(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 February 2012 (23.02.2012)

PCT

(10) International Publication Number
WO 2012/024166 A1

(51) International Patent Classification:
C03C 21/00 (2006.01) *H04M 1/02* (2006.01)

(21) International Application Number:
PCT/US2011/047479

(22) International Filing Date:
11 August 2011 (11.08.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/374,988 18 August 2010 (18.08.2010) US
12/895,823 30 September 2010 (30.09.2010) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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(54) Title: ENHANCED STRENGTHENING OF GLASS BY ION EXCHANGE IN SODIUM BATH FOLLOWED BY ION EXCHANGE IN POTASSIUM BATH

(57) Abstract: Apparatus, systems and methods for improving strength of a thin glass member for an electronic device are disclosed. In one embodiment, the glass member can have improved strength by using multi-bath chemical processing. The multi-bath chemical processing allows greater levels of strengthening to be achieved for glass member. In one embodiment, the glass member can pertain to a glass cover for a housing of an electronic device.

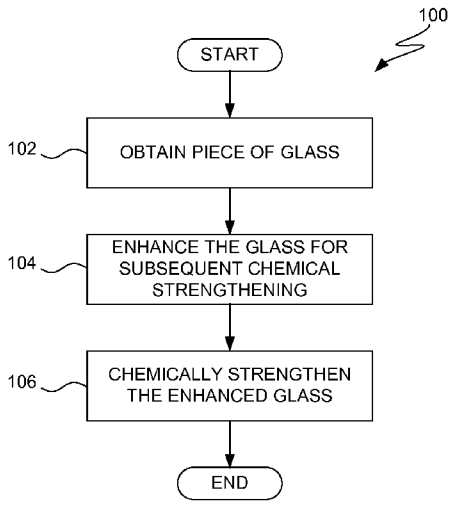

FIG. 1

WO 2012/024166 A1

Published:

— *with international search report (Art. 21(3))*

ENHANCED STRENGTHENING OF GLASS BY ION EXCHANGE IN SODIUM BATH FOLLOWED BY ION EXCHANGE IN POTASSIUM BATH

BACKGROUND OF THE INVENTION

[0001] Conventionally, some portable electronic devices use glass as a part of their devices, either internal or external. Externally, a glass part can be provided as part of a housing, such a glass part is often referred to as a cover glass. The transparent and scratch-resistance characteristics of glass make it well suited for such applications. Internally, glass parts can be provided to support display technology. More particularly, for supporting a display, a portable electronic device can provide a display technology layer beneath an outer cover glass. A sensing arrangement can also be provided with or adjacent 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.

[0002] Unfortunately, however, use of glass with portable electronic devices requires that the glass be relatively thin. Generally speaking, the thinner the glass the more susceptible the glass is to damage when the portable electronic device is stressed or placed under a significant force. Chemically strengthening has been used to strengthen glass. While chemically strengthening is effective, there is a continuing need to provide improved ways to strengthen glass, namely, thin glass.

SUMMARY

[0003] The invention relates generally to increasing the strength of glass. Through multi-bath chemical processing greater levels of strengthening can be

achieved for glass articles. The multi-bath chemical processing can be achieved through the use of successive chemical baths. The use of multi-bath chemical processing for a glass article can enhance the effectiveness of the chemical strengthening process. Accordingly, glass articles that have undergone multi-bath chemical processing are able to be not only thin but also sufficiently strong and resistant to damage. The strengthened glass articles are well suited for use in consumer products, such as consumer electronic devices (e.g., portable electronic devices).

[0004] The invention can be implemented in numerous ways, including as a method, system, device, or apparatus. Several embodiments of the invention are discussed below.

[0005] As a method for strengthening a piece of glass, one embodiment can, for example, include at least obtaining a piece of glass that is to be chemically strengthened, enhancing the glass to make it more susceptible to chemical strengthening, and subsequently chemically strengthening the enhanced glass.

[0006] As a glass strengthening system for glass articles, one embodiment can, for example, includes at least a first bath station providing a sodium solution, and a second bath station providing a potassium solution. The first bath station serves to receive a glass article and to introduce sodium ions into surfaces of the glass article. The second bath station serves to receive the glass article following the first bath station and to exchange potassium ions for sodium ions within the glass article.

[0007] As a method for processing a glass piece to improve its strength, one embodiment can, for example, include at least: submerging the glass piece in a heated sodium bath, determining whether the glass piece should be removed from the heated sodium bath, subsequently submerging the glass piece in a heated potassium bath, determining whether the glass piece should be removed from the heated potassium bath, and performing post-processing on the glass piece following removal of the glass piece from the heated potassium bath.

[0008] As a method for processing a glass piece to improve its strength, another embodiment can, for example, include at least: submerging the glass piece in a heated sodium bath; removing the glass piece from the heated sodium bath after being in the heated sodium solution for a first duration; subsequently submerging the glass piece in a heated potassium bath; removing the glass piece from the heated potassium bath after being in the heated potassium solution for a second duration; and performing post-processing on the glass piece following removal of the glass piece from the heated potassium bath.

[0009] As a glass strengthening control system for glass articles, still another embodiment can, for example, include at least: means for submerging the glass piece in a heated sodium bath; means for removing the glass piece from the heated sodium bath after being in the heated sodium solution for a first duration; means for subsequently submerging the glass piece in a heated potassium bath; means for removing the glass piece from the heated potassium bath after being in the heated potassium solution for a second duration; and means for performing post-processing on the glass piece following removal of the glass piece from the heated potassium bath.

[0010] 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

[0011] 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:

[0012] FIG. 1 is a flow diagram of a glass strengthening process according to one embodiment.

[0013] FIG. 2 illustrates a glass strengthening system according to one embodiment.

[0014] FIG. 3 is a flow diagram of a glass piece process according to one embodiment.

[0015] FIG. 4 illustrates a glass strengthening system according to another embodiment.

[0016] FIG. 5 is a flow diagram of a back exchange process according to one embodiment.

[0017] FIGs. 6A and 6B are diagrammatic representations of electronic device according to one embodiment.

[0018] FIGs. 7A and 7B are a diagrammatic representation of an electronic device according to another embodiment.

[0019] FIG. 8 is flow diagram which illustrates a method of chemically strengthening glass, e.g., a glass cover, according to one embodiment.

[0020] FIG. 9A is a cross-sectional diagram of a glass cover which has been chemically treated according to one embodiment.

[0021] FIG. 9B is a cross-sectional diagram of a glass cover which has been chemically treated, as shown to include a chemically treated portion in which potassium ions have been implanted according to one embodiment.

[0022] FIG. 10 is a diagrammatic representation of a chemical treatment process that involves submerging a glass cover in an ion bath according to one embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0023] The invention relates generally to increasing the strength of glass. Through multi-bath chemical processing greater levels of strengthening can be achieved for glass articles. The multi-bath chemical processing can be achieved

through the use of successive chemical baths. The use of multi-bath chemical processing for a glass article can enhance the effectiveness of the chemical strengthening process. Accordingly, glass articles that have undergone multi-bath chemical processing are able to be not only thin but also sufficiently strong and resistant to damage. The strengthened glass articles are well suited for use in consumer products, such as consumer electronic devices (e.g., portable electronic devices).

[0024] Embodiments of the invention can relate to apparatus, systems and methods for improving strength of a thin glass member for a consumer product, such as a consumer electronic device. In one embodiment, the glass member may be an outer surface of a consumer electronic device. For example, the glass member may, for example, correspond to a glass cover that helps form part of a display area of the electronic device (i.e., situated in front of a display either as a separate part or integrated within the display). As another example, the glass member may form a part of a housing for the consumer electronic device (e.g., may form an outer surface other than in the display area). In another embodiment, the glass member may be an inner component of a consumer electronic device. For example, the glass member can be a component glass piece of a LCD display provided internal to the housing of the consumer electronic device.

[0025] The apparatus, systems and methods for improving strength of thin glass are especially suitable for glass covers or displays (e.g., LCD displays), particularly those 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 glass can be thin in these small form factor embodiments, such as less than 3 mm, or more particularly between 0.3 and 2.5 mm. The apparatus, systems and methods can also be used for glass covers or displays for other devices including, but not limited to including, relatively larger form factor electronic devices (e.g., portable computers, tablet computers, displays, monitors, televisions, etc.). The glass can also be thin in

these larger form factor embodiments, such as less than 5 mm, or more particularly between 0.3 and 3 mm.

[0026] Embodiments of the invention are discussed below with reference to FIGs. 1 – 10. 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. The illustrations provided in these figures are not necessarily drawn to scale; instead, the illustrations are presented in a manner to facilitate presentation.

[0027] FIG. 1 is a flow diagram of a glass strengthening process 100 according to one embodiment. The glass strengthening process 100 serves to chemically strengthen a piece of glass such that it is better suited for its particular usage.

[0028] The glass strengthening process 100 can enhance 104 the glass for subsequent chemical strengthening. In one implementation, the glass can be enhanced 104 chemically through chemical processing. Specifically, the glass can be placed in a sodium solution so that sodium ions can migrate from the sodium solution into the glass, namely into the exposed surfaces of the glass.

[0029] After the glass has been enhanced 104, the enhanced glass can be chemically strengthened 106. In one implementation, the enhanced glass can be chemically strengthened 106 through chemical processing. Specifically, the enhanced glass can be placed in a potassium solution so that potassium ions from the potassium solution can be exchanged for sodium ions within the enhanced glass.

[0030] By enhancing 104 the glass, the glass becomes more susceptible to chemical strengthening 106. In other words, the glass can be strengthened to a greater extent when the glass has been enhanced 104. Following block 106, the piece of glass has been chemically strengthened. Due to the enhancement of the glass, the glass is able to be chemically strengthened to a greater extent.

Following the chemical strengthening, the glass strengthening process 100 can end.

[0031] FIG. 2 illustrates a glass strengthening system 200 according to one embodiment. The glass strengthening system 200 receives a glass article 202 to be strengthened through chemical processing. The glass article 202 is provided to a first bath station in which a first bath 204 is provided. The glass article 202 can be inserted (e.g., immersed) into the first bath 204 which includes a sodium solution 206. Next, the glass article 202 is removed from the first bath station and provided to a second bath station. The second bath station provides a second bath 208. The glass article can be inserted (e.g., immersed) into the second bath 208 which includes a potassium solution 210. Later, the glass article 202 is removed from the second bath 208. At this point, the glass article has been first enhanced and then strengthened. Since the glass article was enhanced, the glass article is able to be chemically strengthened to a greater extent than would otherwise have been determined if the glass article were not first enhanced.

[0032] Furthermore, following removal of the glass article from the second bath 208, post-processing can be performed on the glass article. Post-processing can vary widely dependent on intended application for the glass article. However, post-processing can, for example, include one or more of rinsing, polishing, annealing and the like.

[0033] The sodium solution 206 within the first bath 204 can be heated to a predetermined temperature, and the glass article 202 can be immersed within the first bath 204 for a predetermined period of time. The degree of enhancement of the glass article 202 is dependent on: (1) type of glass, (2) concentration of bath (e.g., Na concentration), (3) time in the first bath 204, and (4) temperature of the first bath 204. Likewise, the potassium solution 210 within the second bath 208 can heated to a predetermined temperature, and the glass article 202 can be immersed within the second bath 208 for a predetermined period of time. The

degree of chemically strengthening provided by the second bath 208 to the glass article is dependent on: (1) type of glass, (2) concentration of bath (e.g., K concentration), (3) time in the second bath 208, and (4) temperature of the second bath 208.

[0034] In one implementation, the glass for the glass article can, for example, be alumina silicate glass or soda lime glass. Also, glass from different suppliers, even if the same type of glass, can have different properties and thus may require different values. The first bath 204 can be a sodium (Na) bath or a sodium nitrate ($NaNO_3$) bath, in either case with a sodium concentration of 30% - 100% mol. In another embodiment the first bath 204 can be a sodium nitrate ($NaNO_3$) and potassium nitrate (KNO_3) bath The time for the glass article 202 to remain immersed in the first bath 204 can be about 4-8 hours and the temperature for the first bath 204 can be about 350 – 450 degrees Celsius. The time for the glass article 202 to remain immersed in the second bath 208 can be about 6-20 hours and the temperature for the second bath 208 can be about 300 – 500 degrees Celsius.

[0035] FIG. 3 is a flow diagram of a glass piece process 300 according to one embodiment. The glass piece process 300 serves to process a piece of glass such that is more suitable for subsequent use in a consumer product.

[0036] The glass piece process 300 initially obtains 302 a piece of glass. The glass piece can be submerged 304 in a heated sodium bath. A decision 306 can then determine whether the glass piece should be removed from the heated sodium bath. For example, the heated sodium bath can be maintained at a predetermined temperature and the glass piece can be submerged within the heated sodium that for a predetermined period of time. As an example, the decision 306 can determine that the glass piece should be removed from the heated sodium bath after the glass piece has been immersed in the heated sodium bath for the predetermined amount of time.

[0037] Once the decision 306 determines that the glass piece is to be removed from the heated sodium bath, the glass piece can then be submerged 308 into a heated potassium bath. A decision 310 can then determine whether the glass piece should be removed from the heated potassium bath. The heated potassium bath can, for example, be maintained at a predetermined temperature and the glass piece can be submerged within the heated potassium bath for a predetermined period of time.

[0038] Once the decision 310 determines that the glass piece is to be removed from the potassium bath, post-processing on the glass piece can be performed 312. The post-processing can vary depending upon application. For example, the post-processing can include one or more of: polishing, grinding, heating, annealing, cleaning and the like for the glass piece. Typically, the post-processing is performed on the glass piece to make the glass piece more suitable for its intended usage.

[0039] Following the performing 312 of the post-processing, the glass piece can be utilized 314 in a consumer product. The glass piece can be used as an outer portion of a housing for the consumer product, or can be used as an internal component (e.g., LCD glass panel) glass piece. For example, the consumer product can be a consumer electronics product, such as a portable electronic device. Following the block 314, the glass piece process 300 can end.

[0040] The predetermined temperature for use with the heated potassium bath can be the same or different than the predetermined temperature for use with the heated sodium bath. The predetermined period of time for use with the heated potassium bath can be the same or different than the predetermined period of time for use with the heated sodium bath. For example, the glass piece can be immersed in a heated sodium bath at a temperature of about 350 – 450 degrees Celsius for a predetermined amount of time of about 4-8 hours. Also, for example, the glass piece can be immersed in a heated potassium bath at a

temperature of about 300 – 500 degrees Celsius for a predetermined amount of time of about 6-20 hours.

[0041] According to another embodiment, glass processing can further include an additional bath. The additional bath can be provided to provide a small amount of back exchange of ions at the surfaces of a glass piece (glass article). The back exchange can serve to exchange potassium ions from the glass piece for sodium ions. This back exchange process can be useful to more a compressive maximum inward from the outer edges (10-70 micrometers) as defects or cracks proximate the edges reside slightly inward from the edges and are weak points that render the glass piece more susceptible to causing damage to the glass member.

[0042] FIG. 4 illustrates a glass strengthening system 400 according to another embodiment. The glass strengthening system 400 receives a glass article 402 to be strengthened through chemical processing. The glass article 402 is provided to a first bath station where a first bath 404 is provided. The glass article 402 can be inserted (e.g., immersed) into the first bath 404 which includes a sodium solution 406. Next, the glass article 402 is removed from the first bath station and provided to a second bath station. The second bath station provides a second bath 408. The glass article can be inserted (e.g., immersed) into the second bath 408 which includes a potassium solution 410. Later, the glass article 402 is removed from the second bath 408. At this point, the glass article has been first enhanced and then strengthened. Since the glass article was enhanced, the glass article is able to be chemically strengthened to a greater extent.

[0043] Additionally, after the glass article 402 has been removed from the second bath 408, the glass article can be provided to a third bath station where a third bath 412 is provided. The glass article 402 can be inserted (e.g., immersed) into the third bath 412 which includes a sodium solution 414. Here, potassium ions from the glass article exchange with sodium ions in the sodium solution.

This can be referred to as a back exchange because some ions previously exchanged with the glass article are effectively unexchanged or returned. Subsequently, the glass article 402 is removed from the third bath 412.

[0044] The sodium solution 406 within the first bath 404 can be heated to a predetermined temperature, and the glass article 402 can be immersed within the first bath 404 for a predetermined period of time. The degree of enhancement of the glass article is dependent on at least: (1) type of glass, (2) concentration of bath (e.g., Na concentration), (3) time in the first bath 402, and (4) temperature of the first bath 402. Likewise, the potassium solution 410 within the second bath 408 can heated to a predetermined temperature, and the glass article 402 can be immersed within the second bath 408 for a predetermined period of time. Still further, the sodium solution 414 within the third bath 412 can heated to a predetermined temperature, and the glass article 402 can be immersed within the third bath 412 for a predetermined period of time.

[0045] The predetermined period of time for use with the second bath 408 can be the same or different than the predetermined period of time for use with the first bath 404 or the third bath 412. The predetermined period of time for use with the third bath 412 can be the same or different than the predetermined period of time for use with the first bath 404 or the second bath 408. Typically, the predetermined period of time for use with the third bath 412 is substantially less than the predetermined period of time for use with the first bath 404.

[0046] Furthermore, following removal of the glass article from the third bath 412, post-processing can be performed on the glass article. Post-processing can vary widely dependent on intended application for the glass article. However, post-processing can, for example, include one or more of rinsing, polishing, annealing and the like.

[0047] The sodium solution 406 within the first bath 404 can be heated to a predetermined temperature, and the glass article 402 can be immersed within the first bath 404 for a predetermined period of time. The degree of enhancement of

the glass article 402 is dependent on: (1) type of glass, (2) concentration of bath (e.g., Na concentration), (3) time in the first bath 404, and (4) temperature of the first bath 404. Likewise, the potassium solution 410 within the second bath 408 can heated to a predetermined temperature, and the glass article 402 can be immersed within the second bath 408 for a predetermined period of time. The degree of chemically strengthening provided by the second bath 408 to the glass article is dependent on: (1) type of glass, (2) concentration of bath (e.g., K concentration), (3) time in the second bath 408, and (4) temperature of the second bath 408.

[0048] In one implementation, the glass for the glass article can, for example, be alumina silicate glass or soda lime glass. Also, glass from different suppliers, even if the same type of glass, can have different properties and thus may require different values. The first bath 404 can be a sodium (Na) bath or a sodium nitrate (NaNO3) bath, in either case with a sodium concentration of 30% - 100% mol. The time for the glass article 402 to remain immersed in the first bath 404 can be about 4-8 hours and the temperature for the first bath 404 can be about 350 – 450 degrees Celsius. The time for the glass article 402 to remain immersed in the second bath 408 can be about 6-20 hours and the temperature for the second bath 408 can be about 300 – 500 degrees Celsius. The third bath 412 can be a sodium (Na) bath or a sodium nitrate (NaNO3) bath, in either case with a sodium concentration of 30% - 100% mol. The time for the glass article 402 to remain immersed in the third bath 412 can be about 1-30 minutes and the temperature for the third bath 412 can be about 350 – 450 degrees Celsius.

[0049] FIG. 5 is a flow diagram of a back exchange process 500 according to one embodiment. The back exchange process 500 provides additional, optional processing that can be used with the glass piece process 300 illustrated in FIG. 3. For example, the back exchange process 500 can be optionally used following block 310 and prior to block 312 of the glass piece process 300.

[0050] The back exchange process 500 provides an additional bath for providing back exchange of sodium into the glass piece. According to the back exchange process 500, the glass piece can be submerged 502 into a heated sodium bath. A decision 504 can then determine whether the glass piece should be removed from the heated sodium bath. For example, the heated sodium bath can be maintained at a predetermined temperature and the glass piece can be submerged within the heated sodium bath for a predetermined period of time. As an example, the decision 504 can determine that the glass piece should be removed from the heated sodium bath after the glass piece has been immersed in the heated sodium bath for the predetermined amount of time.

[0051] Once the decision 504 determines that the glass piece is to be removed from the heated sodium bath, the processing of the glass piece can then return to perform pre-processing at block 312 and subsequent operations of the glass piece process 300 illustrated in FIG. 3.

[0052] In the back exchange process 500, the heated sodium bath can be heated to a predetermined temperature, and the glass piece can be immersed within the heated sodium bath for a predetermined period of time. The extent of the back exchange fir the glass piece can be dependent on: (1) type of glass, (2) concentration of bath (e.g., Na concentration), (3) time in the sodium bath, and (4) temperature of the sodium bath. In one implementation, the glass for the glass piece can, for example, be alumina silicate glass or soda lime glass. Also, glass from different suppliers, even if the same type of glass, can have different properties and thus may require different values. The heated sodium bath can be a sodium (Na) bath or a sodium nitrate ($NaNO_3$) bath, in either case with a sodium concentration of 30% - 100% mol. The predetermined period of time for the glass piece to remain immersed in the heated sodium bath for back exchange can be about 1-30 minutes and the temperature for the heated sodium bath can be about 350 – 450 degrees Celsius.

[0053] As previously discussed, glass covers can be used as an outer surface of portions of a housing for electronic devices, such as portable electronic devices. Those portable electronic devices that are small and highly portable can be referred to as handheld electronic devices. A handheld electronic device may, for example, function as a media player, phone, internet browser, email unit or some combination of two or more of such. A handheld electronic device generally includes a housing and a display area.

[0054] FIGs. 6A and 6B are diagrammatic representations of electronic device 600 according to one embodiment. FIG. 6A illustrates a top view for the electronic device 600, and FIG. 6B illustrates a cross-sectional side view for electronic device 600 with respect to reference line A-A'. Electronic device 600 can include housing 602 that has glass cover window 604 (glass cover) as a top surface. Cover window 604 is primarily transparent so that display assembly 606 is visible through cover window 604. Cover window 604 can be chemically strengthened using the multi-bath chemical processing described herein. Display assembly 606 can, for example, be positioned adjacent cover window 604. Housing 602 can also contain internal electrical components besides the display assembly, such as a controller (processor), memory, communications circuitry, etc. Display assembly 606 can, for example, include a LCD module. By way of example, display assembly 606 may include a Liquid Crystal Display (LCD) that includes a Liquid Crystal Module (LCM). In one embodiment, cover window 604 can be integrally formed with the LCM. Housing 602 can also include an opening 608 for containing the internal electrical components to provide electronic device 600 with electronic capabilities. In one embodiment, housing 602 may need not include a bezel for cover window 604. Instead, cover window 604 can extend across the top surface of housing 602 such that the edges of cover window 604 can be aligned (or substantially aligned) with the sides of housing 602. The edges of cover window 604 can remain exposed. Although the edges of cover window 604 can be exposed as shown in FIGs. 6A and 6B, in alternative embodiment, the edges can be further protected. As one example, the edges of cover window 604 can be recessed (horizontally or vertically) from the outer

sides of housing 602. As another example, the edges of cover window 604 can be protected by additional material placed around or adjacent the edges of cover window 604.

[0055] Cover window 604 may generally be arranged or embodied in a variety of ways. By way of example, cover window 604 may be configured as a protective glass piece that is positioned over an underlying display (e.g., display assembly 606) such as a flat panel display (e.g., LCD) or touch screen display (e.g., LCD and a touch layer). Alternatively, cover window 604 may effectively be integrated with a display, *i.e.*, glass window may be formed as at least a portion of a display. Additionally, cover window 604 may be substantially integrated with a touch sensing device such as a touch layer associated with a touch screen. In some cases, cover window 604 can serve as the outer most layer of the display.

[0056] FIGs. 7A and 7B are diagrammatic representations of electronic device 700 according to another embodiment of the invention. FIG. 7A illustrates a top view for electronic device 700, and FIG. 7B illustrates a cross-sectional side view for electronic device 700 with respect to reference line B-B'. Electronic device 700 can include housing 702 that has glass cover window 704 (glass cover) as a top surface. In this embodiment, cover window 704 can be protected by side surfaces 703 of housing 702. Here, cover window 704 does not fully extend across the top surface of housing 702; however, the top surface of side surfaces 703 can be adjacent to and aligned vertically with the outer surface of cover window 704. Since the edges of cover window 704 can be rounded for enhanced strength, there may be gaps 705 that are present between side surfaces 703 and the peripheral edges of cover window 704. Gaps 705 are typically very small given that the thickness of cover window 704 is thin (e.g., less than 3 mm). However, if desired, gaps 705 can be filled by a material. The material can be plastic, rubber, metal, etc. The material can conform in gap 705 to render the entire front surface of electronic device 700 flush, even across gaps 705 proximate the peripheral edges of cover window 704. The material filling gaps 705 can be compliant. The material placed in gaps 705 can implement a

gasket. By filling the gaps 705, otherwise probably undesired gaps in the housing 702 can be filled or sealed to prevent contamination (e.g., dirt, water) forming in the gaps 705. Although side surfaces 703 can be integral with housing 702, side surface 703 could alternatively be separate from housing 702 and, for example, operate as a bezel for cover window 704.

[0057] Cover window 704 is primarily transparent so that display assembly 706 is visible through cover window 704. Display assembly 706 can, for example, be positioned adjacent cover window 704. Housing 702 can also contain internal electrical components besides the display assembly, such as a controller (processor), memory, communications circuitry, etc. Display assembly 706 can, for example, include a LCD module. By way of example, display assembly 706 may include a Liquid Crystal Display (LCD) that includes a Liquid Crystal Module (LCM). In one embodiment, cover window 704 is integrally formed with the LCM. Housing 702 can also include an opening 708 for containing the internal electrical components to provide electronic device 700 with electronic capabilities.

[0058] The front surface of electronic device 700 can also include user interface control 708 (e.g., click wheel control). In this embodiment, cover window 704 does not cover the entire front surface of electronic device 700. Electronic device 700 essentially includes a partial display area that covers a portion of the front surface.

[0059] Cover window 704 may generally be arranged or embodied in a variety of ways. By way of example, cover window 704 may be configured as a protective glass piece that is positioned over an underlying display (e.g., display assembly 706) such as a flat panel display (e.g., LCD) or touch screen display (e.g., LCD and a touch layer). Alternatively, cover window 704 may effectively be integrated with a display, *i.e.*, glass window may be formed as at least a portion of a display. Additionally, cover window 704 may be substantially integrated with a touch sensing device such as a touch layer associated with a touch screen. In some cases, cover window 704 can serve as the outer most layer of the display.

[0060] As noted above, the electronic device can be a handheld electronic device or a portable electronic device. The invention can serve to enable a glass cover to be not only thin but also adequately strong. 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 glass surfaces for handheld electronic device or a portable electronic device that are designed to be thin.

[0061] The strengthened glass, e.g., glass covers or cover windows, is particularly useful for thin glass applications. For example, the thickness of a glass cover being strengthen can be between about 0.5 – 2.5 mm. In other embodiments, the strengthening is suitable for glass products whose thickness is less than about 2 mm, or even thinner than about 1 mm, or still even thinner than about 0.6 mm.

[0062] Chemically strengthening glass, e.g., glass covers or cover windows, can be more effective for edges of glass that are rounded by a predetermined edge geometry having a predetermined curvature (or edge radius) of at least 10% of the thickness applied to the corners of the edges of the glass. In other embodiments, the predetermined curvature can be between 20% to 50% of the thickness of the glass. A predetermined curvature of 50% can also be considered a continuous curvature, one example of which is illustrated in FIG. 3E.

[0063] 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 size of the glass cover is often not more than five (5) inches (about 12.7 cm) diagonal. As another example, for portable electronic devices, such as smaller portable computers or tablet computers, the size of the glass cover is often between four (4) (about 10.2 cm) to twelve (12) inches (about 30.5 cm) diagonal. As still another example, for portable electronic devices, such as full size portable

computers, displays (including televisions) or monitors, the size of the glass cover is often between ten (10) (about 25.4 cm) to twenty (20) inches (about 50.8 cm) diagonal or even larger.

[0064] 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 0.3 mm for small handheld electronic devices, about 0.5 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. However, more generally, the thickness of the glass cover can depend on the application and/or the size of electronic device.

[0065] As discussed above, glass cover or, more generally, a glass piece may be chemically treated such that surfaces of the glass are effectively strengthened. Through such strengthening, glass pieces can be made stronger so that thinner glass pieces can be used with consumer electronic device. Thinner glass with sufficient strength allows for consumer electronic device to become thinner.

[0066] FIG. 8 illustrates a process 800 of chemically treating surfaces of a glass piece in accordance with one embodiment. The process 800 can represent processing associated with chemical strengthening at a second bath station or a potassium bath as discussed above, according to one embodiment. The process 800 of chemically treating surfaces, e.g., edges, of a glass piece can begin at step 802 in which the glass piece is obtained. The glass piece may be obtained, in one embodiment, after a glass sheet is singulated into glass pieces, e.g., glass covers, and the edges of the glass pieces are manipulated to have a

predetermined geometry. It should be appreciated, however, that a glass piece that is to be chemically treated may be obtained from any suitable source.

[0067] In step 804, the glass piece can be placed on a rack. The rack is typically configured to support the glass piece, as well as other glass pieces, during chemical treatment. Once the glass piece is placed on the rack, the rack can be submerged in a heated ion bath in step 806. The heated ion bath may generally be a bath which includes a concentration of ions (e.g., Alkali metal ions, such as Lithium, Cesium or Potassium). It should be appreciated that the concentration of ions in the bath may vary, as varying the concentration of ions allows compression stresses on surfaces of the glass to be controlled. The heated ion bath may be heated to any suitable temperature to facilitate ion exchange.

[0068] After the rack is submerged in the heated ion bath, an ion exchange is allowed to occur in step 808 between the ion bath and the glass piece held on the rack. A diffusion exchange occurs between the glass piece, which generally includes Na^+ ions, and the ion bath. During the diffusion exchange, Alkali metal ions, which are larger than Na^+ ions, effectively replace the Na^+ ions in the glass piece. In general, the Na^+ ions near surface areas of the glass piece may be replaced by the Alkali ions, while Na^+ ions are essentially not replaced by Alkali ions in portions of the glass which are not surface areas. As a result of the Alkali ions replacing Na^+ ions in the glass piece, a compressive layer is effectively generated near the surface of the glass piece. The Na^+ ions which have been displaced from the glass piece by the Alkali metal ions become a part of the ion solution.

[0069] A determination can be made in step 810 as to whether a period of time for submerging the rack in the heated ion bath has ended. It should be appreciated that the amount of time that a rack is to be submerged may vary widely depending on implementation. Typically, the longer a rack is submerged, i.e., the higher the exchange time for Alkali metal ions and Na^+ ions, the deeper

the depth of the chemically strengthened layer. For example, with thickness of the glass sheet being on the order of 1 mm, the chemical processing (i.e., ion exchange) provided in the ion bath can be provide into the surfaces of the glass pieces 10 micrometers or more. For example, if the glass pieces are formed from soda lime glass, the depth of the compression layer due to the ion exchange can be about 10 microns. As another example, if the glass pieces are formed from alumino silicate glass, the depth of the compression layer due to the ion exchange can be about 50 microns.

[0070] If the determination in step 810 is that the period of time for submerging the rack in the heated ion bath has not ended, then process 800 flow can return to step 817 in which the chemical reaction is allowed to continue to occur between the ion bath and the glass piece. Alternatively, if it is determined that the period of time for submersion has ended, then the rack can be removed from the ion bath in step 812. Upon removing the rack from the ion bath, the glass piece may be removed from the rack in step 814, and the process 800 of chemically treating surfaces of a glass piece can be completed. However, if desired, the glass piece can be polished. Polishing can, for example, remove any haze or residue on the glass piece following the chemical treatment.

[0071] A glass cover which has undergone a chemical strengthening process generally includes a chemically strengthened layer, as previously mentioned. FIG. 9A is a cross-sectional diagram of a glass cover which has been chemically treated such that a chemically strengthened layer is created according to one embodiment. A glass cover 900 includes a chemically strengthened layer 928 and a non-chemically strengthened portion 926. Although the glass cover 900 is, in one embodiment, subjected to chemical strengthening as a whole, the outer surfaces receive the strengthening. The effect of the strengthening is that the non-chemically strengthened portion 926 is in tension, while the chemically strengthened layer 928 is in compression. While glass cover 900 is shown as having a rounded edge geometry 902, it should be appreciated that glass cover 900 may generally have any edge geometry, though rounded geometries at

edges may allow for increased strengthening of the edges of glass cover 900. Rounded edge geometry 902 is depicted by way of example, and not for purposes of limitation.

[0072] Chemically strengthened layer 928 has a thickness (y) which may vary depending upon the requirements of a particular system in which glass cover 900 is to be utilized. Non-chemically strengthened portion 926 generally includes Na^+ ions 934 but no Alkali metal ions 936. A chemical strengthening process causes chemically strengthened layer 928 to be formed such that chemically strengthened layer 928 includes both Na^+ ions 934 and Alkali metal ions 936.

[0073] FIG. 10 is a diagrammatic representation of a chemical treatment process that involves submerging a glass cover in an ion bath according to one embodiment. When glass cover 1000, which is partially shown in cross-section, is submerged or soaked in a heated ion bath 1032, diffusion occurs. As shown, Alkali metal ions 1034 which are present in glass cover 1000 diffuse into ion bath 1032 while Alkali metal ions 1036 (e.g., potassium (K)) in ion bath 1032 diffuse into glass cover 1000, such that a chemically strengthened layer 1028 is formed. In other words, Alkali metal ions 1036 from ion bath 1032 can be exchanged with Na^+ ions 1034 to form chemically strengthened layer 1028. Alkali metal ions 1036 typically would not diffuse into a center portion 1026 of glass cover 1000. By controlling the duration (i.e., time) of a chemical strengthening treatment, temperature and/or the concentration of Alkali metal ions 1036 in ion bath 1032, the thickness (y) of chemically strengthened layer 1028 may be substantially controlled.

[0074] The concentration of Alkali metal ions in an ion bath may be varied while a glass cover is soaking in the ion bath. In other words, the concentration of Alkali metal ions in a ion bath may be maintained substantially constant, may be increased, and/or may be decreased while a glass cover is submerged in the ion bath without departing from the spirit or the scope of the present invention. For example, as Alkali metal ions displace Na^+ ions in the glass, the Na^+ ions become part of the ion bath. Hence, the concentration of Alkali metal ions in the

ion bath may change unless additional Alkali metal ions are added into the ion bath.

[0075] The techniques describe herein may be applied to glass surfaces used by any of a variety of electronic devices including but not limited handheld electronic devices, portable electronic devices and substantially stationary electronic devices. Examples of these include any known consumer electronic device that includes a display. By way of example, and not by way of limitation, the electronic device may correspond to media players, mobile phones (e.g., cellular phones), PDAs, remote controls, notebooks, tablet PCs, monitors, all in one computers and the like.

[0076] The various aspects, features, embodiments or implementations of the invention described above can be used alone or in various combinations.

[0077] Additional details on strengthening edges of glass articles can be found in: (i) U.S. Provisional Patent Application No. 61/156,803, filed March 2, 2009 and entitled "Techniques for Strengthening Glass Covers for Portable Electronic Devices", which is herein incorporated by reference; and (ii) International Patent Application No. PCT/US2010/025979, filed March 2, 2010 and entitled "Techniques for Strengthening Glass Covers for Portable Electronic Devices", which is herein incorporated by reference.

[0078] Additional details on chemical strengthening processing using different chemical baths can be found in U.S. Provisional Patent Application No. 61/301,585, filed February 4, 2010 and entitled "Techniques for Strengthening Glass Covers for Portable Electronic Devices," which is hereby incorporated herein by reference.

[0079] Although only a few embodiments of the invention have been described, it should be understood that the invention may be embodied in many other specific forms without departing from the spirit or the scope of the present invention. By way of example, the steps associated with the methods of the

invention may vary widely. Steps may be added, removed, altered, combined, and reordered without departing from the spirit of the scope of the invention. Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results.

[0080] While this specification contains many specifics, these should not be construed as limitations on the scope of the disclosure or of what may be claimed, but rather as descriptions of features specific to particular embodiment of the disclosure. Certain features that are described in the context of separate embodiments can also be implemented in combination. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination.

[0081] While this invention has been described in terms of several embodiments, there are alterations, permutations, and equivalents, which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.

What is claimed is:

CLAIMS

1. A method for strengthening a piece of glass, said method comprising:

obtaining a piece of glass that is to be chemically strengthened;

enhancing the glass to make it more susceptible to chemical strengthening; and

subsequently chemically strengthening the enhanced glass.

2. A method as recited in claim 1, wherein the enhancing of the glass comprises placing the glass in a sodium solution.

3. A method as recited in claim 1, wherein the chemically strengthening of the enhanced glass comprises placing the enhanced glass in a potassium solution.

4. A method as recited in claim 3, wherein the enhancing of the glass comprises placing the glass in a sodium solution.

5. A method as recited in claim 1, wherein the enhancing of the glass allows the chemical strengthening to be more effective.

6. A method as recited in any of claims 1-5, wherein the piece of glass has a thickness of not more than about 1.0 mm.

7. A glass strengthening system for glass articles, comprising:

a first bath station providing a sodium solution, the first bath station serving to receive a glass article and to introduce sodium ions into surfaces of the glass article; and

a second bath station providing a potassium solution, the second bath station serving to receive the glass article following the first bath station and to exchange potassium ions for sodium ions within the glass article.

8. A glass strengthening system as recited in claim 7,

wherein the sodium solution is heated to a first predetermined temperature, and

wherein the potassium solution is heated to a second predetermined temperature.

9. A glass strengthening system as recited in claim 7, wherein the glass article is alumina silicate glass.

10. A glass strengthening system as recited in any of claims 7-9, wherein the glass article has a thickness of not more than about 1.0 mm.

11. A glass strengthening system as recited in any of claims 7-9, wherein the glass strengthening system comprising:

a third bath station providing a sodium solution, the third bath station serving to receive the glass article following the second bath station and to re-introduce sodium ions for potassium ions into surfaces of the glass article.

12. A method for processing a glass piece to improve its strength, the method comprising:

submerging the glass piece in a heated sodium bath;

determining whether the glass piece should be removed from the heated sodium bath;

subsequently submerging the glass piece in a heated potassium bath;

determining whether the glass piece should be removed from the heated potassium bath; and

performing post-processing on the glass piece following removal of the glass piece from the heated potassium bath.

13. A method as recited in claim 12, wherein the method further comprises:

attaching the glass piece to a consumer electronic product.

14. A method as recited in claim 13, wherein the glass piece serves as a portion of an outer surface of a housing for the consumer electronic product.

15. A method as recited in claim 12, wherein the method further comprises:

attaching the glass piece to a portable electronic device, the glass piece serving as a portion of an outer surface of a housing of the portable electronic device.

16. A method as recited in claim 12, wherein the method further comprises:

utilizing the glass piece in a portable electronic device.

17. A method as recited in any of claims 12-16, wherein the glass piece has a thickness of not more than about 1.0 mm.

18. A method as recited in claim 17, wherein the glass piece is a cover glass for a portable electronic device.

19. A method as recited in any of claims 12-16, wherein the method further comprises:

submerging the glass piece in an additional heated sodium bath after removal of the glass piece from the heated potassium bath and prior to performing the post-processing; and

determining whether the glass piece should be removed from the additional heated sodium bath.

20. A glass strengthening control system for glass articles, comprising:

means for submerging the glass piece in a heated sodium bath;

means for removing the glass piece from the heated sodium bath after being in the heated sodium solution for a first duration;

means for subsequently submerging the glass piece in a heated potassium bath;

means for removing the glass piece from the heated potassium bath after being in the heated potassium solution for a second duration; and

means for performing post-processing on the glass piece following removal of the glass piece from the heated potassium bath.

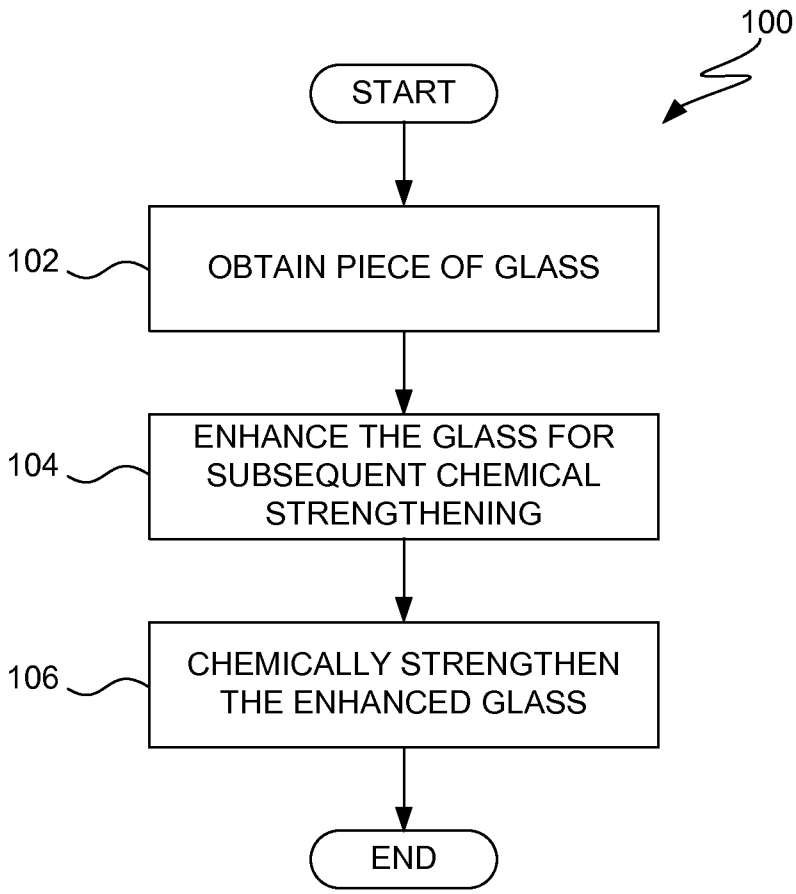
100
START
102
OBTAIN PIECE OF GLASS
104
ENHANCE THE GLASS FOR SUBSEQUENT CHEMICAL STRENGTHENING
106
CHEMICALLY STRENGTHEN THE ENHANCED GLASS
END

FIG. 1

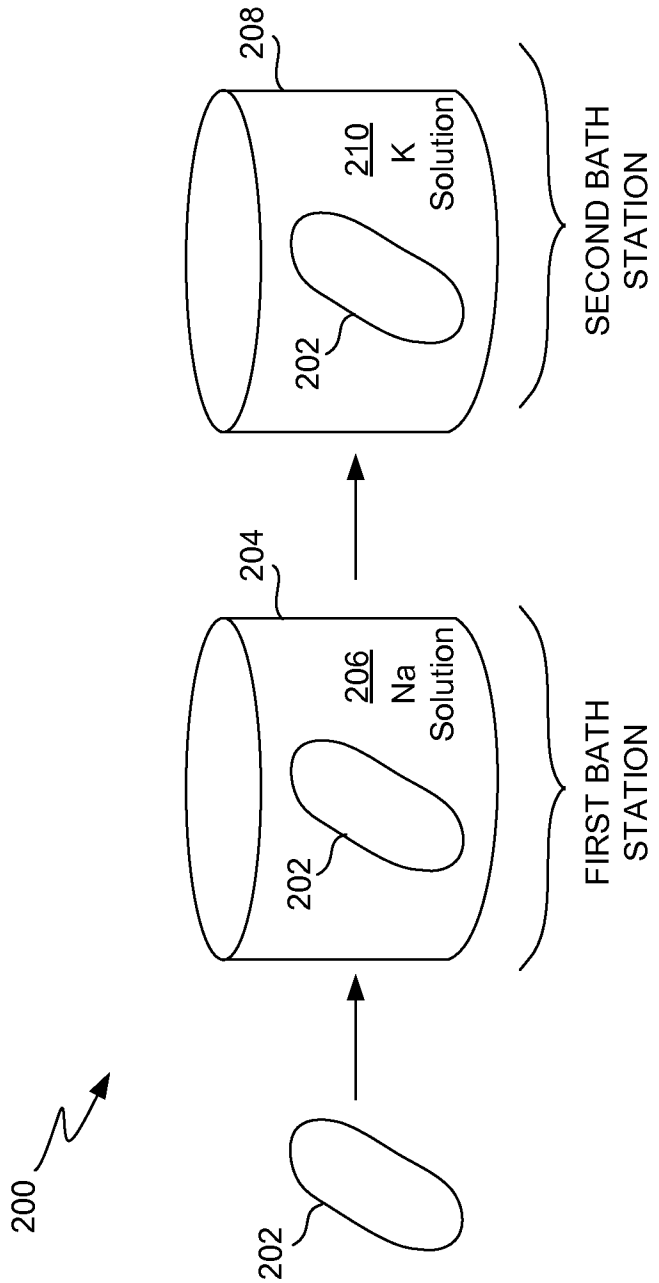
200
202
204
206
Na
Solution
202
FIRST BATH
STATION
208
210
K
Solution
202
SECOND BATH
STATION

FIG. 2

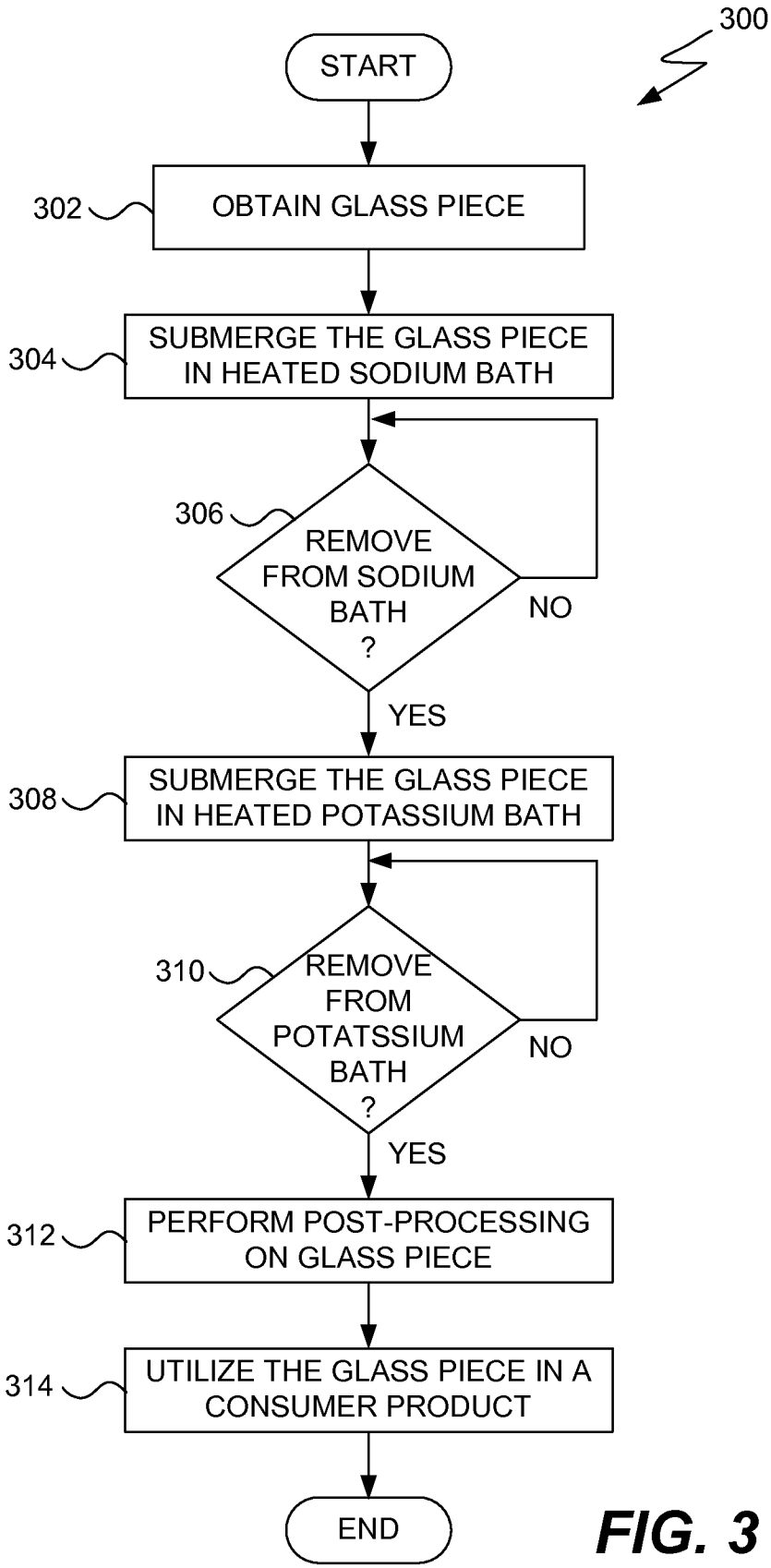
300
START
302
OBTAIN GLASS PIECE
304
SUBMERGE THE GLASS PIECE IN HEATED SODIUM BATH
306
REMOVE FROM SODIUM BATH ?
NO
YES
308
SUBMERGE THE GLASS PIECE IN HEATED POTASSIUM BATH
310
REMOVE FROM POTATSSIUM BATH ?
NO
YES
312
PERFORM POST-PROCESSING ON GLASS PIECE
314
UTILIZE THE GLASS PIECE IN A CONSUMER PRODUCT
END

FIG. 3

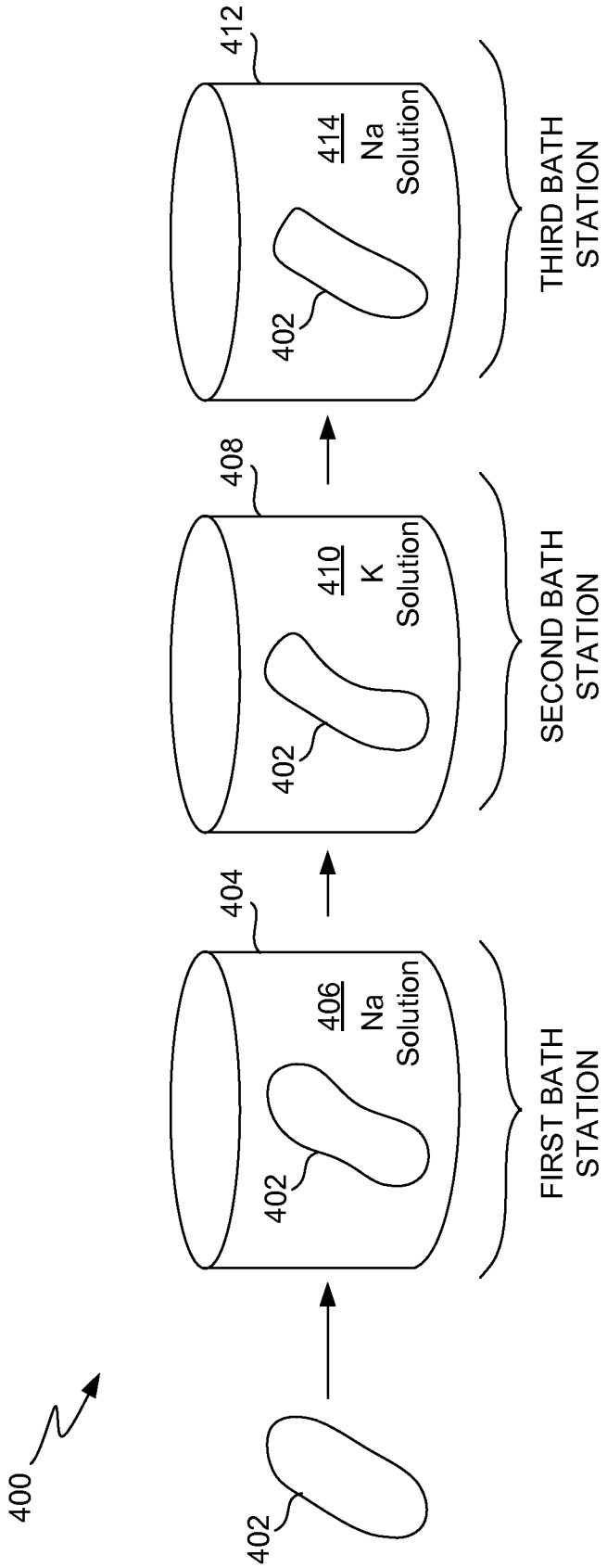
400
402
404
406
Na
Solution
FIRST BATH
STATION
408
410
K
Solution
SECOND BATH
STATION
412
414
Na
Solution
THIRD BATH
STATION

FIG. 4

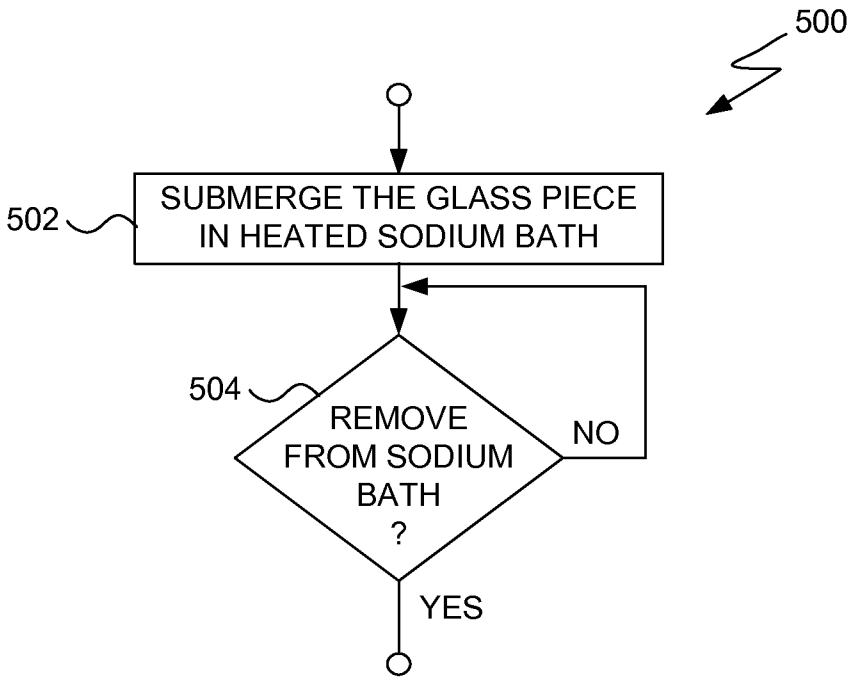
500
SUBMERGE THE GLASS PIECE IN HEATED SODIUM BATH
502
504
REMOVE FROM SODIUM BATH ?
NO
YES

FIG. 5

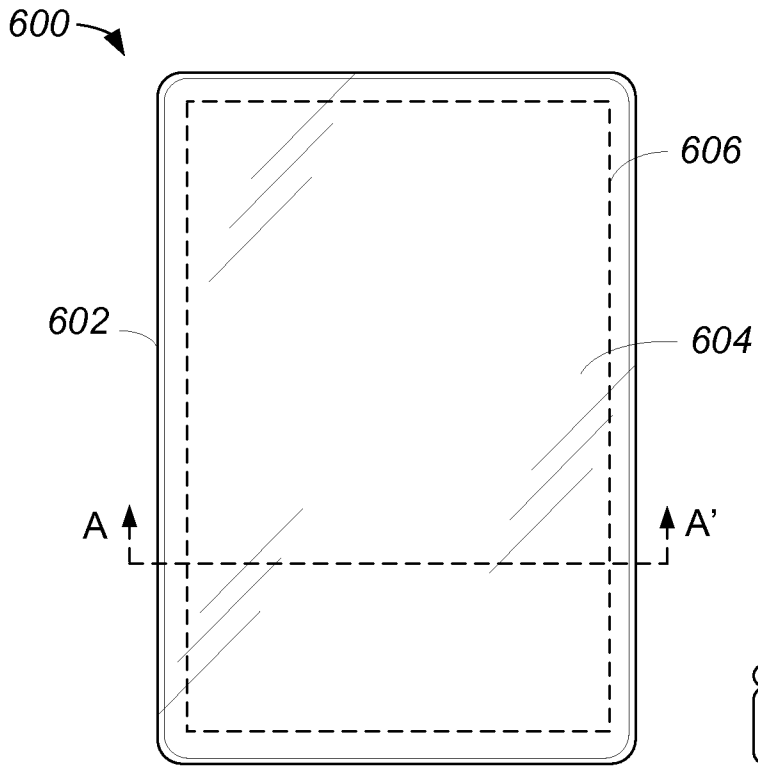

FIG. 6A

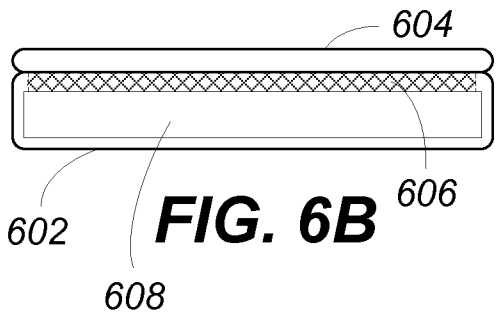

FIG. 6B

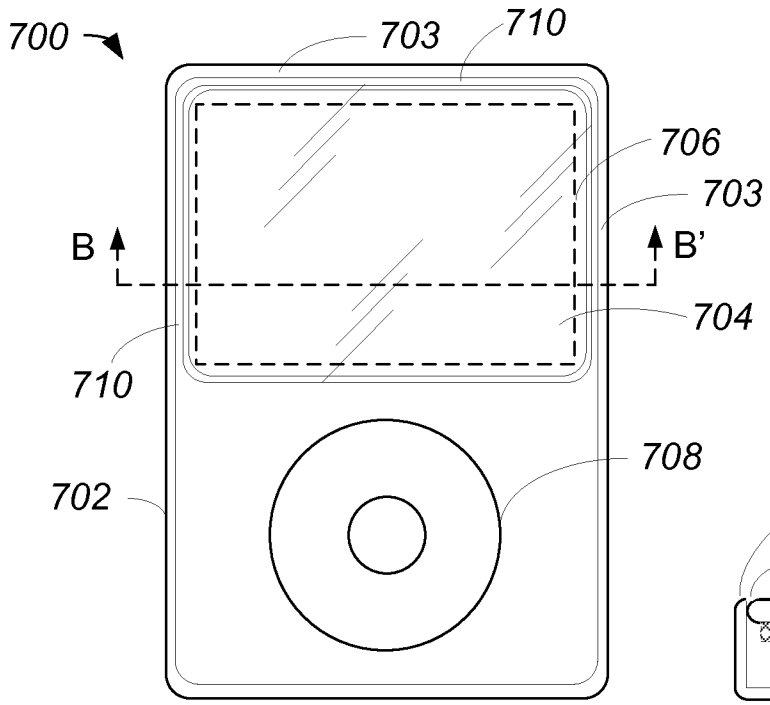

FIG. 7A

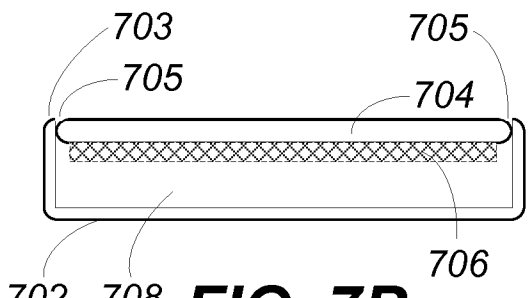

FIG. 7B

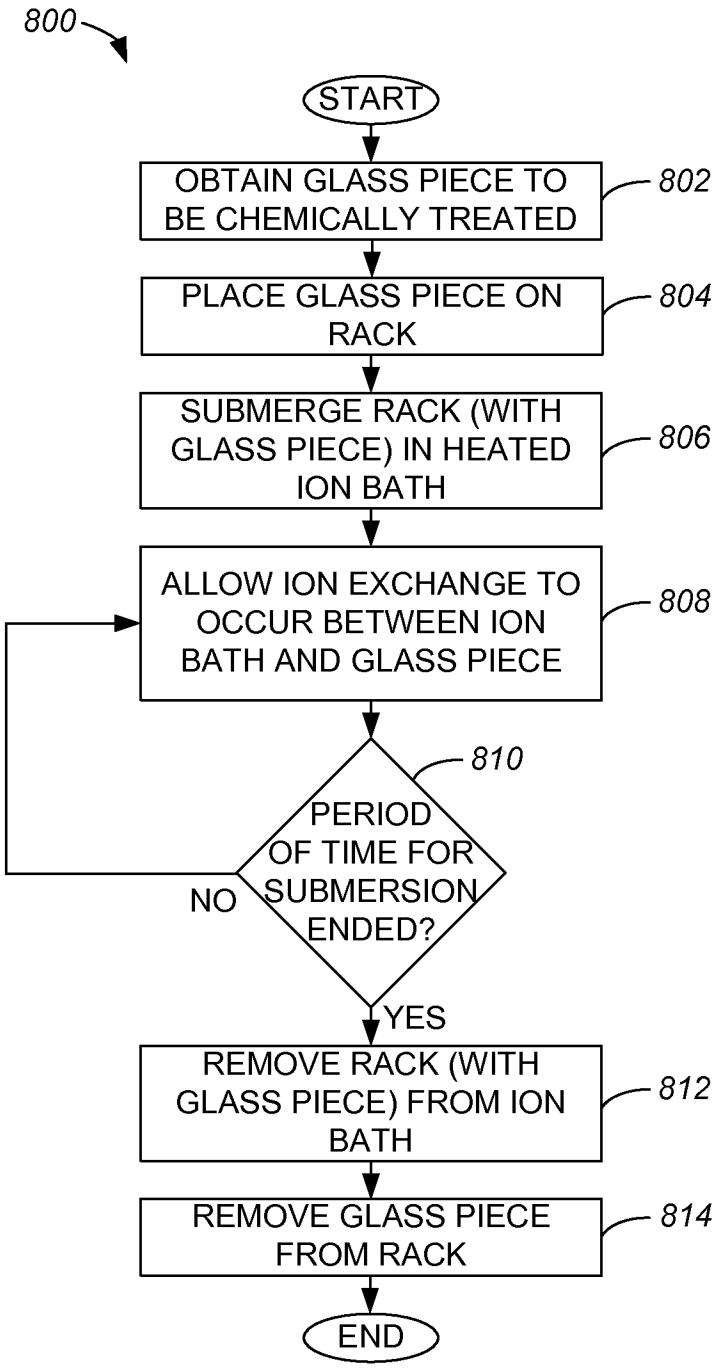
800
START
OBTAIN GLASS PIECE TO BE CHEMICALLY TREATED
802
PLACE GLASS PIECE ON RACK
804
SUBMERGE RACK (WITH GLASS PIECE) IN HEATED ION BATH
806
ALLOW ION EXCHANGE TO OCCUR BETWEEN ION BATH AND GLASS PIECE
808
810
PERIOD OF TIME FOR SUBMERSION ENDED?
NO
YES
REMOVE RACK (WITH GLASS PIECE) FROM ION BATH
812
REMOVE GLASS PIECE FROM RACK
814
END

FIG. 8

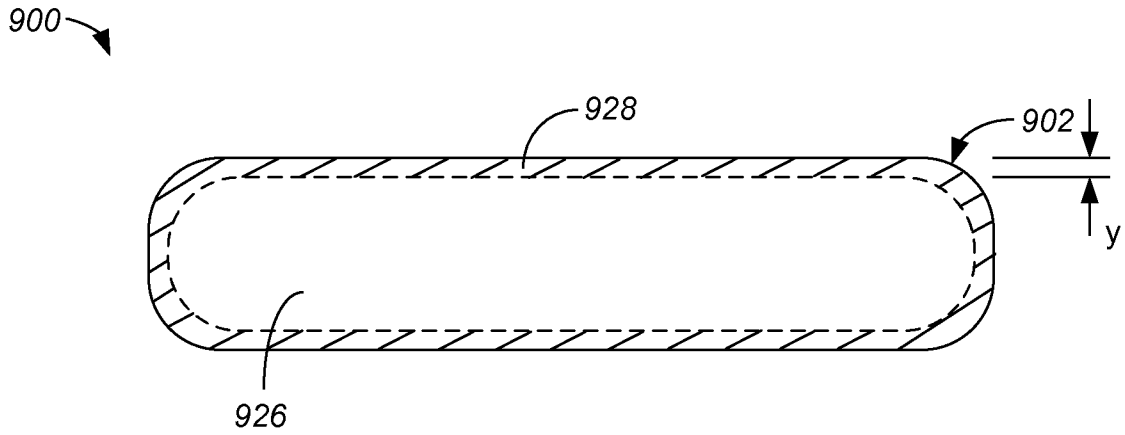
900
928
902
y
926

FIG. 9A

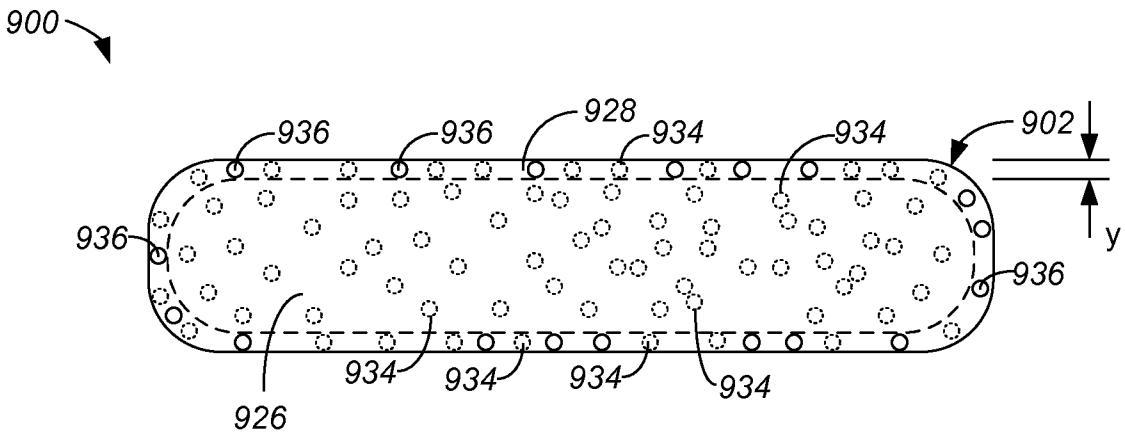
900
936
936
928
934
934
902
y
936
936
934
934
934
934
926

FIG. 9B

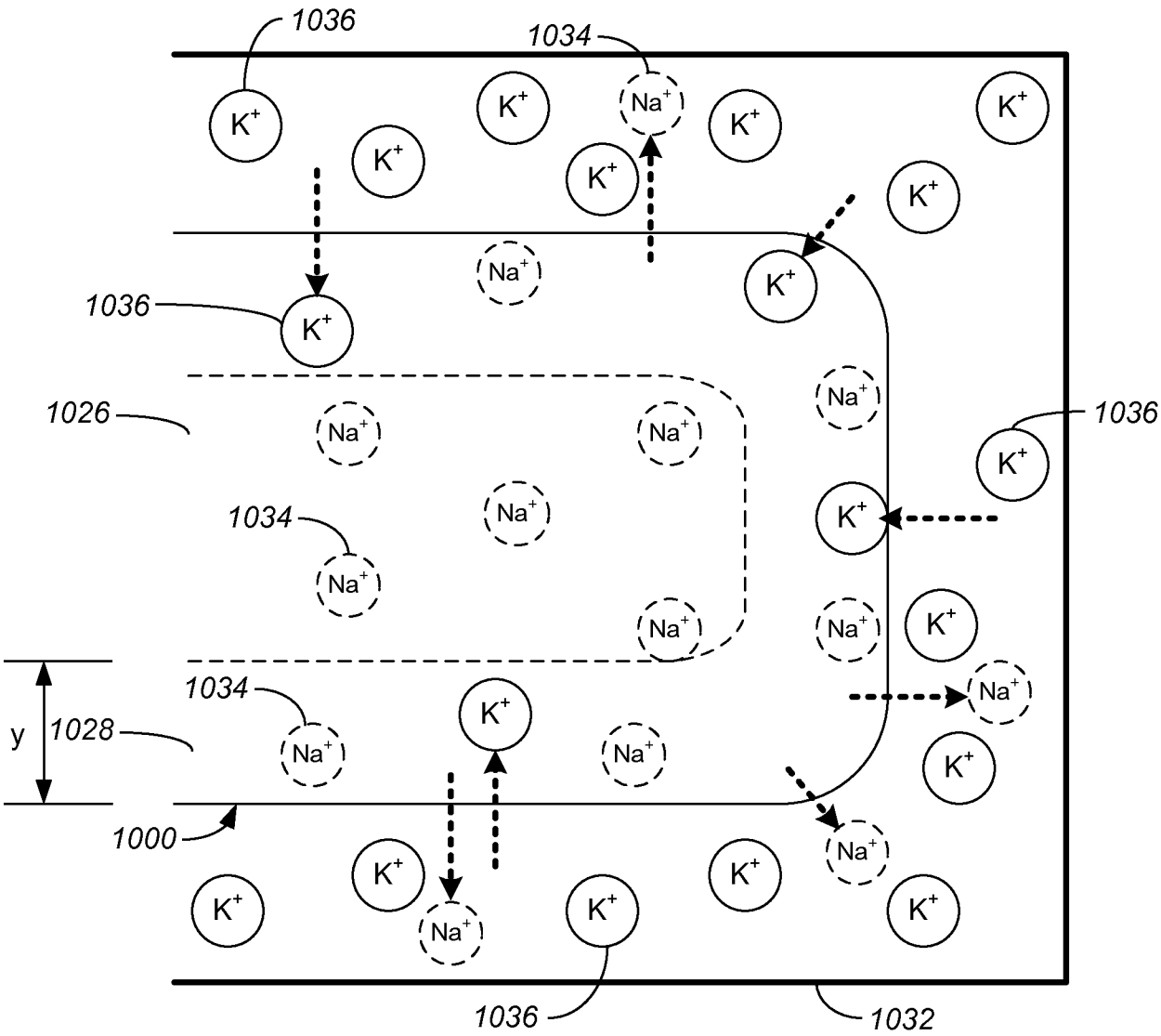

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/047479

A. CLASSIFICATION OF SUBJECT MATTER
INV. C03C21/00 H04M1/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C03C H04M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 798 013 A (HASEGAWA J ET AL) 19 March 1974 (1974-03-19) example 2 -----	1-20
X	DATABASE WPI Week 198817 Thomson Scientific, London, GB; AN 1988-114945 XP002662682, -& JP 63 060129 A (CENTRAL GLASS CO LTD) 16 March 1988 (1988-03-16) abstract; claim 1; examples 1-6; table 1 page 1, left-hand column, paragraph 2 page 3, left-hand column, paragraph 4 ----- -/--	1-20

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 November 2011	11/11/2011

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Flügel, Alexander

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/047479

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"Chemically strengthened glass", Wikipedia , 19 April 2009 (2009-04-19), XP007919663, Retrieved from the Internet: URL:http://en.wikipedia.org/w/index.php?title=Chemically_strengthened_glass&oldid=284794988 [retrieved on 2011-10-28] paragraphs [0002], [0004]	1-5,12, 16
X	GB 1 346 747 A (SAINT GOBAIN) 13 February 1974 (1974-02-13) claim 2	1-5,12, 16
X,P	US 2011/067447 A1 (ZADESKY STEPHEN PAUL [US] ET AL) 24 March 2011 (2011-03-24) claims	1-18
A	WO 00/47529 A1 (UNIV PENNSYLVANIA [US]; GREEN DAVID J [US]; SGLAVO VINCENZO M [IT]; TA) 17 August 2000 (2000-08-17) page 5, lines 14-20; claims 13, 18, 19; example I	9,11,19

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/047479

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 1-20(partially)
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 1-20(partially)

The application does not meet the requirements of Article 6 PCT, because claims 1-20 are not sufficiently supported by the description for the following reasons: The problem underlying the claimed invention is, that display glasses for portable electronic devices need to be relatively thin, which makes them susceptible to breakage, even if the glass is chemically strengthened according to the state of the art (description, paragraphs 1-2). Hence, the technical effect needed to solve the problem is an enhanced strength of the glass, beyond the strength provided by common ion exchange methods (description, paragraph 2). The essential features of the solution claimed by the applicant comprise a two-stage ion exchange process, including a first ion exchange step in a molten salt bath comprising sodium ions at 350-450°C, followed by a second ion exchange step in a molten salt bath comprising potassium ions at 300-500°C (see application as a whole, in particular description, paragraph 34). It is not plausible to a skilled person that the in the application desired technical effect will be achieved by all solutions defined by claims 1-20, and thus all solutions claimed represent solutions to the problem posed in the application, thereby violating Article 6 PCT (support). For instance, the claims are not limited to the temperatures required for an effective ion exchange. Accordingly, the International Search was restricted on the basis of Article 17(2)(b) PCT to the following features: (A) A method according to claim 1 or according to claim 12, the method comprising a first ion exchange step in a molten salt bath comprising sodium ions at 350-450°C, followed by a second ion exchange step in a molten salt bath comprising potassium ions at 300-500°C. (B) A glass strengthening system according to claim 7 or a glass strengthening control system according to claim 20, the system being designed for performing a process according to the method defined in (A).

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.2), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/047479

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