentioned previously, the aperture 612 may be formed in various ways, for example by drilling.

[0072] FIG. 6B shows a cross sectional view of the further processed cover glass 604 after an optical barrier perimeter 610 has been disposed in the aperture 612 formed in the cover glass 604. As mentioned previously, the optical barrier perimeter 410 can be metal. The metal may be selected to have a relatively high melting temperature, for example tungsten or molybdenum. The optical barrier perimeter 610 is highlighted in the figures using hatching.

[0073] FIG. 6C shows a cross sectional view of the further processed cover glass 604 after an elongated transparent camera window 606A has been disposed within optical barrier perimeter 610 and within the aperture extending through cover glass 604. The elongated transparent camera window 606A can be formed as an elongated glass plug or peg, and can be hot pressed in place at a suitable temperature, for example approximately six hundred (600) to approximately seven hundred (700) degrees Celsius (ºC). As will be discussed next, the elongated transparent camera window 606A can be lapped down, using a suitable abrasive slurry (e.g., comprising cesium oxide), so that the exterior surface of the cover glass can be planar.

[0074] For example, as shown in cross sectional view in FIG. 6D, the cover glass 604 can have a substantially smooth exterior surface comprising the transparent camera window 606B substantially encircled by the optical barrier perimeter 610.

The resulting exterior surface of the cover glass 604 can be planar over the transparent camera window 606B, the optical barrier perimeter 610 and the adjacent region 611 of the cover glass 604.

[0075] FIGs. 7A-7C are simplified cross sectional views illustrating cover glass processing according to another embodiment. FIG. 7A shows a cross sectional view of a processed cover glass 704 after an aperture 712 has been formed in the cover glass 604. As mentioned previously, the aperture 712 may be formed in various ways, for example by drilling.

[0076] Rather than disposing an optical barrier perimeter in the aperture 712 formed in the cover glass 604 as just discussed with respect to FIG. 6B, in this alternative embodiment of FIG. 7B an optical barrier perimeter 710 is disposed as a coating onto an elongated transparent camera window 706A. FIG. 7B shows a cross sectional view of the further processed cover glass 704 after the elongated transparent camera window 706A (coated with the optical barrier perimeter 710) has been disposed within the aperture 712 extending through the cover glass 704. The elongated transparent camera window 706A can be formed as an elongated glass plug or peg, and can be hot pressed in place at a suitable temperature, for example approximately six hundred (600) to approximately seven hundred (700) degrees Celsius (ºC). As will be discussed next, the elongated transparent camera window 706A (coated with the optical barrier perimeter 710) can be lapped down, using a suitable abrasive slurry (e.g., comprising cesium oxide), so that the exterior surface of the cover glass 704 can be planar.

[0077] For example, as shown in cross sectional view in FIG. 7C, the cover glass 704 can have a substantially smooth exterior surface comprising the transparent camera window 706B substantially encircled by the optical barrier perimeter 710. The resulting exterior surface of the cover glass 704 can be planar over the transparent camera window 706B, the optical barrier perimeter 710 and adjacent region 711 of the cover glass 704.

[0078] FIGs. 8A-8C are simplified cross sectional views illustrating cover glass processing according to another embodiment. FIG. 8A shows a cross sectional view

of a processed cover glass 804 after an aperture 812 has been formed in the cover glass 804. In the embodiment shown in FIG. 8A, the glass of the cover glass 805 can be dark or opaque, as representatively illustrated by right to left hatching.

[0079] FIG. 8B shows a cross sectional view of the dark or opaque cover glass 804 after an elongated transparent camera window 806A has been disposed within the aperture 812 extending through the dark or opaque cover glass 804. The elongated transparent camera window 806A can be formed as an elongated glass plug or peg, and can be hot pressed in place at a suitable temperature, for example approximately six hundred (600) to approximately seven hundred (700) degrees Celsius (ºC). As will be discussed next, the elongated transparent camera window 806A can be lapped down, using a suitable abrasive slurry (e.g., comprising cesium oxide), so that the exterior surface of the dark opaque cover glass can be planar.

[0080] For example, as shown in cross sectional view in FIG. 8C, the dark or opaque cover glass 804 can have a substantially smooth exterior surface comprising the transparent camera window 806B. The resulting exterior surface of the dark or opaque cover glass 804 can be planar over the transparent camera window 806B and adjacent region 811 of the dark or opaque cover glass 804.

[0081] FIG. 8D is a simplified view of another embodiment of a consumer electronic product 800. The consumer electronic product 800 can comprise a housing and electrical components disposed at least partially internal to the housing. The electrical components can including at least a camera 807.

[0082] The consumer electronic product 800 can include the cover glass 804 coupled to the housing. The cover glass 804 can include the transparent camera window 806B and an adjacent glass region 811 that is dark or opaque. The camera 807 can be arranged adjacent to the transparent camera window 806B. The adjacent glass region 811 can be sufficiently dark or opaque for substantially reducing glare at the camera 807 via the cover glass 804.

[0083] The cover glass 804 can have a substantially smooth exterior surface extending over the transparent camera window 806B and the adjacent glass region

811. The cover glass 804 can have an exterior surface that is lapped to be planar over the transparent camera window 806B and the adjacent glass region 811.

[0084] FIG. 9 is a diagram showing a detailed partial cross sectional view of chemical strengthening of exposed surface portions of cover glass. FIG. 9 diagrammatically illustrates a chemical treatment process of submerging the cover glass 904 in a heated potassium bath 916 (for example a molten KNO3 bath), for chemically strengthening the cover glass 904. When the cover glass 904 is submerged or soaked in the heated potassium bath 916, diffusion and ion exchange can occur at exposed surface portions of the cover glass 904.

[0085] As shown in FIG. 9, Na^+ ions 915 which are present in cover glass 904 can diffuse into potassium bath 916, while K^+ ions 917 in potassium bath 916 can diffuse into cover glass 904 such that a compressive surface layer 919 can be formed. In other words, K^+ ions 917 from potassium bath 916 can be exchanged with Na^+ ions 915 to form compressive surface layer 919. The K^+ ions 917 can provide a compressive stress surface stress (CS) of the compressive surface layer 919, which chemically strengthens the compressive surface layer 919 of the cover glass 904. Compressive surface layer 919 is highlighted using cross hatching.

[0086] Cover glass 904 is shown in FIG. 9 as having a thickness (t). By controlling chemical treatment parameters such as the length of time of chemical strengthening treatment and/or the concentration of K^+ ions 917 in potassium bath 916, a depth (d) of compressive surface layer 919 and compressive stress surface stress (CS) of the compressive surface layer 919 may be substantially controlled. In some cases, K^+ ions 917 may not diffuse into a center portion 921 of the cover glass 904. In FIG. 9, the center portion 921 is shown without cross hatching. The central portion 921 of the cover glass 904 can have a central tension (CT) in response to the compressive stress surface stress (CS) of the compressive surface layer 919.

[0087] FIGs. 10A and 10B are simplified cross sectional views illustrating chemical strengthening of a cover glass 1004 according to one embodiment. FIG. 10A shows

the cover glass 1004 prior to any chemical strengthening. FIG. 10B shows the cover glass 1004 after chemical strengthening.

[0088] As shown in FIGs. 10A and 10B, the cover glass 1004 can have a substantially smooth exterior surface comprising transparent camera window 1006 substantially encircled by an optical barrier perimeter 1010. The exterior surface of the cover glass 1004 can be lapped, for example prior to chemical strengthening, to be planar over the transparent camera window 1006, the optical barrier perimeter 1010 and an adjacent region of the cover glass 1004.

[0089] After chemical strengthening, FIG 10B shows a chemically strengthened surface 1019A of the glass camera window 1006. FIG. 10B also shows a chemically strengthened surface 1019B of the adjacent region 1011 of the cover glass 1004.

[0090] FIG. 10C is a simplified view of another embodiment of a consumer electronic product 1000 comprising a housing and electrical components disposed at least partially internal to the housing, wherein the electrical components include at least a camera 1007. The cover glass 1004 can be coupled to the housing.

[0091] The cover glass 1004 can comprise the glass camera window 1006 having the chemically strengthened surface 1019A. The cover glass 1004 can comprise the adjacent region 1011 having chemically strengthened surface 1019B. The cover glass 1004 can further comprise the optical barrier perimeter 1010. The optical barrier perimeter 1010 can substantially encircle the glass camera window 1006. The optical barrier perimeter 1010 can comprise metal.

[0092] The camera 1007 can be arranged adjacent to the glass camera window 1006. The optical barrier perimeter 1010 can be interposed within the cover glass 1004 between the camera 1007 and the adjacent region 1011 of the cover glass for reducing glare at the camera 1007 via the cover glass. More particularly, the optical barrier perimeter 1010 can be interposed within the cover glass 1004 between the glass camera window 1006 and the adjacent region 1011 of the cover glass 1004 and can serve to reduce glare at the camera 1007 via the cover glass 1004.

[0093] In FIG. 10C, the electronic device 1000 is shown simplified in cross sectional view, so as to illustrate operation of the optical barrier perimeter 1010 in reducing veiling glare at the camera 1007 of the electronics of device 1000. Veiling glare propagating in the cover glass 1004 is depicted in FIG. 10C by notional dashed line arrows. The optical barrier perimeter 1010 may substantially reduce veiling glare, substantially inhibiting such diffuse stray light from reaching the image plane of the camera 1007. Accordingly, the optically barrier perimeter 1010 is shown in FIG. 10C as blocking the notional dashed line arrows, so as to depict such substantial reduction in veiling glare.

[0094] For the consumer electronic product 1000 shown in FIG 10C, the cover glass 1004 can have a substantially smooth exterior surface extending over the glass camera window 1006, the optical barrier perimeter 1010 and the adjacent region 1011 of the cover glass 1004. The cover glass 1004 can have an exterior surface that is planar (e.g., by lapping) over the glass camera window 1006, the optical barrier 1010 and the adjacent region 1011 of the cover glass 1004.

[0095] FIG. 11 is a flow diagram illustrating an assembly process 1100 according to one embodiment. The assembly process 1100 may begin by forming 1102 an aperture in a cover glass. The process 1100 may continue by interposing 1104 an optical barrier perimeter which substantially encircles a camera window. The optical barrier perimeter provided between the camera window and an adjacent glass region.

[0096] The process 1100 may continue by disposing 1106 the transparent camera window in the aperture of the cover glass. For a tight fit, the transparent camera window can be heated (i.e., becomes compliant) and pressed into place within the aperture. The process 1100 may continue with lapping 1108 the transparent camera window such that the transparent camera window and an adjacent glass region of the cover glass yield a planar exterior surface of the cover glass.

[0097] The process 1100 may continue with disposing 1110 the transparent camera window adjacent to a camera. The process 1100 may continue with subsequently attaching 1112 the cover glass to a housing for the electronic product.

Once the cover glass has been attached to the housing, the assembly process 1100 can end.

[0098] This application references U.S. Patent Application No. 12/847,926 filed July 30, 2010, and entitled "Electronic Device Having Selectively Strengthening Glass Cover Glass", which is hereby incorporated herein by reference.

[0099] Embodiments of the invention are well suited for portable, battery-powered electronic devices, and more particularly handheld battery-powered electronic devices. Examples of portable, battery-powered electronic devices can include laptops, tablet computers, media players, phones, GPS units, remote controls, personal digital assistant (PDAs), and the like.

[00100] The various aspects, features, embodiments or implementations of the invention described above can be used alone or in various combinations.

[00101] The advantages of the invention are numerous. Different aspects, embodiments or implementations may (but need not) yield one or more of the following advantages. One advantage of the invention is that cover glass can be strengthened, even at a camera window region, to protect from damage that would otherwise result from a drop event. Another advantage is efficiency and/or pleasing appearance in integrating a transparent camera window into the cover glass. Another advantage is improved image or video quality, which may result from substantially reducing veiling glare.

[00102] The many features and advantages of the invention are apparent from the written description and, thus, it is intended by the appended claims to cover all such features and advantages of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, the invention should not be limited to the exact construction and operation as illustrated and described. Hence, all suitable modifications and equivalents may be resorted to as falling within the scope of the invention.

What is claimed is:

CLAIMS

1. A consumer electronic product, comprising:

a housing;

electrical components disposed at least partially internal to the housing, the electrical components including at least a camera; and

a cover glass coupled to the housing, the cover glass having a substantially smooth exterior surface comprising a transparent region substantially encircled by an optical barrier perimeter, the camera being arranged adjacent to the transparent region and within the optical barrier perimeter so that the transparent region of the cover glass is substantially transparent to the camera, and the optical barrier perimeter being interposed within the cover glass between the camera and an adjacent region of the cover glass for reducing glare at the camera via the cover glass.

2. A consumer electronic product as recited in claim 1 wherein the transparent region comprises glass.

3. A consumer electronic product as recited in claim 1 wherein the transparent region comprises plastic.

4. The consumer electronic product as in claim 1 wherein the glare is veiling glare.

5. The consumer electronic product as in claim 1 wherein the optical barrier perimeter comprises metal.

6. The consumer electronic product as in claim 1 wherein the adjacent region of the cover glass comprises a majority region of the cover glass, and wherein the transparent region comprises a minority region of cover glass arranged adjacent to the camera.

7. The consumer electronic product as recited in claim 1 wherein the transparent region comprises a peripheral region of cover glass adjacent to the camera.

8. The consumer electronic product as recited in claim 1 wherein the cover glass substantially overlaps the camera.

9. The consumer electronic product as recited in any of claims 1-8 wherein the electrical components further comprise an illuminator; and wherein the cover glass is substantially transparent to the illuminator and arranged so that illumination projects outwardly from the cover glass.

10. The consumer electronic product as recited in claim 9 wherein the optical barrier region serves to substantially reduce light from the illuminator from coupling into the camera by way of the cover glass.

11. A consumer electronic product, comprising:

a housing;

electrical components disposed at least partially internal to the housing, said electrical components including at least a camera; and

a cover glass coupled to the housing, the cover glass comprising a chemically strengthened glass camera window and an optical barrier, the camera

being arranged adjacent to the chemically strengthened glass camera window, and the optical barrier being interposed within the cover glass between the camera and an adjacent region of the cover glass for reducing glare at the camera via the cover glass.

12. The consumer electronic product as recited in claim 11 wherein the optical barrier comprises an optical barrier perimeter substantially encircling the chemically strengthened glass camera window.

13. The consumer electronic product as recited in claim 11 wherein the cover glass has a substantially smooth exterior surface extending over the chemically strengthened glass camera window and the optical barrier.

14. The consumer electronic product as recited in claim 11 wherein the cover glass has a substantially smooth exterior surface extending over the chemically strengthened glass camera window, the optical barrier and the adjacent region of the cover glass.

15. The consumer electronic product as recited in claim 11 wherein the cover glass has an exterior surface that is lapped to be planar over the chemically strengthened glass camera window and the optical barrier.

16. The consumer electronic product as recited in claim 11 wherein the cover glass has an exterior surface that is lapped to be planar over the chemically strengthened glass camera window, the optical barrier and the adjacent region of the cover glass.

17. The consumer electronic product as recited in claim 11 wherein the adjacent region of the cover glass is chemically strengthened.

18. The consumer electronic product as recited in any of claims 11-17 wherein the optical barrier comprises metal.

19. A consumer electronic product, comprising:

a housing;

electrical components disposed at least partially internal to the housing, said electrical components including at least a camera; and

a cover glass coupled to the housing, the cover glass comprising a transparent camera window and an adjacent glass region that is dark or opaque, the camera being arranged adjacent to the transparent camera window, and the adjacent glass region being sufficiently dark or opaque for substantially reducing glare at the camera via the cover glass.

20. The consumer electronic product as recited in claim 19 wherein the cover glass has a substantially smooth exterior surface extending over the transparent camera window and the adjacent glass region.

21. The consumer electronic product as recited in claim 19 wherein the cover glass has an exterior surface that is lapped to be planar over the transparent camera window and the adjacent glass region.

22. A consumer electronic product, comprising:

a housing;

electrical components disposed at least partially internal to the housing, said electrical components including at least a camera; and

a cover glass coupled to the housing, the cover glass comprising a camera window and an optical barrier,

wherein the camera is arranged adjacent to the camera window, and

wherein the optical barrier comprises an optical barrier perimeter substantially encircling the camera window, the optical barrier perimeter comprising a layer of material applied by physical vapor deposition.

23. The consumer electronic product as recited in claim 22 wherein the optical barrier perimeter is provided onto an inner surface of an aperture in the cover glass for the camera window.

24. The consumer electronic product as recited in claim 22 wherein the camera window comprises a glass insert that is placed in an aperture in the cover glass for the camera window, and wherein the optical barrier perimeter is provided on an outer surface of the glass insert.

25. A method for assembling an electronic product comprising:

forming an aperture in a cover glass;

disposing a transparent camera window in the cover glass;

lapping the transparent camera window and an adjacent glass region of the cover glass into a planar exterior surface of the cover glass;

disposing the transparent camera window adjacent to a camera; and

subsequently attaching the cover glass to a housing for the electronic product.

26. A method as recited in claim 25 further comprising:

interposing an optical barrier perimeter, which substantially encircles the camera window, between the camera window and the adjacent glass region.

27. A method as recited in claim 25 further comprising:

disposing, prior to the disposing of the transparent camera window, a layer of metal on inner surfaces of the aperture.

28. A method as recited in claim 25 further comprising:

disposing, prior to the disposing of the transparent camera window, a layer of metal on outer surfaces of the transparent camera window.

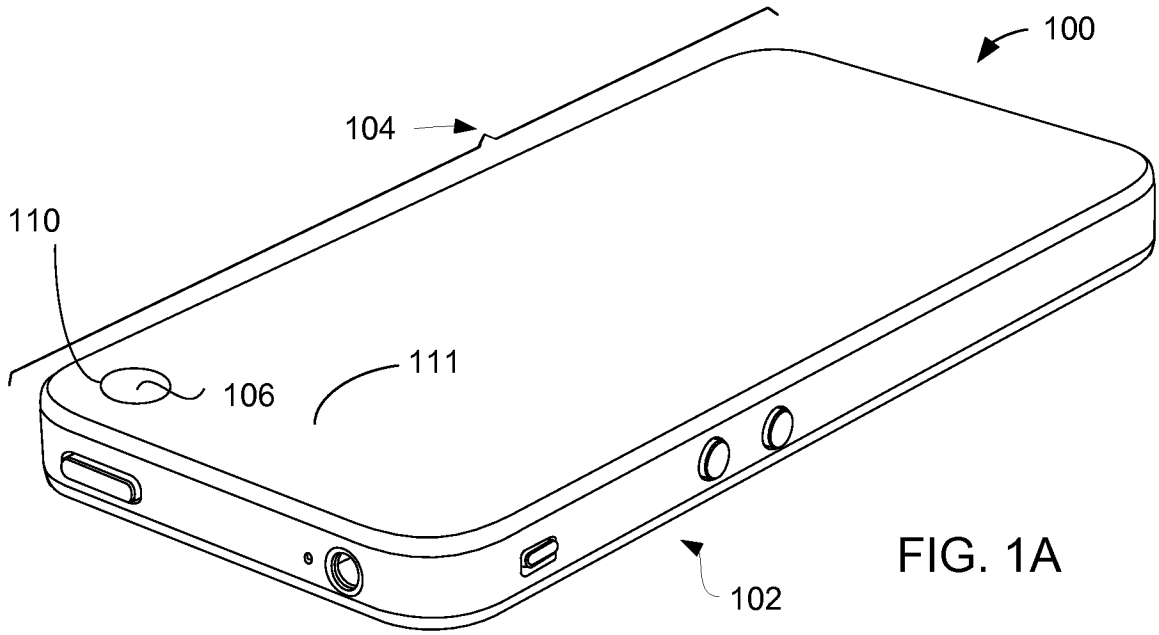


FIG. 1A

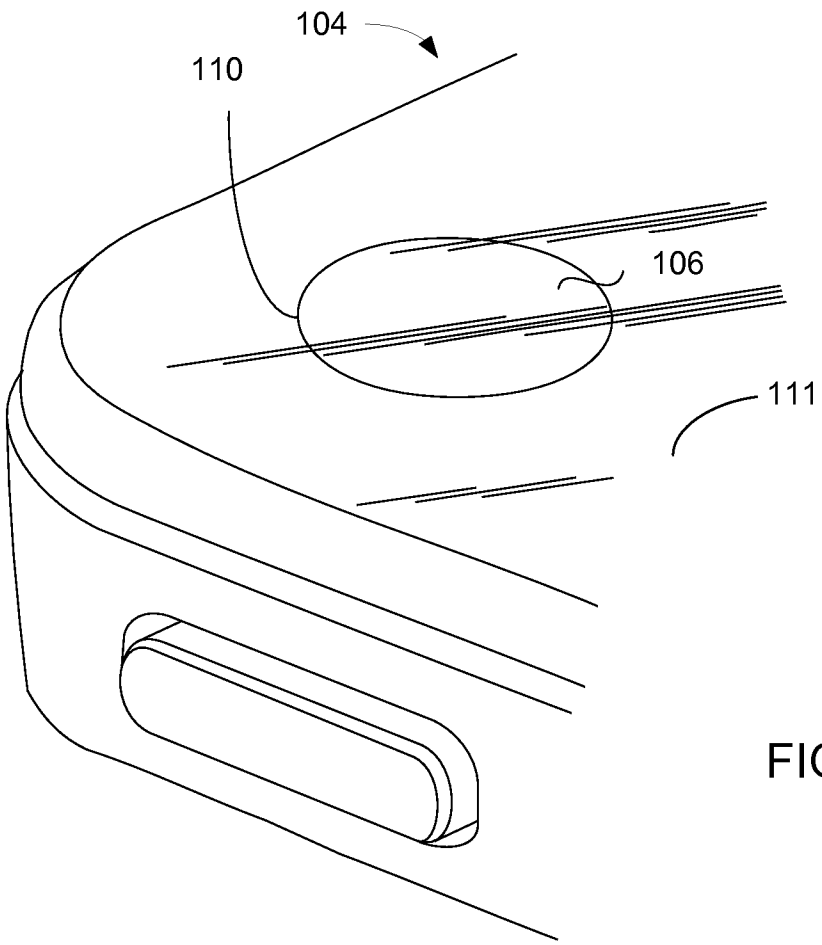


FIG. 1B

FIG. 1C

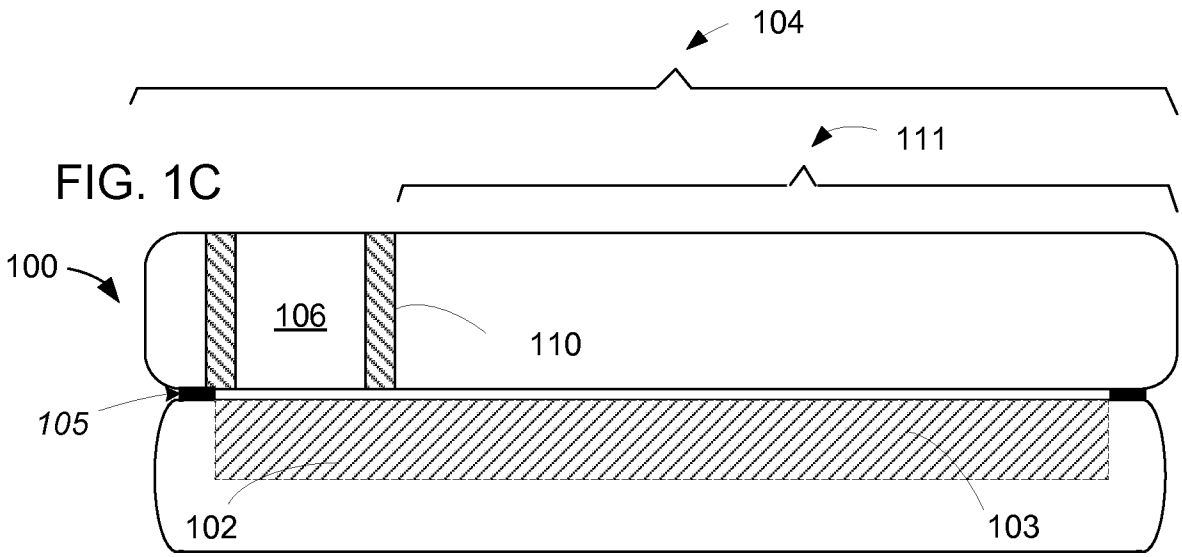


FIG. 1D

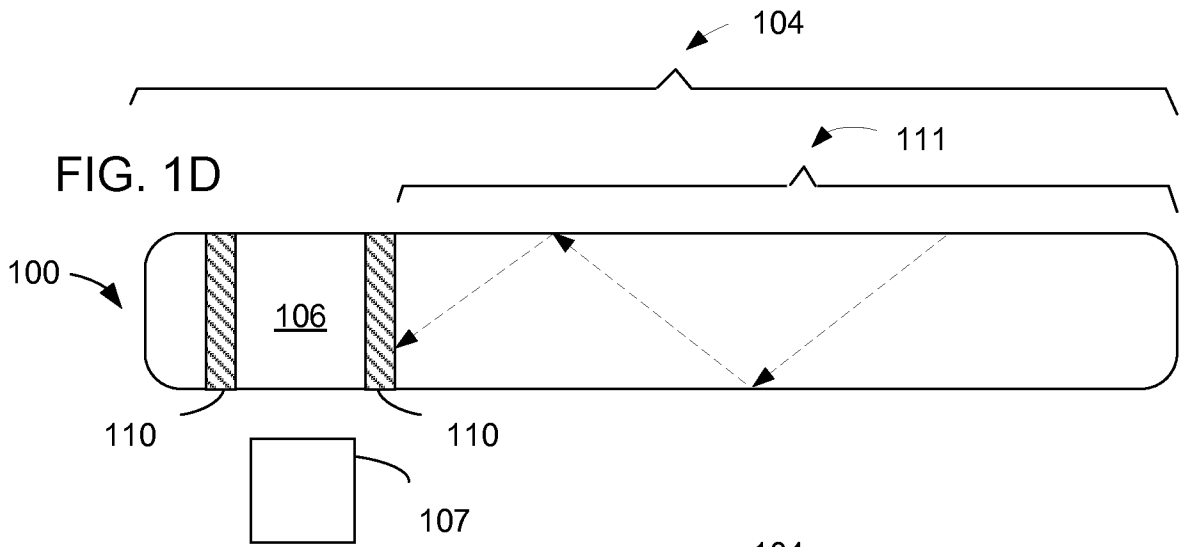
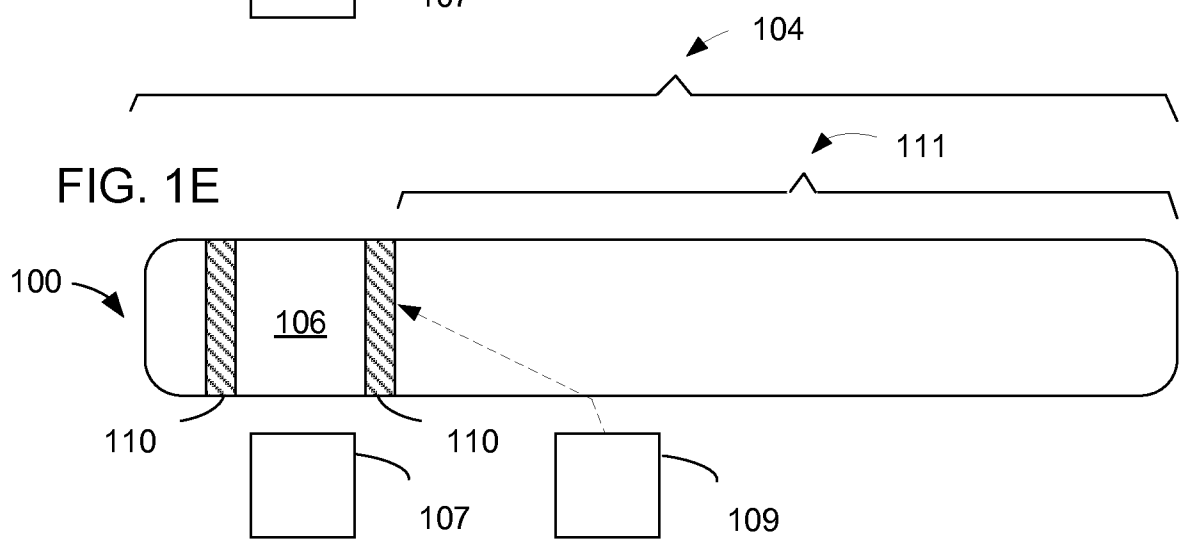


FIG. 1E



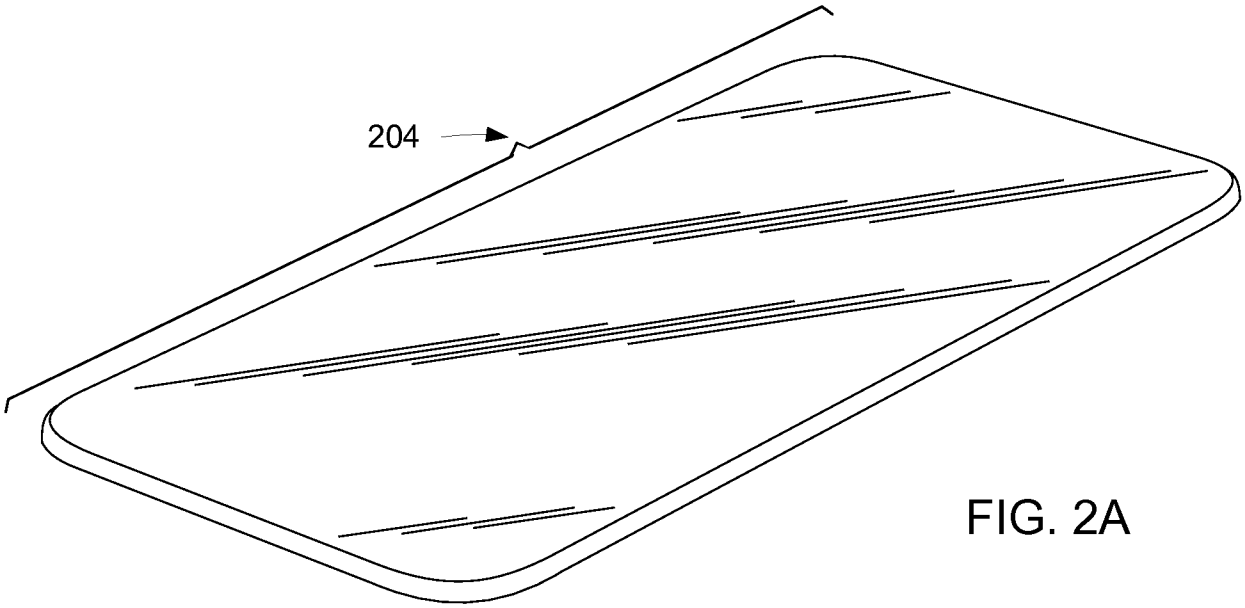


FIG. 2A

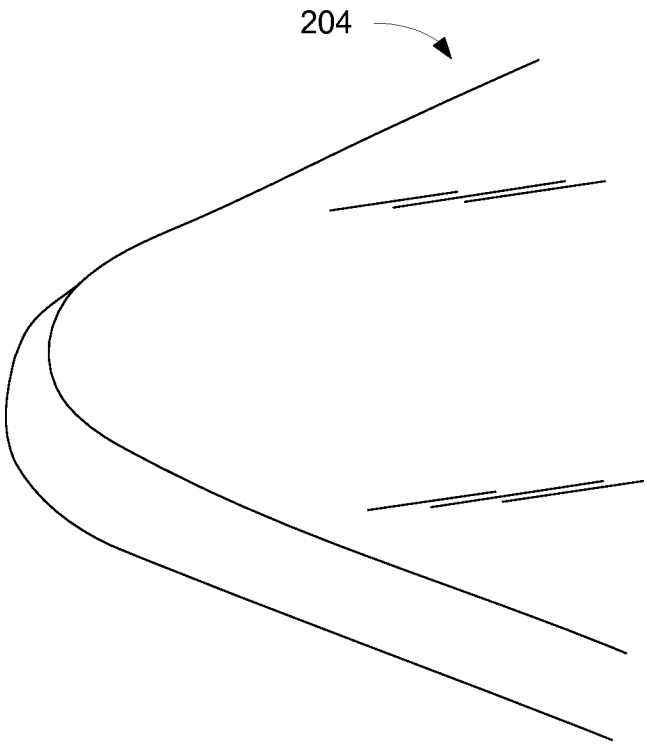


FIG. 2B

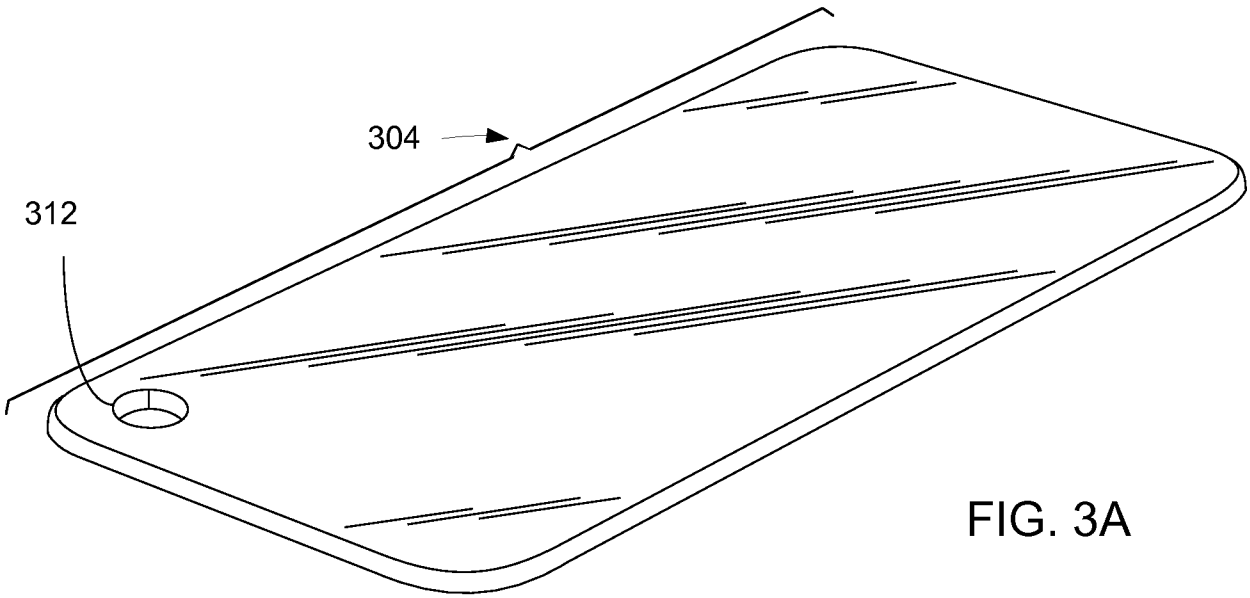


FIG. 3A

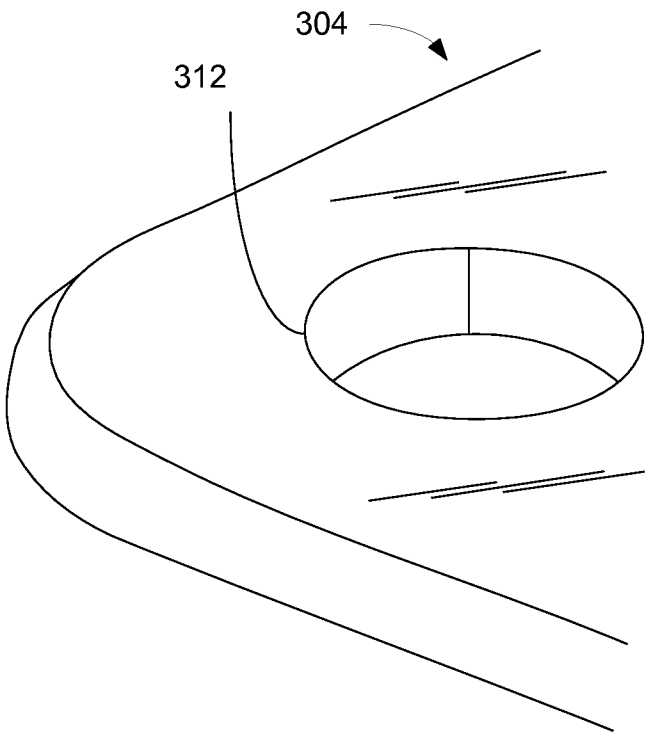


FIG. 3B

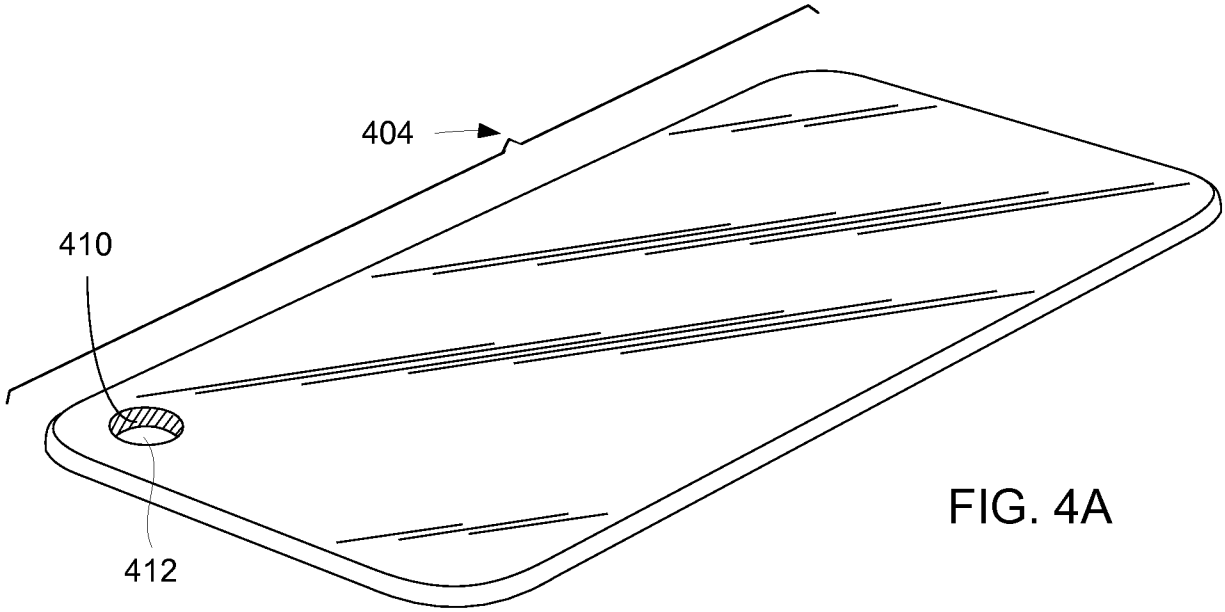


FIG. 4A

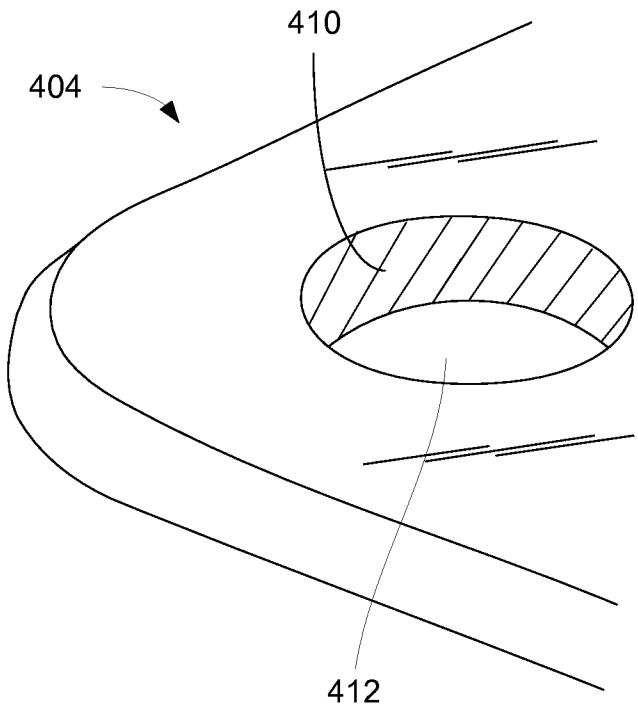


FIG. 4B

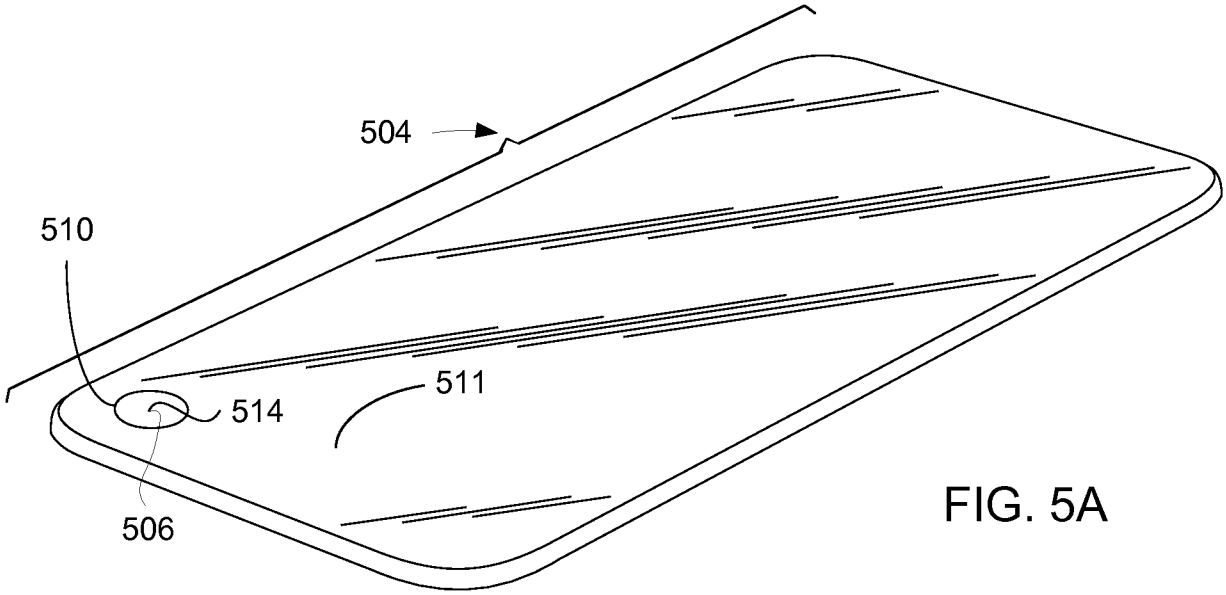


FIG. 5A

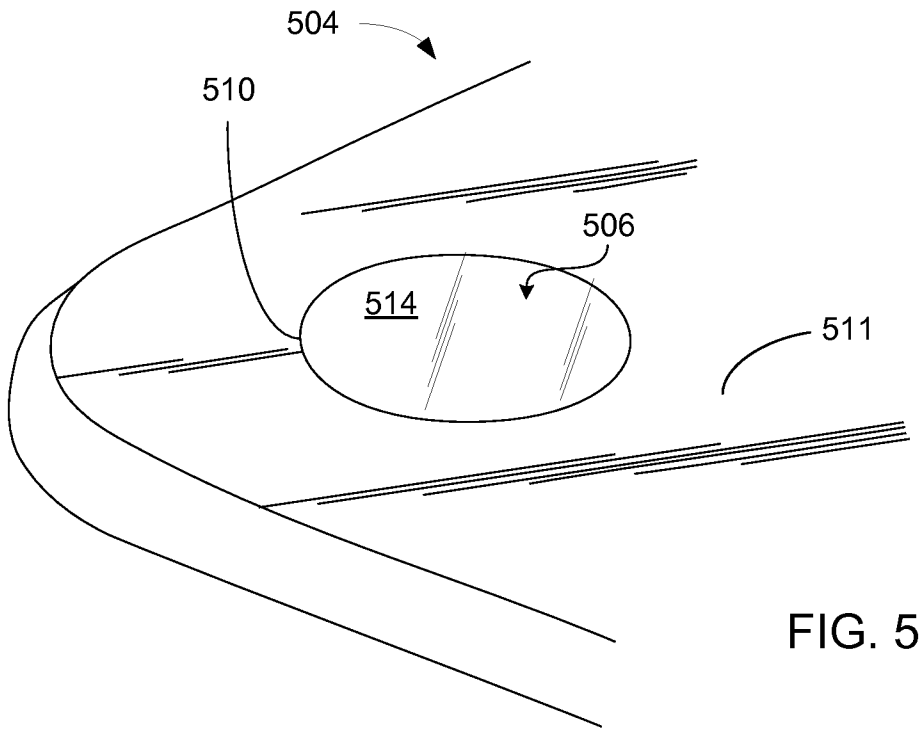


FIG. 5B



FIG. 6A

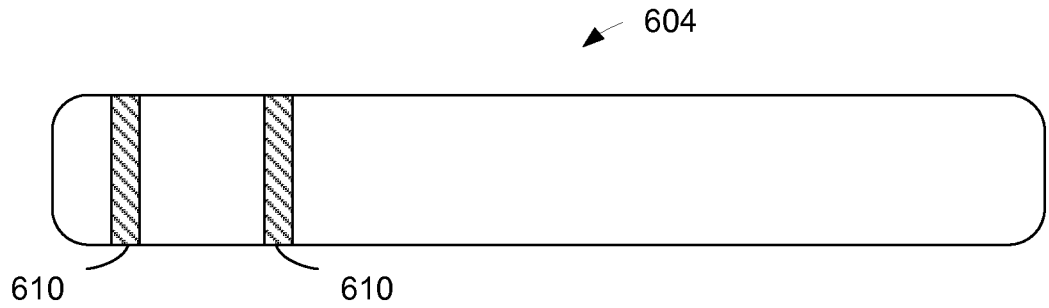


FIG. 6B

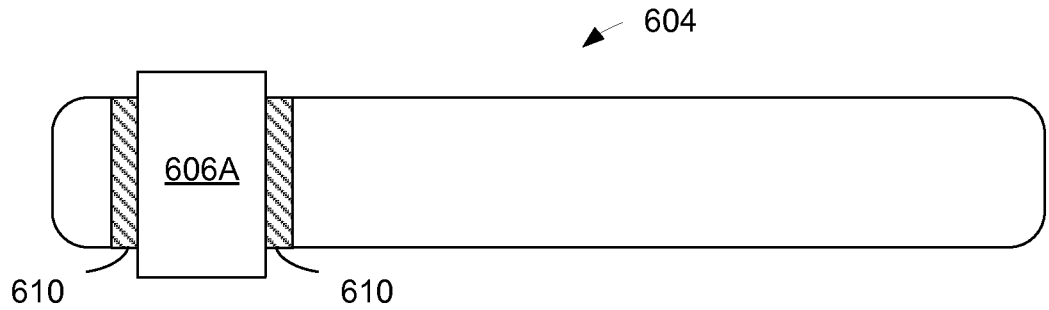


FIG. 6C

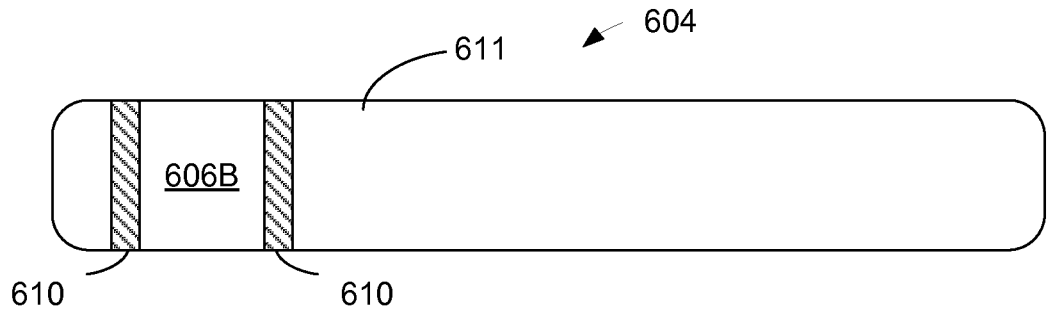


FIG. 6D

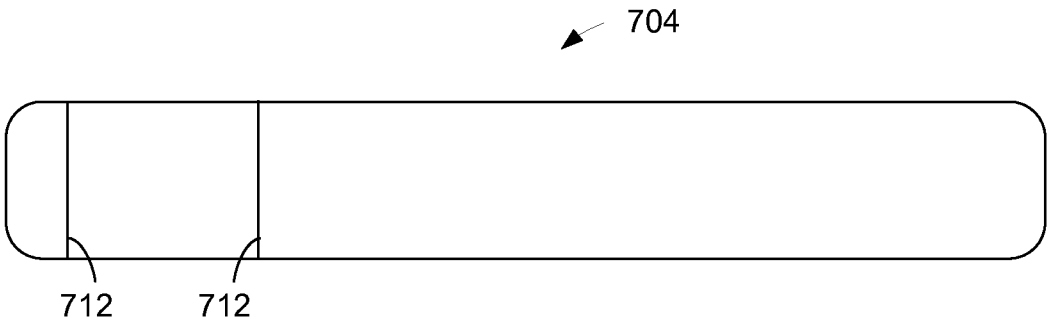


FIG. 7A

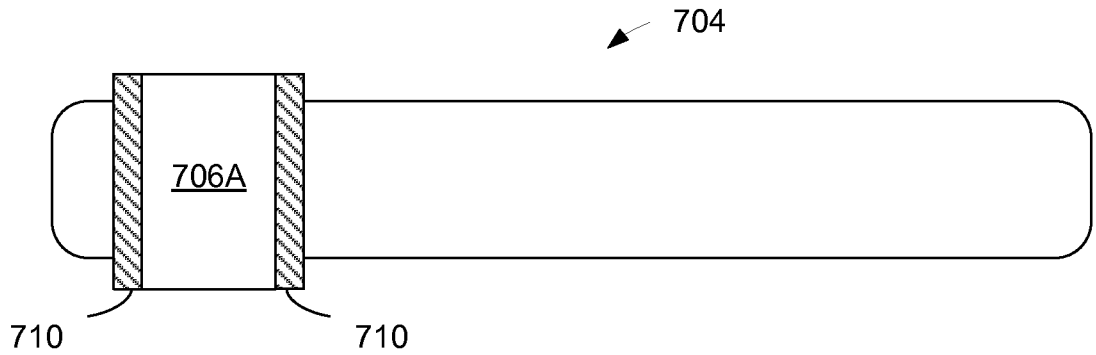


FIG. 7B

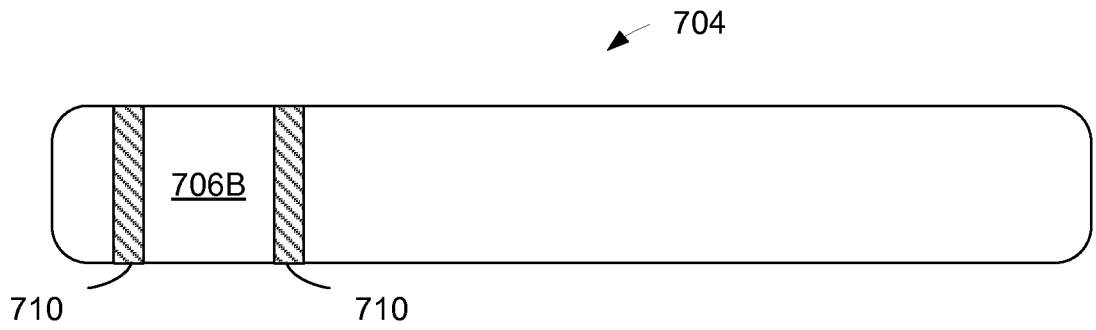


FIG. 7C

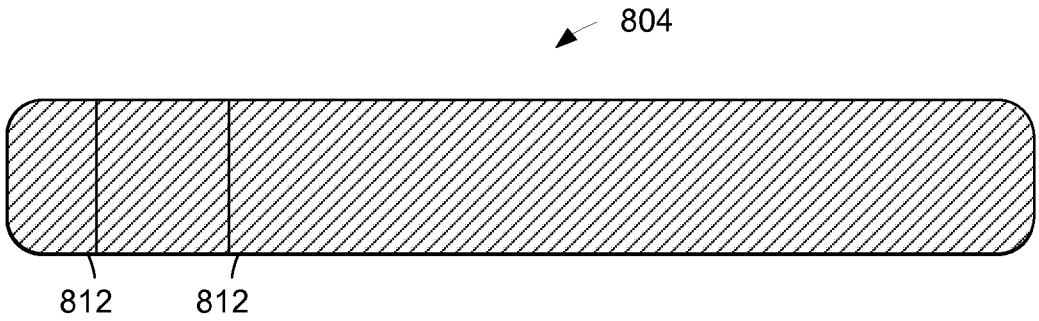


FIG. 8A

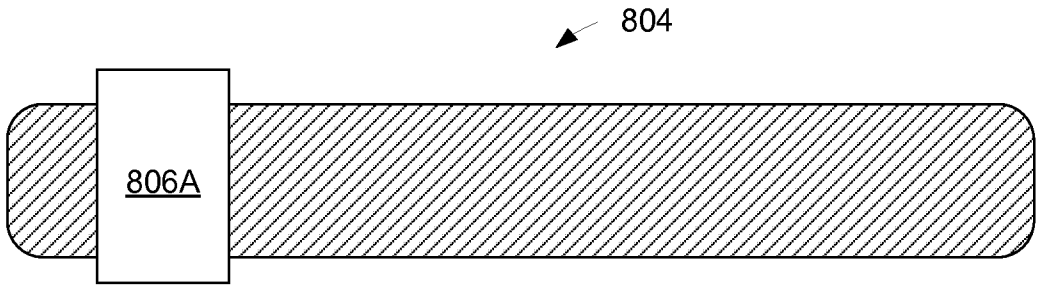


FIG. 8B

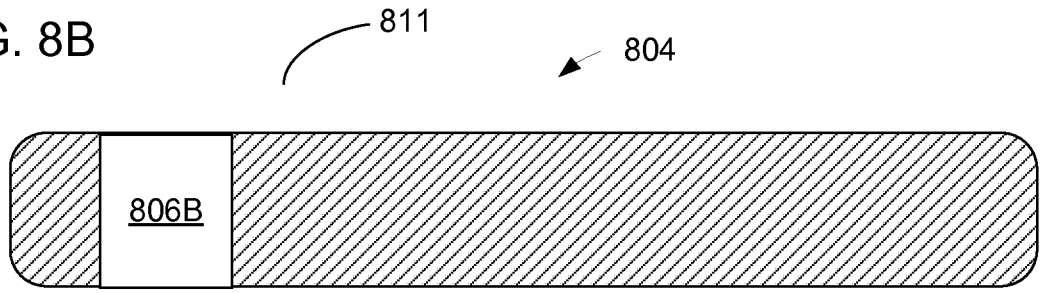


FIG. 8C

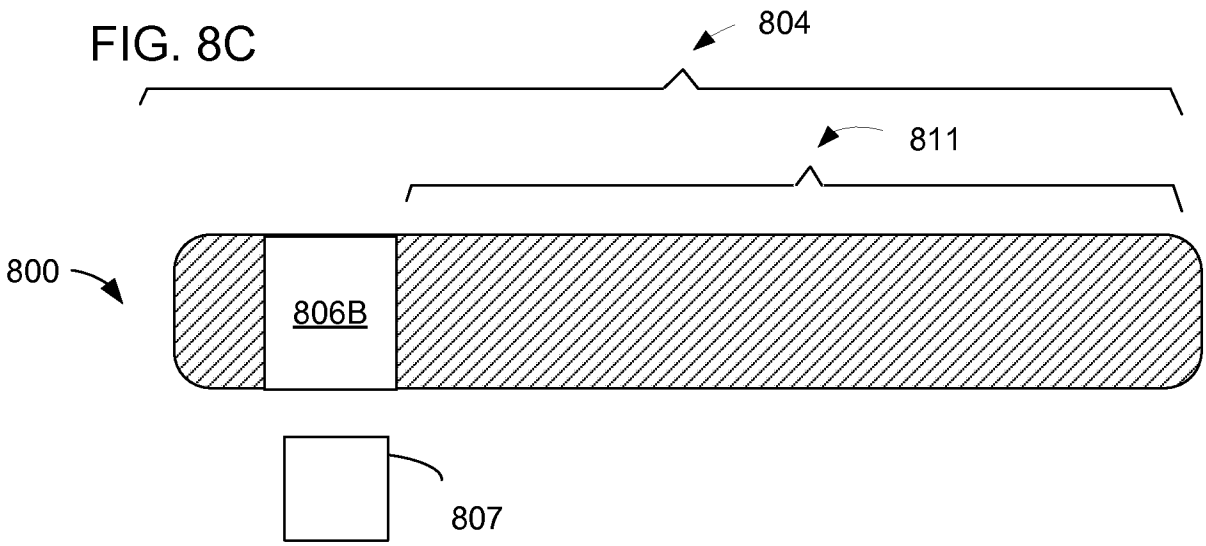


FIG. 8D

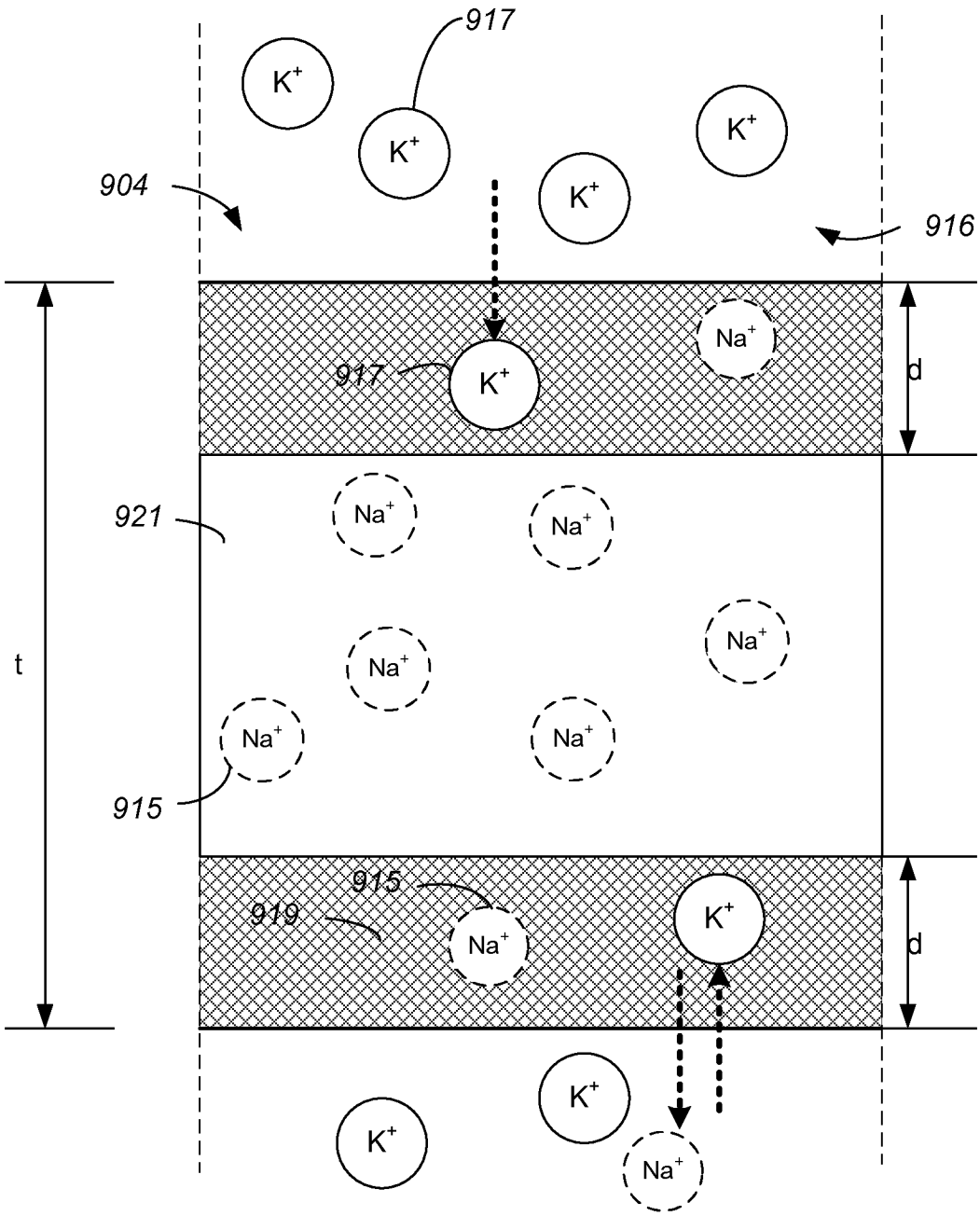

917
K+
K+
K+
K+
904
916
Na+
917
K+
d
921
Na+
Na+
Na+
Na+
t
Na+
Na+
915
915
919
Na+
K+
d
K+
K+
Na+

FIG. 9



FIG. 10A

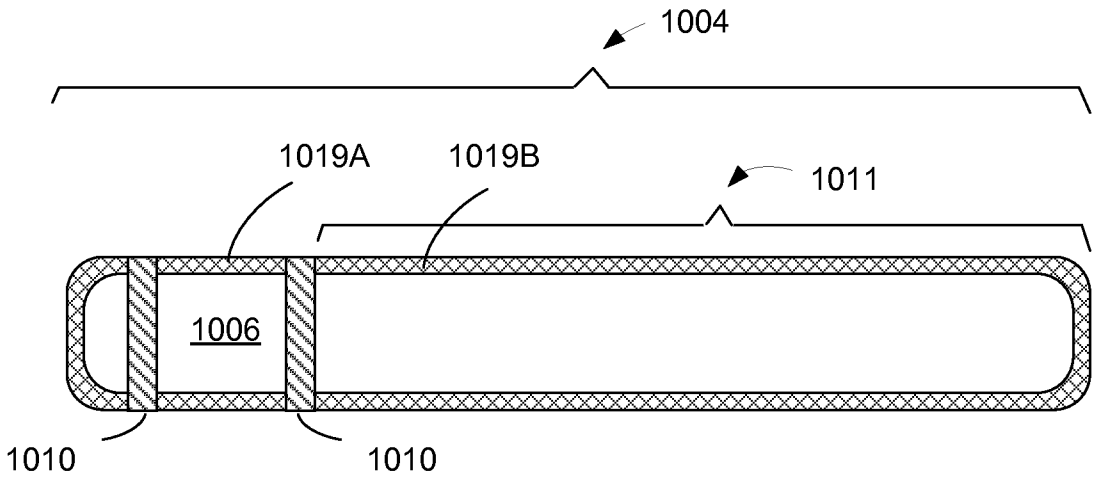


FIG. 10B

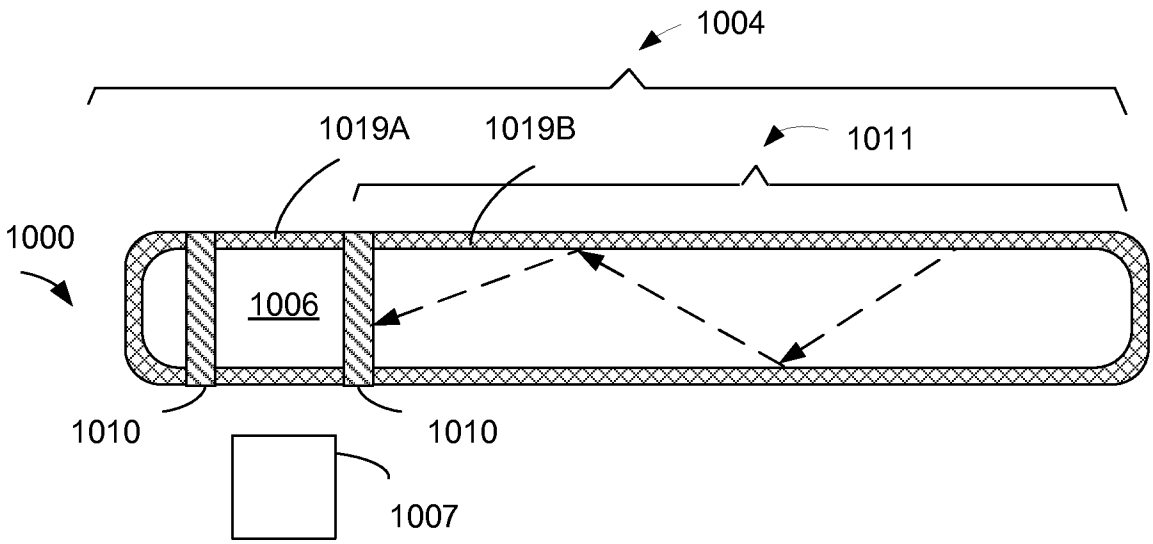


FIG. 10C

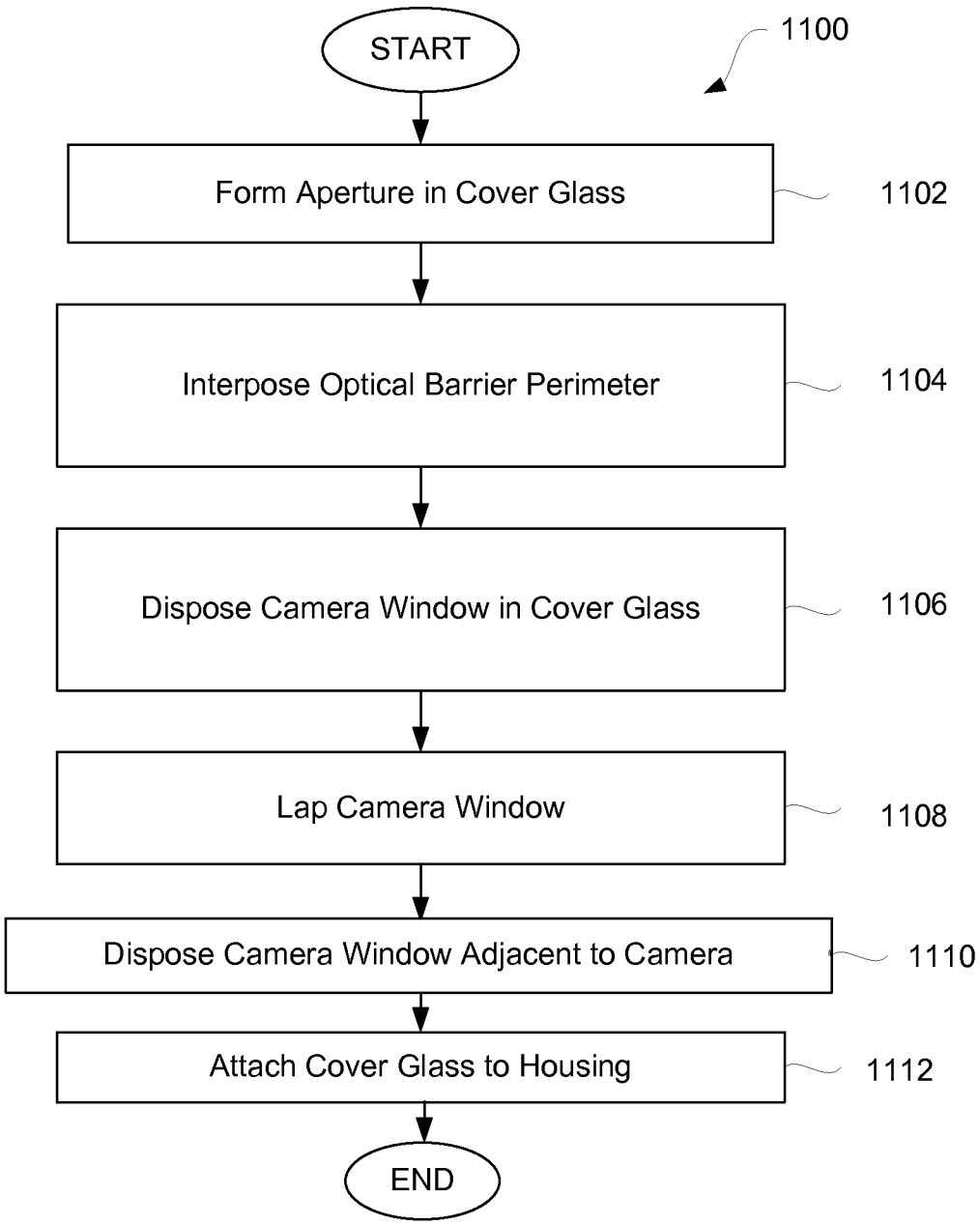

START
1100
Form Aperture in Cover Glass
1102
Interpose Optical Barrier Perimeter
1104
Dispose Camera Window in Cover Glass
1106
Lap Camera Window
1108
Dispose Camera Window Adjacent to Camera
1110
Attach Cover Glass to Housing
1112
END

FIG. 11