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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 May 2007 (24.05.2007)

PCT

(10) International Publication Number
WO 2007/058451 A1

(51) International Patent Classification:
G02B 3/14 (2006.01)

(21) International Application Number:
PCT/KR2006/004758

(22) International Filing Date:
14 November 2006 (14.11.2006)

(25) Filing Language: Korean

(26) Publication Language: English

(30) Priority Data:
10-2005-0109182
15 November 2005 (15.11.2005) KR

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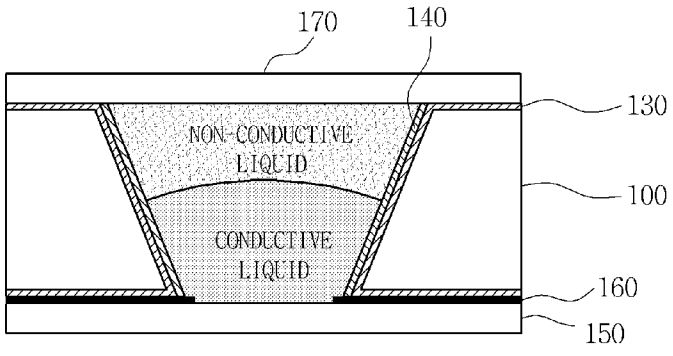
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, 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, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: LIQUID LENS AND A METHOD FOR PRODUCING THE SAME



(57) Abstract: Disclosed are a method for producing a liquid lens capable of forming an electrode and an insulator film more stably through a simple process, and a liquid lens produced by the method. The method according to an embodiment of the present invention comprises steps of providing a silicon substrate having a hole in the center, forming an insulator film on the silicon substrate and coating the insulator film with a hydrophobic film, providing a transparent lower substrate mounted with an electrode on an upper surface thereof, hermetically bonding the silicon substrate onto the lower substrate, putting conductive liquid and non-conductive liquid into a liquid storage enclosed by the hole and the lower substrate, and hermetically bonding the upper substrate onto the silicon substrate.

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Description

LIQUID LENS AND A METHOD FOR PRODUCING THE SAME

Technical Field

[1] The present invention relates to a liquid lens, and more particularly to a method for producing a liquid lens capable of forming more stable electrode and insulator film through a simple process, and a liquid lens produced by the method.

[2]

Background Art

[3] A liquid lens applies the principle of a crystalline lens of a human eye, which adjusts the focus by transforming itself. Since having a relatively simple structure without a mechanical driver, the liquid lens has high reliability and massive productivity. Furthermore, the liquid lens promptly reacts, consumes minor voltage, and can be downsized to less than several millimeters. Therefore, the liquid lens is applied to various fields such as, but not limited to, a digital camera, a camera phone, an endoscope, a security system, and an optical recording apparatus.

[4] The principle of the liquid lens will be described more specifically with reference to FIGS. 1 and 2.

[5] As shown in FIG. 1, when a drop of conductive solution such as water is disposed on a substrate constituted by an insulator and a metal plate, and voltage is applied between the metal plate and the conductive solution drop, hydrophilicity of the insulator is increased. Accordingly, shape of the conductive solution drop on the insulator changes from a dotted-line shape A to a solid-line shape B of FIG. 1. Such a phenomenon is referred to as electrowetting.

[6] Instead of the water drop placed in the air as shown in FIG. 1, oil and water not mixing well with each other and having the same density but different refractive indexes, can also be used to cause the electrowetting. In FIG. 2, with the oil drop submerged in the water, the oil which is non-conductive liquid and the water which is conductive liquid, when voltage is applied, hydrophilicity of the insulator is increased. Accordingly, the shape of the water drop is changed from a solid-line shape A to a dotted-line shape B. Briefly, the electrowetting means changing an contact angle of the conductive liquid and shape of the interface between two liquids, by controlling surface tension of the conductive liquid by applying voltage to the electrode and the conductive liquid from the outside, in a state where the conductive liquid and the non-conductive liquid are contacting with each other on the electrode coated with the insulator.

[7] A liquid lens shown in FIGS. 3 and 4 was introduced by Koninklijke Philips

Electronics N. V. in CeBIT held in Hanover, Germany in 2004.

[8] The liquid lens of FIG. 3 comprises a substrate 10, a sidewall 20, and an upper board 30 mainly made of transparent glass, and lower and intermediate electrodes 40 and 50 disposed along outer circumferences of the substrate 10 and the sidewall 20, respectively. An inside of the sidewall 20 is coated with an insulator 60 to generate the electrowetting. In addition, a hydrophobic film 70 is spread on the insulator 60. The insulator 60 and the hydrophobic film 70 insulate conductive and non-conductive liquids 80 and 90 from the intermediate electrode 50 and as a result, only conductive liquid 80 remains in contact with an end of the lower electrode 40.

[9] As shown in FIG. 4, upon voltage application, electric charges are accumulated to the intermediate electrode 50 while opposite electric charges are gathering to an interface between the conductive liquid 80 and the hydrophobic film 70. Static electricity accordingly generated decreases the surface tension between the conductive liquid 80 and the hydrophobic film 70. Consequently, a contact angle θ and a focal distance of the liquid lens is reduced.

[10] In fabrication of such a liquid lens, the most essential elements are the electrode and the insulator. Since uniform and constant application of voltage is required in order to make sure stable operation of the liquid lens, material and shape of the electrode should be considerately selected. Material and shape of the insulator also matter for stable insulation between the two operating liquids and a metal electrode.

[11] Glass is used as a basic material for a conventional liquid lens as shown in FIG. 4. In order to fabricate the conventional liquid lens, more specifically, an electrode is made of Indium Tin Oxide (ITO) which is the material of a transparent electrode, the electrode is coated with an insulator film, and the electrode is then coated with a hydrophobic film. However, it is difficult to form the ITO electrode, the insulator film coating, and the hydrophobic film coating on a vertical surface of the glass. Property of the insulator film formed on the vertical glass surface may be deteriorated.

[12] In addition, during the fabrication of the liquid lens, it is indispensable to prevent leakage of the conductive and non-conductive liquids and prevent inflow of air bubbles to the liquids from the outside.

[13] In the liquid lens as shown in FIGS. 3 and 4, a lens structure holding liquid therein is sealed usually by a liquid epoxy adhesive, and this causes air bubbles in the liquid due to outgassing from the epoxy being cured. Since the epoxy is denatured when contacted with the liquid, reliable adhesion can hardly be guaranteed.

[14] Volume of the liquid varying according to temperature also hinders sealing of the liquid. For instance, when the liquid expands and contracts by variation of the temperature, pressure is generated inside the lens containing the liquid, thereby causing cracks to the epoxy. Sometimes, the whole liquid lens structure can even be broken.

[15] Thus, in order to make sure reliable and cost-effective fabrication of the liquid lens, the electrode and the insulator film should be stably and reliably formed, the air bubbles should be prevented from generating, and the liquid needs to be effectively sealed.

[16]

Disclosure of Invention

Technical Problem

[17] Therefore, the present invention has been made in view of the above-mentioned problems, and it is an object of the present invention to provide a method for producing a liquid lens structure reliably and massively, by using silicon for a substrate so that an electrode and an insulator film can be stably mounted.

[18] It is another object of the present invention to provide a method for producing a liquid lens structure highly improved in stability and reliability, by sealing the liquid using a solid O-ring so that air bubbles are not generated and by fixing the liquid lens structure using a dedicated packaging module.

[19] It is yet another object of the present invention to provide a method for producing a liquid lens structure capable of preventing inflow of air bubbles and breakage of the liquid lens structure, by compensating expansion and contraction of the liquid using resilience of the O-ring.

[20] It is still another object of the present invention to provide an improved liquid lens structure produced by the above methods.

[21]

Technical Solution

[22] According to an aspect of the present invention, there is provided a method for producing a liquid lens comprising steps of providing a silicon substrate having a hole in the center; forming an insulator film on the silicon substrate and coating the insulator film with a hydrophobic film; providing a transparent lower substrate mounted with an electrode on an upper surface thereof; bonding the silicon substrate onto the lower substrate hermetically; putting conductive liquid and non-conductive liquid into a liquid storage enclosed by the hole and the lower substrate; and bonding an upper substrate onto the silicon substrate hermetically.

[23] According to another aspect of the present invention, there is provided a liquid lens structure comprising a silicon substrate having a hole in the center thereof; a transparent lower substrate mounted with an electrode on an upper part thereof and bonded to a lower part of the silicon substrate hermetically; and a transparent upper substrate bonded to an upper part of the silicon substrate hermetically.

Advantageous Effects

[24] According to the present invention, difficulty in forming an electrode can be overcome by using a conductive material, such as silicon, for a substrate. In addition, since thermal oxidation, one of reliable semiconductor fabrication processes, helps improve stability of an insulator film, uniform and constant application of voltage can be achieved. Consequently, the liquid lens can be stably driven.

[25] Moreover, use of a silicon wafer facilitates formation of the insulator film and the hydrophobic film thereon, thereby enhancing massive productivity. Also, properties of the insulator film and the hydrophobic film are improved.

[26] Because the liquid is sealed using a thermally cured epoxy O-ring in the solid form, air bubbles from outgassing are not caused and denaturation of the epoxy due to contact with the liquid can be prevented during bonding. Furthermore, firmness and reliability of the liquid lens structure can be highly improved by using dedicated packaging modules to fix the liquid lens structure.

[27] The O-ring having resiliency compensates expansion and contraction of the liquid, thereby preventing inflow of air bubbles and breakage of the liquid lens structure.

[28] Finally, a more reliable and cost-effective liquid lens structure can be produced by stably forming the electrode and insulator film.

[29]

Brief Description of the Drawings

[30] The foregoing and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

[31] FIG. 1 and 2 schematically show the principle of a liquid lens;

[32] FIGS. 3 and 4 are schematic views showing a conventional liquid lens structure;

[33] FIGS. 5 through 11 show processes for fabricating a liquid lens according to an embodiment of the present invention;

[34] FIG. 12 schematically shows the structure of the liquid lens according to the embodiment of the present invention;

[35] FIG. 13 schematically shows the structure of a liquid lens according to another embodiment of the present invention;

[36] FIGS. 14 through 23 show processes for fabricating a liquid lens according to the another embodiment of the present invention;

[37] FIGS. 24 through 27 schematically show respective structures of the liquid lenses according to other various embodiments of the present invention;

[38] FIG. 28 schematically shows the structure of a liquid lens according to yet another embodiment of the present invention; and

[39] FIGS. 29 and 30 are cross-sectional views of the liquid lens according to the

embodiment of the present invention.

[40]

Mode for the Invention

[41] Reference will now be made in detail to exemplary embodiments of the present invention.

[42] FIGS. 5 through 11 show the processes for fabricating a liquid lens according to an embodiment of the present invention.

[43] In FIG. 5, a silicon substrate 100 is provided. In FIG. 6, a hole 120 is formed in the silicon substrate 100.

[44] In FIG. 7, an insulator film 130 is formed on the silicon 100 holding the hole 120 thereon. The insulator film 130 may be implemented by a SiO_2 film obtained through thermal oxidation of the silicon substrate 100. In FIG. 8, next, the insulator film 130 is coated with a hydrophobic film 140 such as a Teflon film. By the hydrophobic film 140, water, which is conductive liquid, is contacted with only a lower glass substrate 150 which is hydrophilic while being prevented from contacting with a sidewall of the hole 120 which is hydrophobic. As a result, the liquid lens can be maintained in constant shape. On the contrary, when the sidewall of the silicon hole 120 is hydrophilic, the contact line between the water and the sidewall becomes irregular. Accordingly, curvature of the interface between conductive liquid and non-conductive liquid becomes irregular, thereby deteriorating reliability of the liquid lens. The hydrophobic film 140 can be implemented by dipping or spraying using a Teflon coating solution produced by DuPont or 3M.

[45] As shown in FIG. 9, a lower electrode 160 is formed on the lower glass substrate 150.

[46] In FIG. 10, the lower glass substrate 150 mounted with the lower electrode 160 is bonded to the silicon substrate 100.

[47] In FIG. 11, conductive liquid and non-conductive liquid are injected in sequence. In FIG. 12, an upper glass substrate 170 is bonded to the upper part of the silicon substrate 100, thereby completing the liquid lens structure.

[48] If liquid epoxy is used for bonding of the glass substrates 150 and 170 with the silicon substrate 100, air bubbles may be generated by outgassing from the epoxy being cured. In this embodiment, therefore, an O-ring made of cured epoxy such as thermal-cured epoxy and UV epoxy is used for sealing the glass substrates 150 and 170 and the silicon substrate 100, in order to prevent generation of the air bubbles. In this case, the cured epoxy O-ring (not shown) is disposed at the bonding portion between two substrates. The sealing method using the cured epoxy O-ring will be described hereinafter in greater detail with reference to FIGS. 14 through 23.

[49] The liquid lens as shown in FIG. 12 is obtained through the processes according to an embodiment of the present invention. In the step of FIG. 6, if the hole 120 on the silicon substrate 100 is formed vertically, the liquid lens having a vertical structure can be obtained as shown in FIG. 13.

[50] According to the processes of FIGS. 14 through 23, a liquid lens structure capable of preventing leakage of the liquid and inflow of air bubbles can be produced.

[51] Firstly, a silicon substrate 200 is provided in the step of FIG. 14. A hole 220 is formed on the silicon substrate 200 in the step of FIG. 15.

[52] In the step of FIG. 16, an insulator film 230 made of a SiO_2 film is formed on the silicon substrate 200 holding the hole 220 thereon by thermal oxidation. Next, in the step of FIG. 17, coating of a hydrophobic film 240 is formed on the insulator film 230.

[53] In the step of FIG. 18, a lower electrode 260 is formed on a lower glass substrate 250. In the step of FIG. 19, a first O-ring 270 for sealing the liquid is formed on the lower electrode 260. As well as a general O-ring made of rubber or urethane, an epoxy O-ring cured by dispensing or screen-printing can be used for the first O-ring 270.

[54] In the step of FIG. 20, the lower glass substrate 250 mounted with the first O-ring 270 is firstly fixed to the silicon substrate 200 by bonding, using a first packaging module 300.

[55] In the step of FIG. 21, conductive liquid and non-conductive liquid are put into a liquid storage in sequence. Here, the non-conductive liquid is put in so that the surface thereof is convexed higher than the surface of the silicon substrate 200 using surface tension of the non-conductive liquid.

[56] In the step of FIG. 22, an upper glass 290 mounted with a second O-ring 280 covers the silicon substrate 200, pushing away the non-conductive liquid, so that air bubbles are not generated. Finally, as shown in FIG. 23, the upper glass 290mounted with the second O-ring 280 is secondly fixed to the silicon substrate 200 securely using a second packaging module 310 so that the solution inside the liquid lens can not leak out.

[57] In the embodiment shown in FIG. 22, the second O-ring 280 is formed on both the upper and the lower sides of the upper glass 290 while the lower glass substrate 250 has the first O-ring 270 only on the upper side. However, the present invention is not limited so but can be structured in various types shown in FIGS. 24 through 27, as long as the liquid can be properly sealed. Also, the silicon substrate 200 may have another structure as shown in FIG. 28.

[58] Cross-sectional surfaces of the packaging modules 300 and 310 can be square (FIG. 29) or circular (FIG. 30).

[59] While the invention has been shown and described with reference to certain embodiments thereof, it will be understood by those skilled in the art that various changes

in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

[60]

Industrial Applicability

[61] A liquid lens and a method for producing the same according to the present invention are applicable to various fields utilizing a conventional optical lens, such as a digital camera, a camera phone, an endoscope, a security system, and an optical recording apparatus.

[62]

Claims

[1] A method for producing a liquid lens comprising steps of:
providing a silicon substrate having a hole in the center;
forming an insulator film on the silicon substrate and coating the insulator film with a hydrophobic film;
providing a transparent lower substrate mounted with an electrode on an upper surface thereof;
bonding the silicon substrate onto the lower substrate hermetically;
putting conductive liquid and non-conductive liquid into a liquid storage enclosed by the hole and the lower substrate; and
bonding an upper substrate onto the silicon substrate hermetically.

[2] The method of claim 1, wherein the insulator film is made of a SiO_2 film obtained by thermal oxidation.

[3] The method of claim 1, wherein, in the step of bonding the silicon substrate to the lower substrate, a first O-ring is formed on at least one of upper and lower surfaces of the lower substrate, and a first packaging module is used for the bonding so that the lower substrate and the silicon substrate can be hermetically fixed.

[4] The method of claim 1, wherein, in the step of bonding the upper substrate to the silicon substrate, a second O-ring is formed on at least one of upper and lower surfaces of the upper substrate, and a second packaging module is used for the bonding so that the upper substrate and the silicon substrate are hermetically fixed.

[5] The method of any of claim 1 to claim 4, wherein the O-ring is selected from a group comprising a rubber O-ring, an urethane O-ring, and a thermal-cured epoxy O-ring.

[6] The method of any of claim 1 to claim 4, wherein, in the step of putting in the liquid, a surface of the liquid is convexed higher than the upper surface of the silicon substrate using surface tension of liquid, and in the step of bonding the upper substrate, the upper substrate pushes away part of the liquid higher than the silicon substrate.

[7] A method for producing a liquid lens comprising steps of:
providing a conductive substrate having a hole in the center;
forming an insulator film on the conductive substrate and coating the insulator film with a hydrophobic film;
providing a transparent lower substrate mounted with an electrode on an upper surface thereof;

bonding the conductive substrate onto the lower substrate hermetically;
putting conductive liquid and non-conductive liquid into a liquid storage enclosed by the hole and the lower substrate; and
bonding the upper substrate onto the conductive substrate hermetically.

[8] The method of claim 7, wherein the bonding steps use an O-ring for sealing between the lower and the conductive substrates and between the upper and the conductive substrates, and use a dedicated packaging module for fixing the respective substrates.

[9] The method of claim 7 or claim 8, wherein the hydrophobic film coating is restricted to a sidewall of the hole.

[10] A method for producing a liquid lens comprising steps of:
providing a silicon substrate having a hole in the center;
forming a SiO_2 film on the silicon substrate and coating the SiO_2 film with a hydrophobic film;
providing a transparent lower substrate mounted with an electrode on an upper surface thereof;
bonding the silicon substrate onto the lower substrate hermetically using a first packaging module;
putting conductive liquid and non-conductive liquid into a liquid storage enclosed by the hole and the lower substrate, so that a surface of the liquid is convexed higher than an upper surface of the silicon substrate using surface tension of liquid;
bonding a transparent upper substrate onto the silicon substrate hermetically, while pushing away part of the liquid higher than the silicon substrate using the upper substrate mounted with an O-ring on at least one of upper and lower surfaces thereof; and
fixing the upper substrate and the silicon substrate using a second packaging module connected to the first packaging module.

[11] A liquid lens structure comprising:
a silicon substrate having a hole in the center thereof;
a transparent lower substrate mounted with an electrode on an upper part thereof and bonded to a lower part of the silicon substrate hermetically; and
a transparent upper substrate bonded to an upper part of the silicon substrate hermetically.

[12] The liquid lens structure of claim 11, further comprising a SiO_2 film formed on the surface of the silicon substrate.

[13] The liquid lens structure of claim 11 or claim 12, further comprising a first packaging module for bonding and fixing the lower substrate and the silicon

substrate to each other.

[14] The liquid lens structure of claim 13, further comprising a first O-ring on at least one of upper and lower surfaces of the upper substrate.

[15] The liquid lens structure of claim 14, further comprising a second packaging module for bonding and fixing the upper substrate and the silicon substrate to each other.

[16] The liquid lens structure of claim 15, further comprising a second O-ring on at least one of upper and lower surfaces of the lower substrate.

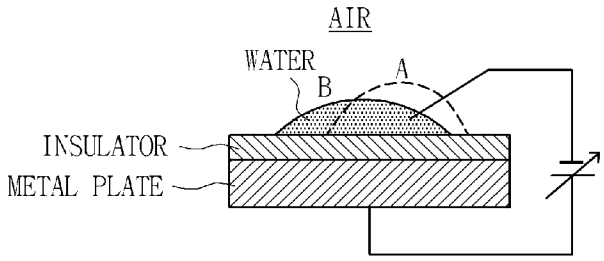
[17] The liquid lens structure of claim 16, further comprising a hydrophobic film on the SiO_2 film within a range of the hole formed in the center of the silicon substrate.

[18] The liquid lens structure of claim 17, wherein the transparent upper and the lower substrates are made of glass.

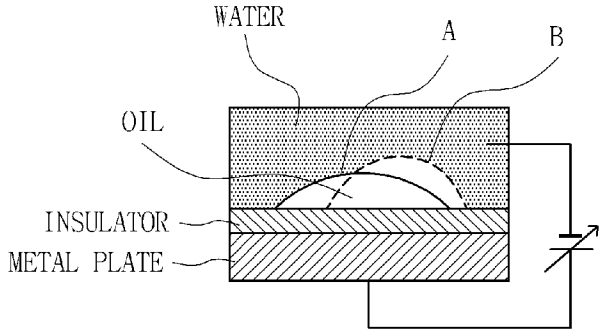
[19] A liquid lens structure comprising:
a silicon substrate having a hole in the center thereof;
a hydrophobic film spread on at least a part of the silicon substrate surface;
a transparent lower substrate mounted with an electrode on an upper part thereof and bonded to a lower surface of the silicon substrate hermetically;
a transparent upper substrate bonded to an upper part of the silicon substrate hermetically;
a first packaging module for bonding and fixing the lower substrate and the silicon substrate to each other;
a second packaging module for bonding and fixing the upper substrate and the silicon substrate to each other;
a first O-ring formed on at least one of upper and lower surfaces of the upper substrate; and
a second O-ring formed on at least one of upper and lower surfaces of the lower substrate.

[20] The liquid lens structure of claim 19, wherein the first and the second O-rings are selected from a group comprising a rubber O-ring, a urethane O-ring, and a thermal-cured epoxy O-ring.

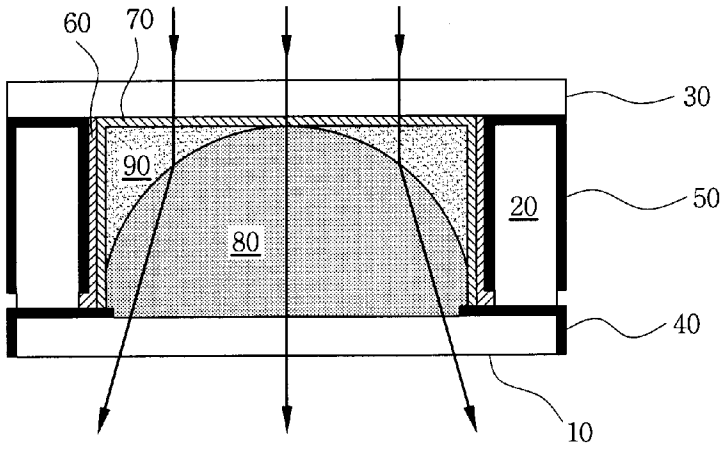
[Fig. 1]



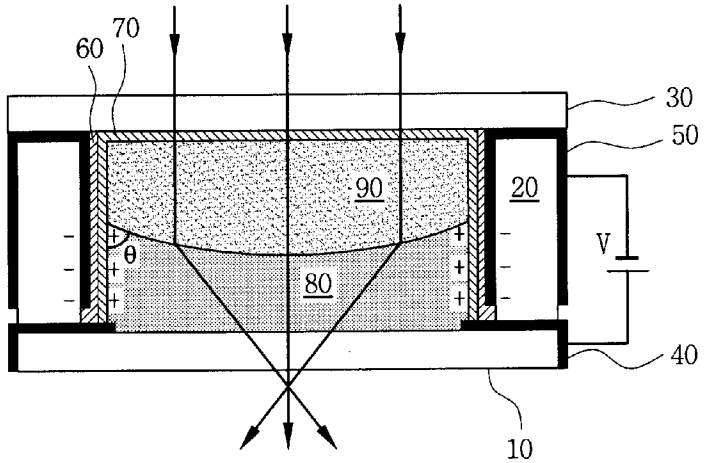
[Fig. 2]



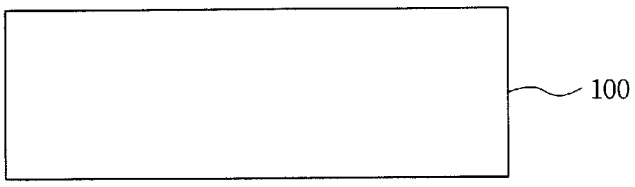
[Fig. 3]



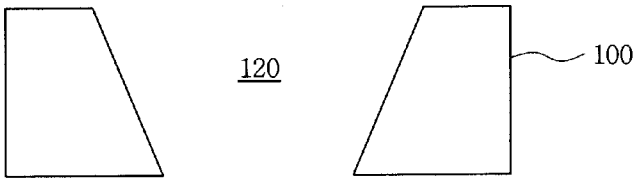
[Fig. 4]



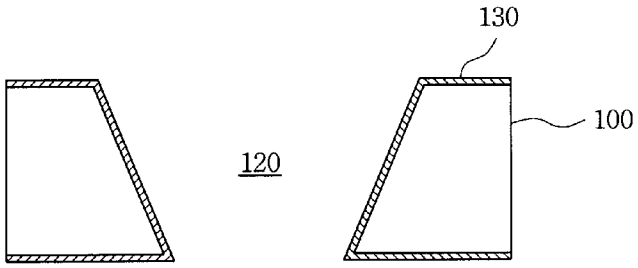
[Fig. 5]



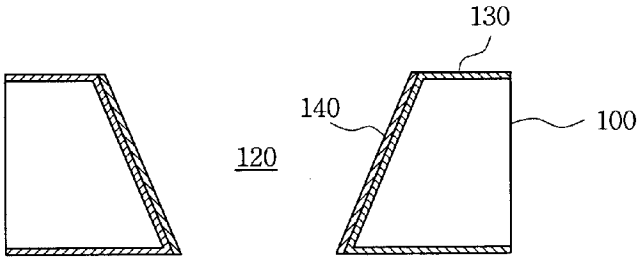
[Fig. 6]



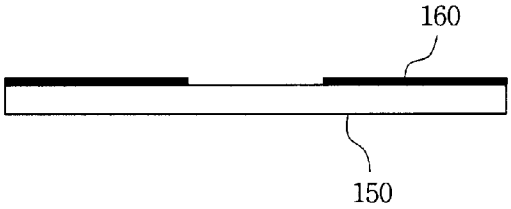
[Fig. 7]



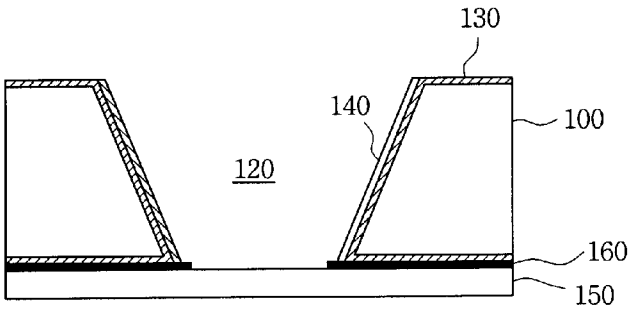
[Fig. 8]



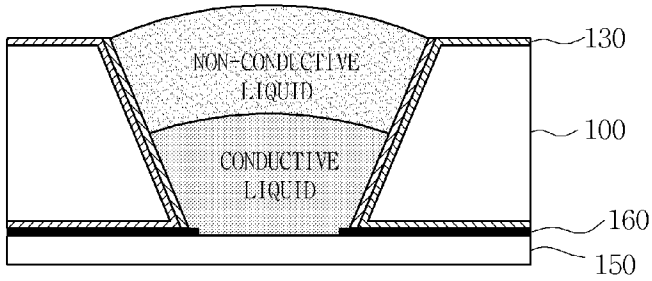
[Fig. 9]



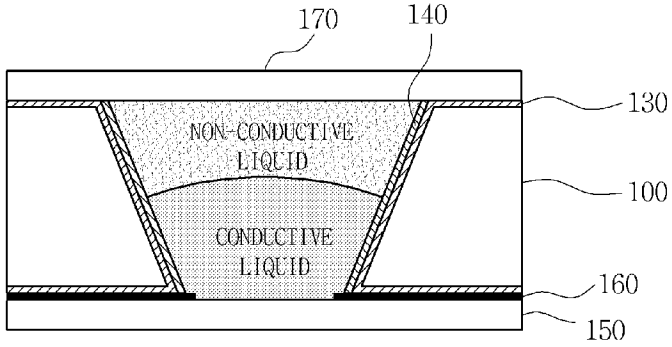
[Fig. 10]



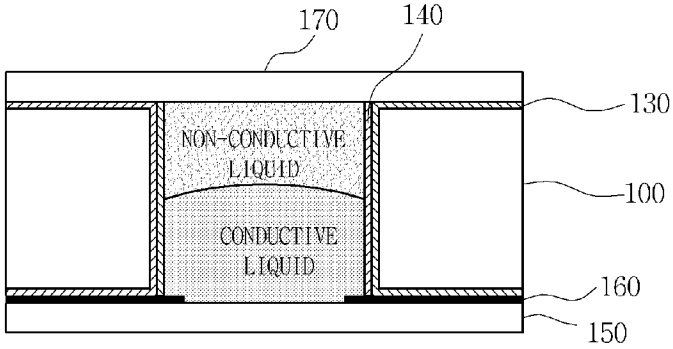
[Fig. 11]



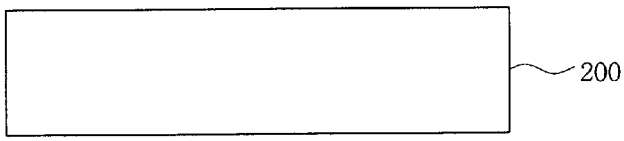
[Fig. 12]



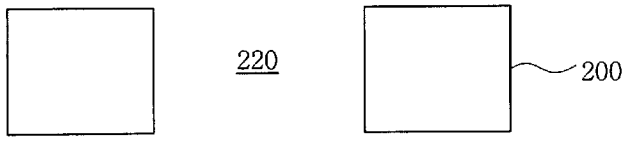
[Fig. 13]



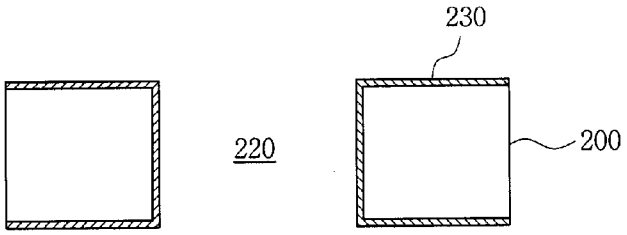
[Fig. 14]



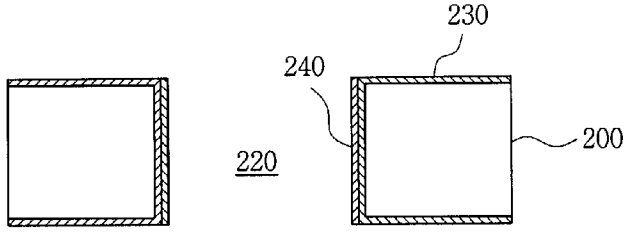
[Fig. 15]



[Fig. 16]

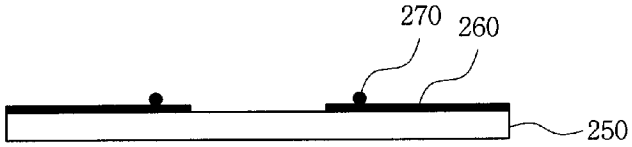


[Fig. 17]

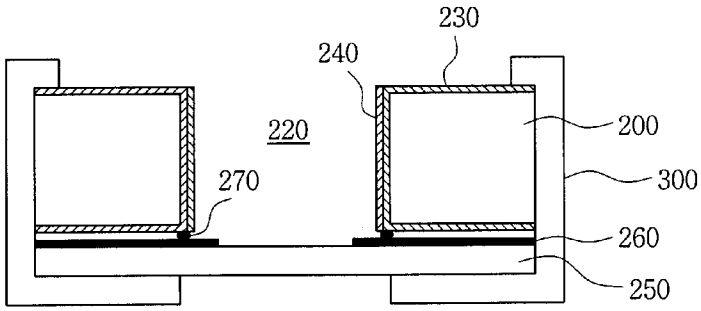


[Fig. 18]

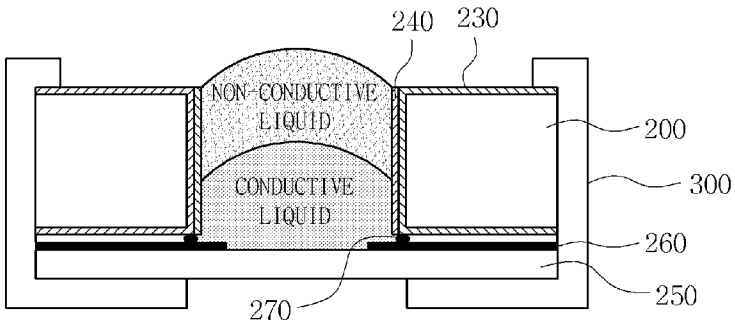
[Fig. 19]



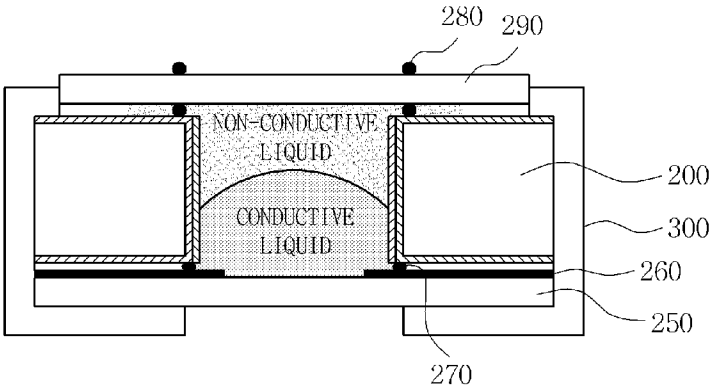
[Fig. 20]



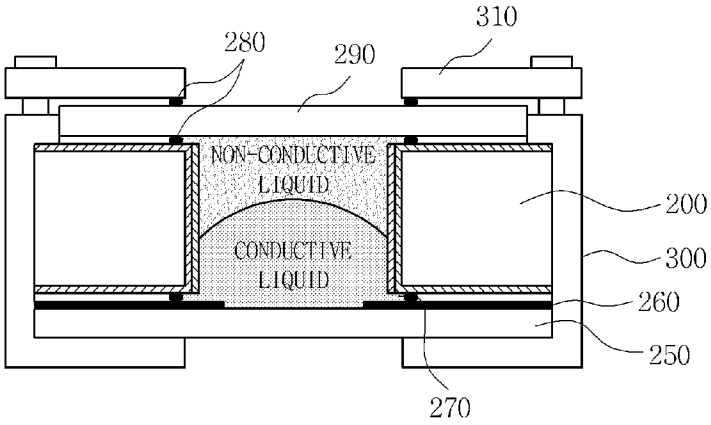
[Fig. 21]



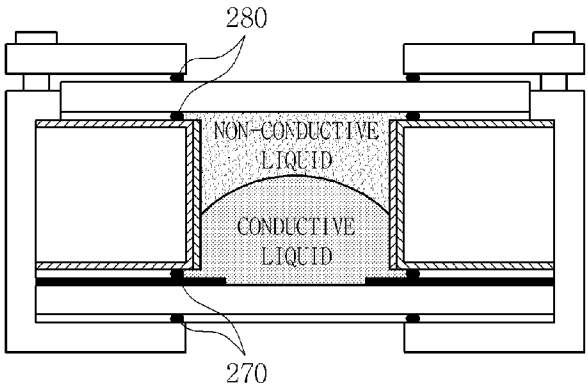
[Fig. 22]



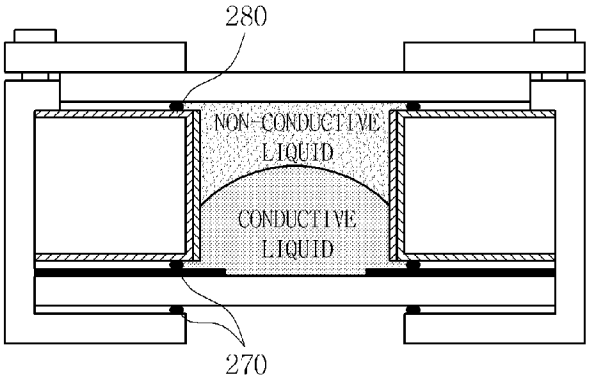
[Fig. 23]



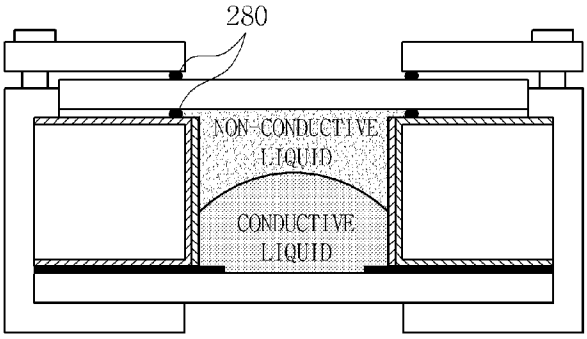
[Fig. 24]



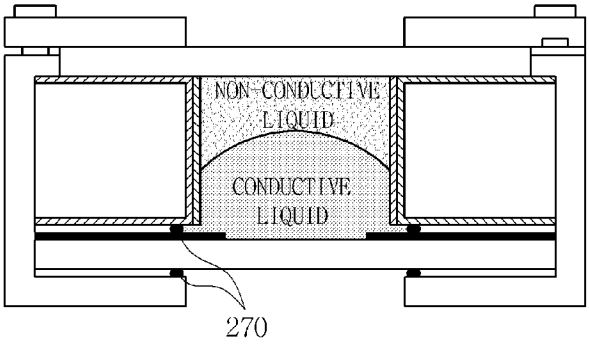
[Fig. 25]



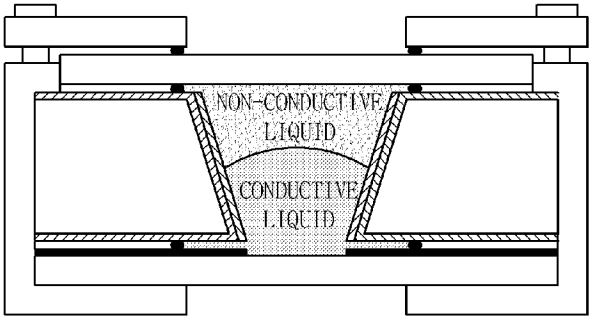
[Fig. 26]



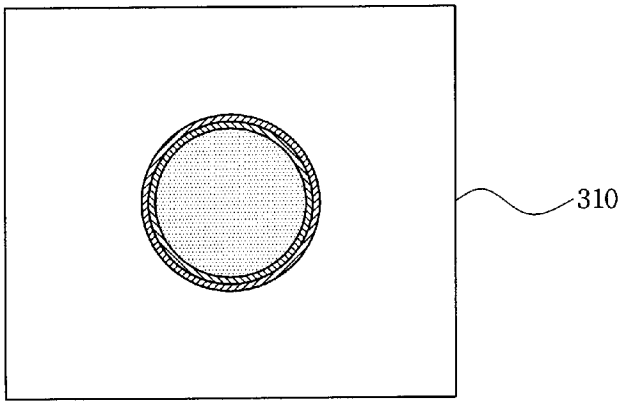
[Fig. 27]



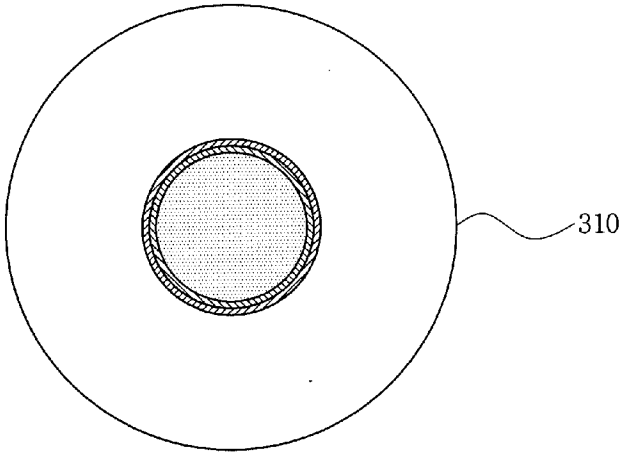
[Fig. 28]



[Fig. 29]



[Fig. 30]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2006/004758

A. CLASSIFICATION OF SUBJECT MATTER

G02B 3/14(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G02B3/14 IPC8

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
KR, JP as above IPC

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)
KIPONET, "liquid", "lens", "filem", "surface"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP15057410A(CANON INC) 26 FEB 2003 see page3-8, claim 1, fig 1.	1-18
Y	JP11133210A(DENSO CORP) 21 MAY 1999 see page 4-8, claim 1, fig. 1	1-18
A	JP10268110A(SUZUKI KENICHI) 9 OCT 1998 see the entire documents	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 FEBRUARY 2007 (26.02.2007)	**26 FEBRUARY 2007 (26.02.2007)**

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CHUNG, Sang Tae
Telephone No. 82-42-481-5497

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/KR2006/004758

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