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(54) **Title**: INTERDIGITATED CAPACITOR AND DIELECTRIC MEMBRANE SENSING DEVICE

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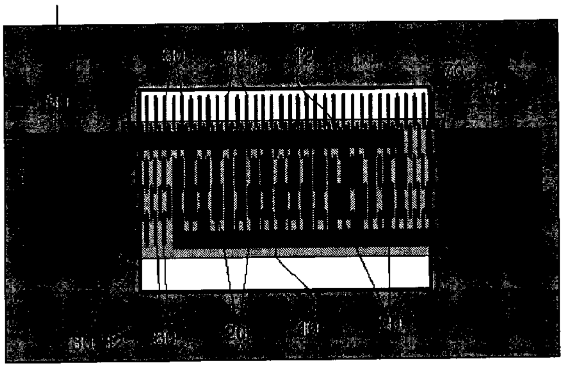

Figure 4

(57) **Abstract**: A device for sensing ions comprising: a pair of electrodes, each electrode having a plurality fingers, said fingers in an interdigitated manner in relation to each other; a bottom and a top sensor membrane sandwiching said pair of electrodes; and a substrate housing said sensor membranes, said substrate having an opening to allow said ions to come into contact with said sensor membranes. A pair of contact pads is provided, each contact pad attached and in electrical connection with each electrode. The sensor membranes may comprise a plurality of nanowires or nanotubes grown on or around the fingers, with an electrical insulating layer between said nanowires and said fingers.

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Interdigitated capacitor and dielectric membrane sensing device

FIELD OF INVENTION

The present invention relates to a device for chemical sensing applications using interdigitated capacitive sensors and sensing membrane.

BACKGROUND OF INVENTION

Interdigitated capacitors incorporated with dielectric sensor membranes have been widely used for chemical sensing applications. Typically, the physical structure of the device comprises of a sensing membrane sitting on top of an array of interdigitated fingers. The sensing mechanism is based on the dielectric properties of membrane material which includes physical, chemical, or structural properties influencing the fringing electric field between the finger electrodes resulting in a change in capacitance.

US patent application 20100054299 (Werner, et al.) discloses a sensor device for detecting thawing on surfaces with interdigital electrodes formed in a resistance layer. Another US patent application, US 20090084686 (Yun, et al.) discloses a biosensor for detecting presence and concentration of various bio-materials such as genes and proteins using an interdigitated electrode sensor unit.

Both these prior arts and all other known art incorporate the sensing membrane only on one side, or on top of the interdigitated electrode. Having a sensing membrane on one side of the interdigitated electrode only utilises 50% of the fringing field effect. Figure 1 shows a cross sectional view of a typical sensing device with only a top sensing membrane layer hence only utilising 50% of its fringing field effect. The interdigitated electrodes (20) sit beneath a sensor membrane (32). The utilised fringe electric field (102) is only on the top, where the sensor membrane is present. At the bottom side, the fringing electric field is not utilised (104).

What is desirable is a device that utilises fully its fringing field effect.

SUMMARY OF INVENTION

The present invention aims at providing a device that fully utilises its fringing field effect by incorporating a second sensing membrane on the opposite side of the interdigitated electrode to the side with the first sensing membrane.

This invention relates to a dual sided MEMS interdigitated capacitive sensor with sensing membranes formed on both sides of the capacitive fingers. A through substrate opening beneath the bottom sensing membrane allows for it to be in contact with the sensed ions. Having sensing membranes on both sides of the interdigitated structures allows full utilisation of the fringing field of the capacitor device. The sensitivity and performance of the device will hence be significantly improved. The suspended sensor device can be hinged onto the substrate at the contact pad areas or at part of the interdigitated fingers. As each half of the finger array is only connected to one pad, flexural rigidity of the overall structure is highly dependent on whether the sensing membrane is able to support the interdigitated structure. If the sensing membrane is very thin, hinging at the fingers would prevent the structure from collapsing. The sensing membrane material can be of ferroelectric and piezoelectric materials such as barium strontium titanate (BST), lead zircornate titanate (PZT) and zinc oxide (ZnO), polymer material such polyimide, and metal oxides such as tin oxide (SnO_2), tantalum pentoxide (Ta_2O_5), aluminium oxide (Al_2O_3), hafnium oxide (HfO_2), and tungsten oxide (WO_x).

In another embodiment, nanostructures such as nanotubes or nanowires can be used as the device's sensing membrane, comprising carbon nanotubes, silicon nanowires, tungsten nanowires, tungsten oxide nanowires, zinc oxide nanowires, indium oxide nanowires, tin oxide nanowires, gold nanowires. They can be grown using a thin metal catalyst material by a variety of methods including chemical vapour deposition (CVD), metalorganic chemical vapour deposition (MOCVD), plasma enhanced chemical vapour deposition (PECVD), hot wire chemical vapour deposition (HWCVD), atomic layer deposition (ALD), electrochemical deposition, solution chemical deposition. Catalyst materials used are typically gold (Au), cobalt

(Co), iron (Fe), nickel (Ni), indium (In) and copper (Cu). The interdigitated capacitor strcuture must be of a material that is able to withstand the high nanowire growth temperature, which is typically above 400°C. Such material includes gold, platinum, nickel, tungsten, cobalt and copper. These nanowires or nanotubes can be of highly ordered vertical arrays or non-ordered multidirectional arrays covering both sides of the interdigitated finger surfaces allowing a dual sided device with high sensitivity. The fabrication method is compatible to standard integrated circuit (IC) processing, allowing it to be integrated on the same platform as other MEMS or IC type devices and electronic systems.

The present invention relates to a device for sensing ions comprising: a pair of electrodes, each electrode having a plurality fingers, said fingers arranged in an interdigitated manner in relation to each other; a bottom and a top sensor membrane sandwiching said pair of electrodes; and a substrate housing said sensor membranes, said substrate having an opening to allow said ions to come into contact with said sensor membranes. A pair of contact pads is provided, each contact pad attached and in electrical connection with each electrode.

In a first embodiment, the sensor membranes are hinged to the substrate either at the contact pad or at the fingers, and are made from any or a combination of the following: ferroelectric and piezoelectric materials such as barium strontium titanate (BST), lead zircornate titanate (PZT) and zinc oxide (ZnO); polymer materials such as polyimide; and metal oxides such as tin oxide (SnO2), tantalum pentoxide (Ta2O5), aluminium oxide (Al2O3), hafnium oxide (HfO2), and tungsten oxide (WOx).

In a second embodiment, the sensor membranes comprise a plurality of nanowires or nanotubes grown on or around the fingers, with an electrical insulating layer between said nanowires and said fingers. The nanowires or nanotubes are made from any or a combination of the following: carbon nanotubes, silicon nanowires, tungsten nanowires, tungsten oxide nanowires, zinc oxide nanowires, indium oxide nanowires, tin oxide nanowires, and gold nanowires. The nanowires or nanotubes may be either uni-directional or multi-directional.

The present invention also relates to a method of fabricating an ion sensor device comprising the steps of:

a) depositing a first insulating layer onto top and bottom sides of a substrate;

b) etching the said bottom first insulating layer using either Tetrafluoromethane (CF4) and Trifluoromethane (CHF3) plasma or in a hydrofluoric acid (HF) based chemical solution;

c) depositing a bottom sensor membrane on top of the said top first insulating layer;

d) depositing and etching a conductive layer to form the interdigitated fingers and contact pads on top of the said bottom sensor membrane using a physical or chemical vapour deposition (PVD or CVD) method;

e) depositing a top sensor membrane layer on top of the said interdigitated fingers; and

f) etching the said substrate from the bottom to form an opening beneath the said interdigitated fingers using an inductively coupled plasma reactive ion etching (ICP-RIE) method with sulphur hexafluoride (SF6) based plasma or with a wet chemical etchant of potassium hydroxide (KOH) or Tetramethylammonium Hydroxide (TMAH).

The said insulating layers are any or a combination of: silicon dioxide or silicon nitride deposited by physical or chemical vapour deposition; or silicon dioxide grown by a thermal oxidation method. The sensor membranes are made from any or a combination of: ferroelectric and piezoelectric materials such as barium strontium titanate (BST), lead zircornate titanate (PZT) and zinc oxide (ZnO); polymer material such as polyimide; and metal oxides such as tin oxide (SnO2), tantalum pentoxide (Ta2O5), aluminium oxide (Al2O3), hafnium oxide (HfO2), and tungsten oxide (WOx). The conductive layer includes any or a combination of the following materials: gold (Au), platinum (Pt), nickel (Ni), tungsten (W), cobalt (Co) and copper (Cu).

The present invention further relates to a method of fabricating an ion sensor device comprising the steps of:

a) depositing a first insulating layer onto top and bottom sides of a substrate;

b) depositing a bottom catalyst layer on top of the said top first insulating layer using a physical or chemical vapour deposition (PVD or CVD) and material(s) selected from a group consisting and not limited to gold (Au), cobalt (Co), iron (Fe), nickel (Ni), indium (In) and copper (Cu);

c) depositing a second insulating layer on top of the said bottom catalyst layer;

d) depositing and etching a conductive layer to form the interdigitated fingers and contact pads on top of the said second insulating layer;

e) depositing a third insulating layer on top of the conductive layer to cover the said interdigitated fingers and etching the ends of the said third insulating layer to expose said contact pads;

f) depositing a second metal catalyst layer on top of the said third insulating layer;

g) etching the said substrate from the bottom to form an opening beneath the said interdigitated fingers; and

h) growing of nanotubes or nanowires at the exposed metal catalyst areas by any or a combination of the following methods: chemical vapour deposition (CVD); metalorganic chemical vapour deposition (MOCVD); plasma enhanced chemical vapour deposition (PECVD); hot wire chemical vapour deposition (HWCVD); atomic layer deposition (ALD); electrochemical deposition; and solution chemical deposition.

These and other objects of the present invention will become more readily apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating the preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 shows a cross sectional view of a typical sensing device with only a top sensing membrane layer of a prior art.

Figure 2 shows a plan view of a sensor device in a first embodiment of this invention.

Figure 3 shows a plan view of a sensor device in a second embodiment of this invention.

Figure 4 shows a plan view of a sensor device in a third embodiment of this invention.

Figure 5 shows a cross sectional view of a sensor device in a third embodiment of this invention.

Figure 6 shows a cross sectional view of a sensor device in a fourth embodiment of this invention.

Figures 7 (a) through (f) show stages in the fabrication process of first and second embodiments of this invention.

Figures 8 (a) through (h) show stages in the fabrication process of third and fourth embodiments of this invention.

DETAILED DESCRIPTION OF INVENTION

It should be noted that the following detailed description is directed to a sensing device that fully utilises its fringing field effect by incorporating a second sensing membrane on the opposite side of the interdigitated electrode to the side with the first sensing membrane and the fabrication method thereof and is not limited to any particular size or configuration but in fact a multitude of sizes and configurations within the general scope of the following description.

Referring to Figures 2 and 3, there is shown, respectively, a first and second embodiment of this invention and an ion sensor device comprising a pair of electrodes (10, 12), each electrode having a plurality fingers (20), said fingers arranged in an interdigitated manner in relation to each other; a bottom (30) and a top (32) sensor membrane sandwiching said pair of electrodes; and a substrate

(40) housing said sensor membranes, said substrate having an opening to allow said ions to come into contact with said sensor membranes. A pair of contact pads (50, 52) is provided, with each contact pad attached and in electrical connection with each electrode (10, 12). In the first embodiment, the sensor membranes (30, 32) are hinged to the substrate at the contact pads (50, 52). In the second embodiment, the sensor membranes (30, 32) are hinged to the substrate at the fingers (20). The sensor membranes (30, 32) are made from any or a combination of the following: ferroelectric and piezoelectric materials such as barium strontium titanate (BST), lead zircornate titanate (PZT) and zinc oxide (ZnO); polymer materials such as polyimide; and metal oxides such as tin oxide (SnO2), tantalum pentoxide (Ta2O5), aluminium oxide (Al2O3), hafnium oxide (HfO2), and tungsten oxide (WOx).

Referring to Figure 4 and Figure 5, there is shown a third embodiment of this invention and an ion sensor device comprising a pair of electrodes (10, 12), each electrode having a plurality fingers (20), said fingers arranged in an interdigitated manner in relation to each other; a bottom (30) and a top (32) sensor membrane sandwiching said pair of electrodes; and a substrate (40) housing said sensor membranes, said substrate having an opening to allow said ions to come into contact with said sensor membranes. A pair of contact pads (50, 52) is provided, with each contact pad attached and in electrical connection with each electrode (10, 12). In this third embodiment, the sensor membranes comprise a plurality of nanowires or nanotubes (60) grown uni-directionally (601) on or around the fingers (20), with an electrical insulating layer (70) between said nanowires (60) and said fingers (20).

Referring to Figure 6, there is shown a fourth embodiment of this invention and an ion sensor device comprising a pair of electrodes, each electrode having a plurality fingers (20), said fingers arranged in an interdigitated manner in relation to each other; a bottom and a top sensor membrane sandwiching said pair of electrodes; and a substrate housing said sensor membranes, said substrate having an opening to allow said ions to come into contact with said sensor membranes. A pair of contact pads is provided, with each contact pad attached and in electrical connection with each electrode. In this third embodiment, the sensor membranes comprise a plurality of nanowires or nanotubes grown multi-directionally (602) on or around the fingers (20), with an electrical insulating layer (70) between said nanowires and said fingers (20).

The nanowires or nanotubes (60) of both the third and fourth embodiments of this invention are made from any or a combination of the following: carbon nanotubes, silicon nanowires, tungsten nanowires, tungsten oxide nanowires, zinc oxide nanowires, indium oxide nanowires, tin oxide nanowires, and gold nanowires. The nanowires or nanotubes may be either uni-directional or multi-directional.

Referring to Figure 7 (a) through (f), there is shown stages in the fabrication process of the first and second embodiments of this invention, comprising the steps of:

a) depositing a first insulating layer onto top (700) and bottom (701) sides of a substrate (40), wherein the said insulating layers (700, 701) are any or a combination of: silicon dioxide or silicon nitride deposited by physical or chemical vapour deposition; or silicon dioxide grown by a thermal oxidation method;

b) etching the said bottom first insulating layer (701), wherein the said etching of the said bottom first insulating layer (701) is done using either Tetrafluoromethane (CF4) and Trifluoromethane (CHF3) plasma or in a hydrofluoric acid (HF) based chemical solution;

c) depositing a bottom sensor membrane (30) on top of the said top first insulating layer (700);

d) depositing and etching a conductive layer to form the interdigitated fingers (20) and contact pads (50, 52) on top of the said bottom sensor membrane (30), wherein the said deposition of said conductive layer is done using a physical or chemical vapour deposition (PVD or CVD) method and the said conductive layer includes any or a combination of the following materials: gold (Au), platinum (Pt), nickel (Ni), tungsten (W), cobalt (Co) and copper (Cu);

e) depositing a top sensor membrane layer (32) on top of the said interdigitated fingers (20); and

f) etching the said substrate (40) from the bottom to form an opening beneath the said interdigitated fingers (20), wherein the said etching of the said substrate is done using an inductively coupled plasma reactive ion etching (ICP-RIE) method with sulphur hexafluoride (SF6) based plasma or with a wet chemical etchant of potassium hydroxide (KOH) or Tetramethylammonium Hydroxide (TMAH).

The said sensor membranes (30, 32) is made from any or a combination of: ferroelectric and piezoelectric materials such as barium strontium titanate (BST), lead zircornate titanate (PZT) and zinc oxide (ZnO); polymer material such as polyimide; and metal oxides such as tin oxide (SnO2), tantalum pentoxide (Ta2O5), aluminium oxide (Al2O3), hafnium oxide (HfO2), and tungsten oxide (WOx).

Referring to Figure 8 (a) through (h), there is shown stages in the fabrication process of the third and fourth embodiments of this invention, comprising the steps of:

a) depositing a first insulating layer onto top (700) and bottom (701) sides of a substrate (40);

b) depositing a bottom catalyst layer (801) on top of the said top first insulating layer (700), wherein the said deposition of said bottom catalyst layer (801) is done using a physical or chemical vapour deposition (PVD or CVD) and material(s) selected from a group consisting and not limited to gold (Au), cobalt (Co), iron (Fe), nickel (Ni), indium (In) and copper (Cu);

c) depositing a second insulating layer (702) on top of the said bottom catalyst layer (801);

d) depositing and etching a conductive layer to form the interdigitated fingers (20) and contact pads (50, 52) on top of the said second insulating layer (702);

e) depositing a third insulating layer (703) on top of the conductive layer to cover the said interdigitated fingers (20) and etching the ends of the said third insulating layer to expose said contact pads (50, 52);

f) depositing a second metal catalyst layer (802) on top of the said third insulating layer (703);

g) etching the said substrate (40) from the bottom to form an opening beneath the said interdigitated fingers (20); and

h) growing of nanotubes or nanowires (60) at the exposed metal catalyst areas, wherein the said nanotubes or nanowires are grown by any or a combination of the following methods: chemical vapour deposition (CVD); metalorganic chemical vapour deposition (MOCVD); plasma enhanced chemical vapour deposition (PECVD); hot wire chemical vapour deposition (HWCVD); atomic layer deposition (ALD); electrochemical deposition; and solution chemical deposition.

The overall capacitance of the device is determined by the dimensions and dielectric permittivity of the sensing membrane:

$$C = \varepsilon_0 \cdot \varepsilon_r \cdot A/d$$

where ε_0 is the dielectric constant, ε_r the dielectric permittivity of the sensing membrane, A is the total area and d is the gap between fingers.

While several particularly preferred embodiments of the present invention have been described and illustrated, it should now be apparent to those skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the invention. Accordingly, the following claims are intended to embrace such changes, modifications, and areas of application that are within the spirit and scope of this invention.

CLAIMS

1. A device for sensing ions comprising:

   a pair of electrodes (10, 12), each electrode having a plurality fingers (20), said fingers arranged in an interdigitated manner in relation to each other;

   a bottom (30) and a top (32) sensor membrane sandwiching said pair of electrodes (10, 12); and

   a substrate (40) housing said sensor membranes (30), said substrate having an opening to allow said ions to come into contact with said sensor membranes (30, 32).

2. A device for sensing ions according to claim 1 further comprising a pair of contact pads (50, 52), each said contact pad attached and in electrical connection with each said electrode (10, 12).

3. A device for sensing ions according to any of claims 1 to 2 wherein the said sensor membranes (30, 32) are hinged to the said substrate (40) at the said contact pad (50, 52).

4. A device for sensing ions according to any of claims 1 to 2 wherein the said sensor membranes (30, 32) are hinged to the said substrate (40) at the said fingers (20).

5. A device for sensing ions according to any of claims 1 to 4 wherein the said sensor membranes (30, 32) are made from any or a combination of the following: ferroelectric and piezoelectric materials such as barium strontium titanate (BST), lead zircornate titanate (PZT) and zinc oxide (ZnO); polymer materials such as polyimide; and metal oxides such as tin oxide (SnO_2), tantalum pentoxide (Ta_2O_5), aluminium oxide (Al_2O_3), hafnium oxide (HfO_2), and tungsten oxide (WO_x).

6. A device for sensing ions according to any of claims 1 to 4 wherein the said sensor membranes (30, 32) comprise a plurality of nanowires (60) on

the said fingers (20), with an electrical insulating layer (70) between said nanowires and said fingers.

7. A device for sensing ions according to claim 6 wherein said nanowires (60) have a hollow center.

8. A device for sensing ions according to claim 6 or 7 wherein said nanowires (60) are made from any or a combination of the following: carbon nanotubes, silicon nanowires, tungsten nanowires, tungsten oxide nanowires, zinc oxide nanowires, indium oxide nanowires, tin oxide nanowires, and gold nanowires.

9. A device for sensing ions according to any of claims 6 to 8 wherein the said nanowires (60) are located all around the said fingers (20).

10. A device for sensing ions according to any of claims 6 to 9 wherein the said nanowires (60) may be either uni-directional (601) or multi-directional (602).

11. A method of fabricating an ion sensor device comprising the steps of:
    a) depositing a first insulating layer onto top (700) and bottom (701) sides of a substrate (40);
    b) etching the said bottom first insulating layer (701);
    c) depositing a bottom sensor membrane (30) on top of the said top first insulating layer (700);
    d) depositing and etching a conductive layer to form the interdigitated fingers (20) and contact pads (50, 52) on top of the said bottom sensor membrane (30);
    e) depositing a top sensor membrane layer (32) on top of the said interdigitated fingers (20); and
    f) etching the said substrate (40) from the bottom to form an opening beneath the said interdigitated fingers (20).

12. A method of fabricating an ion sensor device according to claim 11 wherein the said insulating layers (700, 701) are any or a combination of:

silicon dioxide or silicon nitride deposited by physical or chemical vapour deposition; or silicon dioxide grown by a thermal oxidation method.

13. A method of fabricating an ion sensor device according to claim 11 or 12 wherein the said etching of the said bottom first insulating layer (701) is done using either Tetrafluoromethane (CF_4) and Trifluoromethane (CHF_3) plasma or in a hydrofluoric acid (HF) based chemical solution.

14. A method of fabricating an ion sensor device according to any of claims 11 to 13 wherein the said sensor membranes (30, 32) is made from any or a combination of: ferroelectric and piezoelectric materials such as barium strontium titanate (BST), lead zircornate titanate (PZT) and zinc oxide (ZnO); polymer material such as polyimide; and metal oxides such as tin oxide (SnO_2), tantalum pentoxide (Ta_2O_5), aluminium oxide (Al_2O_3), hafnium oxide (HfO_2), and tungsten oxide (WO_x).

15. A method of fabricating an ion sensor device according to any of claims 11 to 14 wherein the said deposition of said conductive layer is done using a physical or chemical vapour deposition (PVD or CVD) method.

16. A method of fabricating an ion sensor device according to any of claims 11 to 15 wherein the said conductive layer includes any or a combination of the following materials: gold (Au), platinum (Pt), nickel (Ni), tungsten (W), cobalt (Co) and copper (Cu).

17. A method of fabricating an ion sensor device according to any of claims 11 to 16 wherein the said etching of the said substrate is done using an inductively coupled plasma reactive ion etching (ICP-RIE) method with sulphur hexafluoride (SF_6) based plasma or with a wet chemical etchant of potassium hydroxide (KOH) or Tetramethylammonium Hydroxide (TMAH).

18. A method of fabricating an ion sensor device comprising the steps of:

a) depositing a first insulating layer onto top (700) and bottom (701) sides of a substrate (40);

b) depositing a bottom catalyst layer (801) on top of the said top first insulating layer (700);

c) depositing a second insulating layer (702) on top of the said bottom catalyst layer (801);

d) depositing and etching a conductive layer to form the interdigitated fingers (20) and contact pads (50, 52) on top of the said second insulating layer (702);

e) depositing a third insulating layer (703) on top of the conductive layer to cover the said interdigitated fingers (20) and etching the ends of the said third insulating layer to expose said contact pads (50, 52);

f) depositing a second metal catalyst layer (802) on top of the said third insulating layer (703);

g) etching the said substrate (40) from the bottom to form an opening beneath the said interdigitated fingers (20); and

h) growing of nanotubes or nanowires (60) at the exposed metal catalyst areas.

19. A method of fabricating an ion sensor device according to claim 18 wherein the said deposition of said bottom catalyst layer (801) is done using a physical or chemical vapour deposition (PVD or CVD) and material(s) selected from a group consisting and not limited to gold (Au), cobalt (Co), iron (Fe), nickel (Ni), indium (In) and copper (Cu).

20. A method of fabricating an ion sensor device according to claim 18 or 19 wherein the said nanotubes or nanowires are grown by any or a combination of the following methods: chemical vapour deposition (CVD); metalorganic chemical vapour deposition (MOCVD); plasma enhanced chemical vapour deposition (PECVD); hot wire chemical vapour deposition (HWCVD); atomic layer deposition (ALD); electrochemical deposition; and solution chemical deposition.

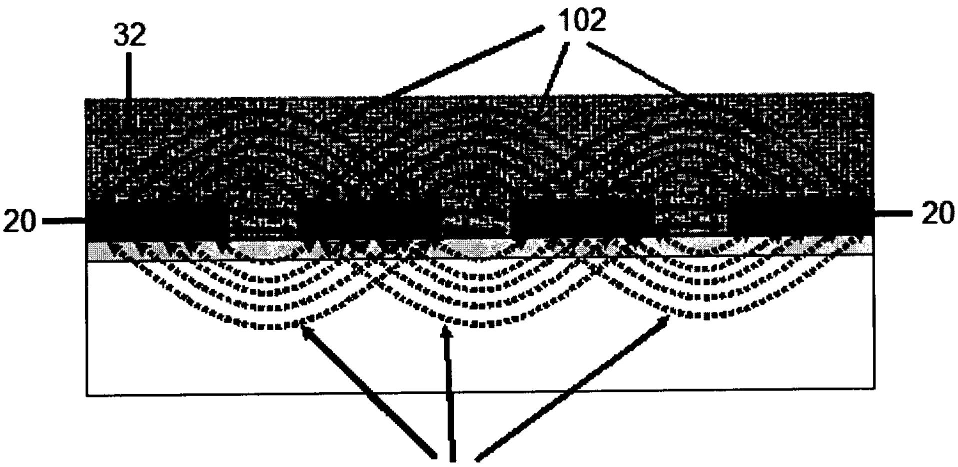

Figure 1

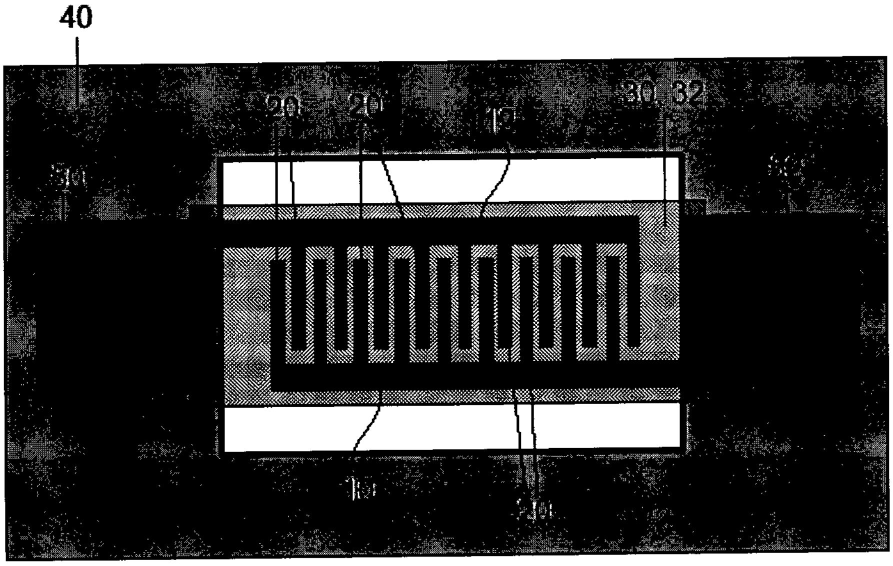

Figure 2

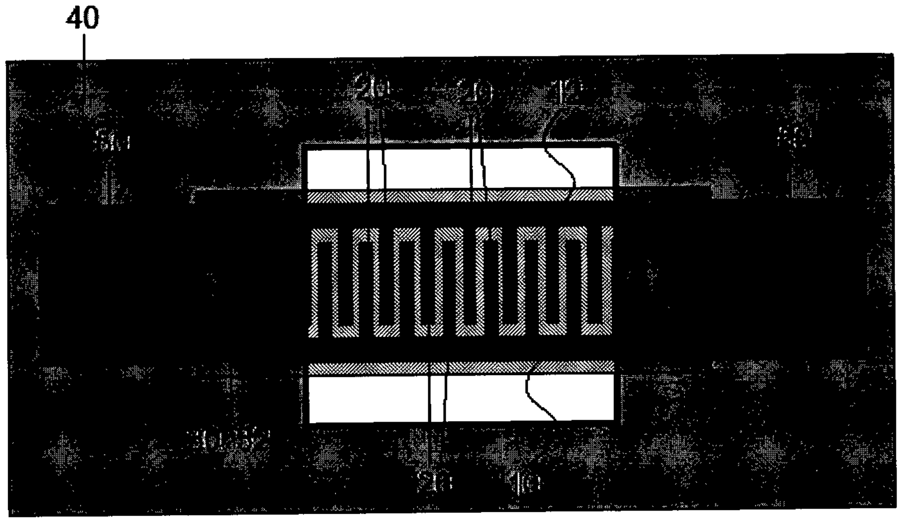

Figure 3

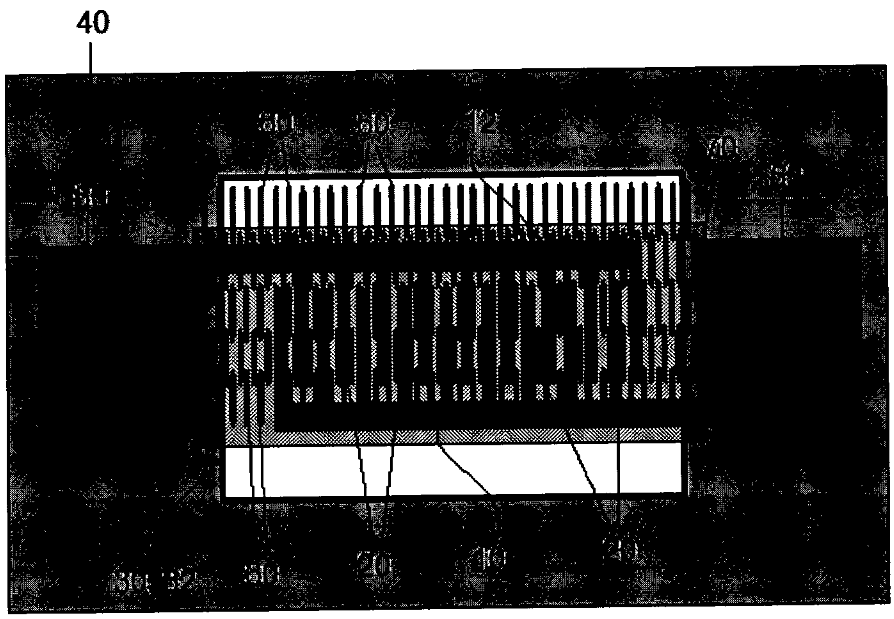

Figure 4

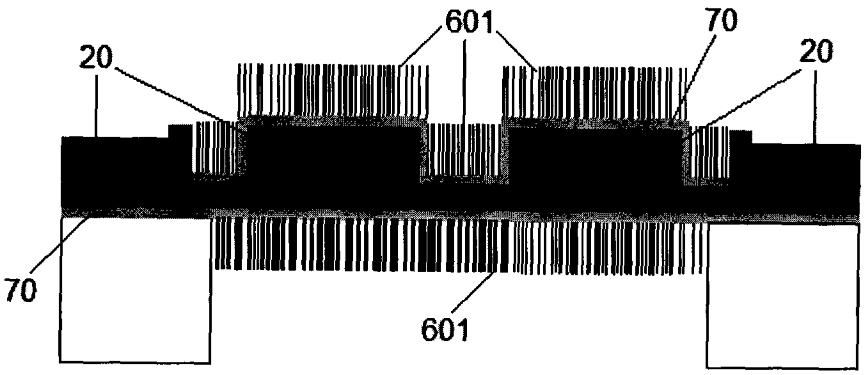

Figure 5

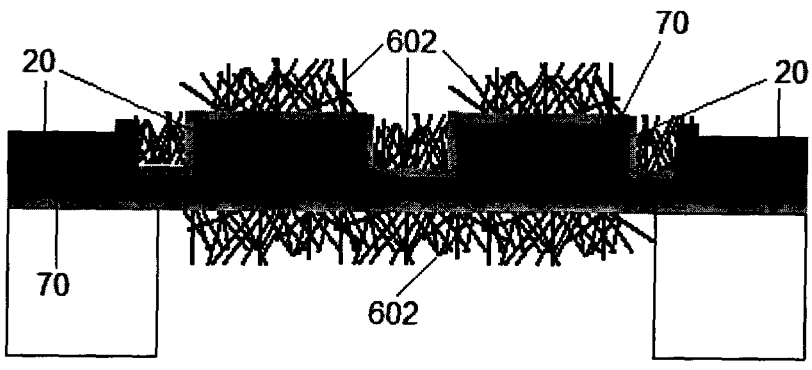

Figure 6

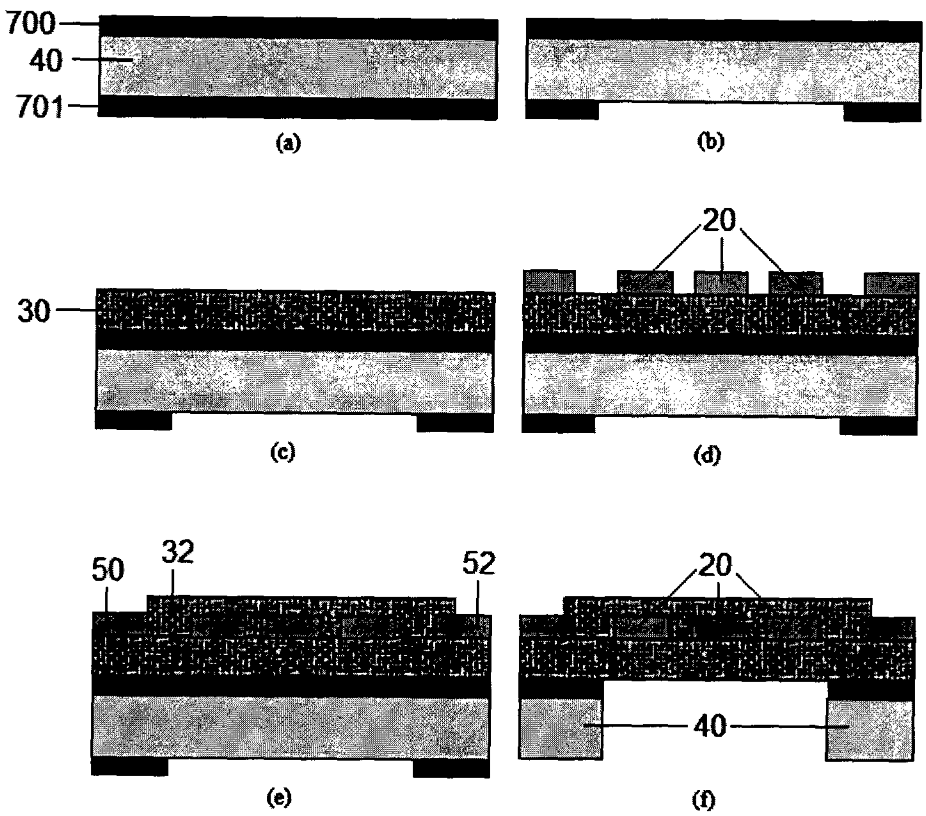

Figure 7

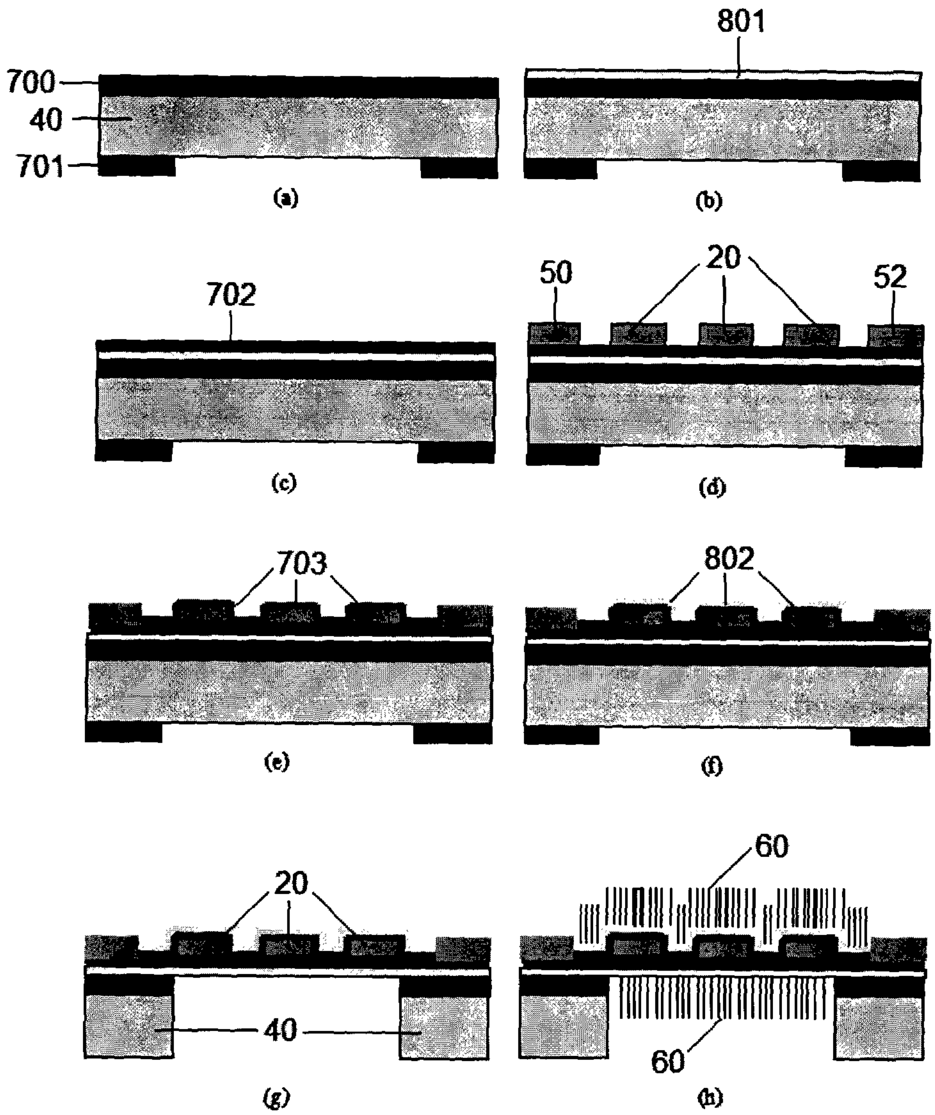

Figure 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/MY2011/000149

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

G01N 27/22 (2006.01)

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)

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 practicable, search terms used)
EPODOC,WPI, google: capacitor, sensor, ion, particle, comb, interdigitated, electrodes, fluid, cavity, contact pad, side, membrane, fringe and similar terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007/ 0284699 A1 (MILLER et al) 13 December 2007 See abstract, fig 5, paras 42, 43, 47, 49 ,53,59.	
A	US 2005/0067920 A1 (WEINBERG et al) 31 March 2005 See figs 4, 8, paras 68 and 25.	
A	US 5 552 655 A (STOKES et al) 3 September 1996 See abstract, fig 3a,b, col 3 lines 51-53.	

☐ Further documents are listed in the continuation of Box C

☒ 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 application or patent 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
26 September 2011	04/10/2011

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	**SUSAN PRING** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2210

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	2007284699	EP	2010450	JP	2009534174	KR	20080113074
		US	8004021	WO	2007127107		
US	2005067920	AU	2004278769	CA	2540691	CN	1883059
		EP	1671378	JP	2007510138	KR	20060088558
		KR	20080075024	US	7109633	US	2006260108
		US	7468138	WO	2005033660		
US	5552655	NONE					

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX