Title: HUMIDITY SENSOR AND A METHOD FOR FABRICATING THE SAME

Abstract: The present invention relates to a sensor for determining humidity. A humidity sensor (30) comprises a substrate (32); a bottom membrane (34) positioned above the substrate (32) and a top membrane (36) positioned above the bottom membrane (34) forming a dielectric layer (38); and a plurality of inter-digitated electrodes (40) with changing capacitance in accordance to change in humidity detected by the dielectric layer (38) embedded to the top membrane (36) wherein a plurality of trenches (42) are embedded to the bottom membrane (34) or to the substrate (32) thereby increasing area of exposure to humidity. The present invention also relates to a method for fabricating a humidity sensor.
Description

Title of Invention: HUMIDITY SENSOR AND A METHOD FOR FABRICATING THE SAME

Technical Field

The present invention relates to a sensor for determining humidity and a method for fabricating the same.

Background Art

Monitoring of temperature, humidity and ambient atmosphere composition with low cost, low power and highly sensitive sensor is of interest for many application fields. The measurement of humidity has received great attention due to the recognised importance of water partial pressure in various industries such as the production of electronic devices, agricultural and greenhouse environments, textiles and foodstuffs.

Humidity level is often measured by a humidity sensor. Generally, the humidity sensor comprises of an inter-digitated capacitor sandwiched between moisture absorbing membranes which are top membrane and lower membrane. The humidity sensor functions based on a change in permittivity of membrane layer at different humidity levels resulting in a change in electrical capacitance of the sensor. High capacitance value indicates high humidity level while low capacitance value indicates low humidity level.

However, lower membrane is partially exposed to the environment. This leads to poor moisture absorption rate hence limiting the sensor sensitivity.

Thus, there is a need to provide a humidity sensor with high sensitivity and fast response time.

Disclosure of Invention

Technical Problem

Summary of the invention

According to a first aspect of the present invention, there is provided a humidity sensor comprises of a substrate; a bottom membrane positioned above the substrate and a top membrane positioned above the bottom membrane forming a dielectric layer; and a plurality of inter-digitated electrodes with changing capacitance in accordance to change in humidity detected by the dielectric layer embedded to the top membrane.
wherein a plurality of trenches are embedded to the bottom membrane or to the substrate thereby increasing area of exposure to humidity.

The provision of having a plurality of trenches embedded in the bottom membrane or to the substrate is advantageous as it increases overall exposed surface area of the membrane thus increases moisture absorption rate and thereby increases the humidity sensor sensitivity.

Preferably, the dielectric layer is selected from silicon dioxide, silicon nitride, polymer or the like. This is beneficial as the silicon dioxide, silicon nitride, polymer or the like having characteristic of changeable dielectric permittivity according to change in humidity level.

According to a second aspect of the present invention, there is provided a flexible humidity sensor comprises of a bottom membrane and a top membrane positioned above the bottom membrane forming a dielectric layer; and a plurality of inter-digitated electrodes with changing capacitance in accordance to change in humidity detected by the dielectric layer embedded to the top membrane wherein a plurality of trenches are embedded to the bottom membrane thereby increasing area of exposure to humidity.

Accordingly, the flexible humidity sensor is elastic and bendable therefore ease adaptation and integration of the sensor on different platform.

According to a third aspect of the present invention, there is provided a method for fabricating a humidity sensor comprises of:

- providing a substrate;
- depositing a first layer;
- etching the first layer forming an etched layer;
- forming a bottom membrane above the etched layer;
- depositing a conductive layer above the bottom membrane;
- etching the conductive layer forming a plurality of inter-digitated electrodes;
- forming a top membrane above the plurality of inter-digitated electrodes; and
- etching the etched layer forming a plurality of trenches.

Accordingly, second step to eight step are repeated to obtain a plurality of top membrane and bottom membrane.

Accordingly, additional step of depositing an insulator layer above the substrate is required for the substrate made from silicon.

According to a fourth aspect of the present invention, there is provided a method for fabricating a humidity sensor comprises of:

- providing a substrate;
- etching the substrate forming an etched substrate;
- depositing a first layer on the etched substrate;
etching excessive of the first layer;
form a bottom membrane above the etched substrate;
depositing a conductive layer above the bottom membrane;
etching the conductive layer forming a plurality of inter-digitated electrodes;
forming a top membrane above the plurality of inter-digitated electrodes; and
etching the etched layer forming a plurality of trenches.

Description of Drawings

FIGURE 1: illustrates the humidity sensor.
FIGURE 2: illustrates the stacked type capacitive layer.
FIGURE 3: illustrates the flexible humidity sensor.
FIGURE 4: illustrates (a) vertical (b) horizontal and (c) criss-cross pattern of the plurality of trenches.
FIGURE 5a, b: illustrates the method for fabricating a humidity sensor.
FIGURE 6a, b: illustrates the method for fabricating a humidity sensor on silicon substrate.
FIGURE 7a, b: illustrates the method for fabricating a humidity sensor with the plurality of trenches embedded to the substrate.
FIGURE 8: illustrates etching of the substrate from the bottom membrane to form flexible humidity sensor.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates to a humidity sensor 30. In one embodiment as seen in FIGURE 1, the humidity sensor 30 comprises of a substrate 32, a dielectric layer 38, a plurality of inter-digitated electrodes 40 and a plurality of trenches 42.

The substrate 32 forms a base of the humidity sensor 30. The substrate 32 is preferably made from silicon or glass. The dielectric layer 38 is further comprises of a bottom membrane 34 and a top membrane 36. The bottom membrane 34 is positioned above the substrate 32 and the top membrane 36 is positioned above the bottom membrane 34. The dielectric layer 38 functions in detecting humidity as the dielectric layer 38 is able to absorb moisture from the environment. High amount of absorbed moisture indicate high humidity level while low amount of absorbed moisture indicate low humidity level. The dielectric layer 38 is made from any material where its dielectric permittivity changes according to change in humidity level. The dielectric layer 38 is preferably made from silicon dioxide, silicon nitride, polysilicon and polymer such as polyimide, PDMS and PMMA. The plurality of inter-digitated electrodes 40 with changing capacitance in accordance to change in humidity are embedded to the top membrane 36. The inter-digitated electrodes 40 are made from conductive material such as doped silicon, metals and conductive polymer. The
plurality of trenches 42 are embedded to the bottom membrane 34 or to the substrate 32. Preferably, the trenches 42 are of vertical, horizontal or criss-cross pattern as seen in FIGURE 4a, 4b and 4c respectively. The trenches 42 have a dimension ranging from 10.6 to 10-9 m.

The embedding trenches 42 increase overall exposed surface area of the membrane and thus increases moisture absorption. During operation, there will be a larger or more significant change in relative permittivity of the membrane and the overall inter-digital capacitance hence the trenches 42 increase sensitivity of the humidity sensor 30 and response time. This enable the humidity sensor 30 to detect very small change in humidity that comes from very small effect.

As seen in FIGURE 1, the dielectric layer 38 of the humidity sensor 30 is of a single type.

In another embodiment of the humidity sensor, the dielectric layer 38 could also be in stacked type as seen in FIGURE 2. To obtain a humidity sensor 30 with the stacked type dielectric layer 38, the dielectric layer 38 is repeated to n-layer where n is the desired number of layer. The stacked type dielectric layer 38 increases absorption of moisture.

FIGURE 1 and FIGURE 2 show a rigid humidity sensor 30 as the dielectric layer 38 is hinged on the substrate 32.

In further embodiment, the humidity sensor 30 could also be flexible as seen in FIGURE 3. The flexible humidity sensor 30 comprises of a bottom membrane 34 and a top membrane 36 positioned above the bottom membrane 34 forming a dielectric layer 38; and a plurality of inter-digitated electrodes 40 with changing capacitance in accordance to change in humidity detected by the dielectric layer 38 embedded to the top membrane 36 wherein a plurality of trenches 42 are embedded to the bottom membrane 34 thereby increasing area of exposure to humidity. The flexible humidity sensor 30 is elastic and bendable therefore ease adaptation and integration of the sensor on different platform.

In one embodiment, a method for fabricating the humidity sensor 30 is provided. As seen in FIGURE 5a and 5b, the method for fabricating a humidity sensor comprises of first 82, providing a substrate 32. Second 84, depositing a first layer 33. Third 86, etching the first layer 33 forming an etched layer 35. Fourth 88, forming a bottom membrane 34 above the etched layer 35. Fifth 90, depositing a conductive layer 39 above the bottom membrane 34. Sixth 92, etching the conductive layer 39 forming a plurality of inter-digitated electrodes 40. Seventh 94, forming a top membrane 36 above the plurality of inter-digitated electrodes 40 and eighth 96, etching the etched layer 35 forming a plurality of trenches 42.

The first layer 33 is preferably made from silicon dioxide and polysilicon.
The plurality of trenches 42 are formed by etching the etched layer 35 by a material etch selectivity process. The second steps 84 to the eighth step 96 are repeated for obtaining a plurality of top membrane 36 and bottom membrane 34. Top membrane 36 and bottom membrane 34 form the dielectric layer 38. Hence, repeating the second step 84 to eighth step 96 produces a plurality of dielectric membrane 38 which also known as stacked type dielectric layer 38. The dielectric layer 38 is repeated to n-layer where n is the desired number of layer.

To obtain a flexible humidity sensor 30, the method further comprises additional step of separating the substrate 32 from the bottom membrane 34 using an etchant as seen in FIGURE 8. Preferably, hydrofluoric acid is used as the etchant. The separated substrate 32 could be reused to fabricate other humidity sensor 30 and hence reduce the cost of fabrication.

In another embodiment of a method for fabricating the humidity sensor, an insulator layer 37 is deposited between the substrate 32 and the bottom membrane 34. The insulator layer 37 such as silicon nitride provides electrical isolation from the inter-digitated electrodes 40. The deposition of insulator layer 37 is required when the substrate 32 is made from a non insulating material such as silicon.

As seen in FIGURE 6a and 6b, a method for fabricating the humidity sensor 30 on silicon substrate comprises of first 82, providing a substrate 32. Second 83, depositing an insulator layer 37 above the substrate 32. Third 85, depositing a first layer 33 above the insulator layer 37. Fourth 86, etching the first layer 33 forming an etched layer 35. Fifth 88, forming a bottom membrane 34 above the etched layer 35. Sixth 90, depositing a conductive layer 39 above the bottom membrane 34. Seventh 92, etching the conductive layer 39 forming a plurality of inter-digitated electrodes 40. Eighth 94, forming a top membrane 36 above the plurality of inter-digitated electrodes 40 and ninth 96, etching the etched layer 35 forming a plurality of trenches 40. Third step 85 to ninth step 96 are repeated to obtain stacked type dielectric layer 38.

In further embodiment of a method for fabricating the humidity sensor, the plurality of trenches 42 could also be embedded to the substrate 32 as seen in FIGURE 7a and 7b. A method for fabricating the humidity sensor 30 with the plurality of trenches embedded to the substrate comprises of first 82 providing a substrate 32. Second 87, etching the substrate 32 forming an etched substrate 31. Third 89, depositing a first layer 33 on the etched substrate 31. Fourth 91, etching excessive of the first layer 33. Fifth 93, forming a bottom membrane 34 above the substrate 32. Sixth 90, depositing a conductive layer 39 above the bottom membrane 34. Seventh 92, etching the conductive layer 39 forming a plurality of inter-digitated electrodes 40. Eighth 94, forming a top membrane 36 above the plurality of inter-digitated electrode 40 and ninth 96, etching the first layer 33 forming a plurality of trenches 42.
The invention being thus described, it will be apparent that the same may be varied in many ways. Such variations are to be regarded as within the scope of the invention, and all such modifications as would be apparent to one skilled in the art are intended to be within the scope of the following claims.

Best Mode

Mode for Invention

Industrial Applicability

Sequence List Text
Claims

[Claim 1] 1. A humidity sensor 30 comprising:
   a substrate 32;
   a bottom membrane 34 positioned above the substrate 32 and a top membrane 36 positioned above the bottom membrane 34 forming a dielectric layer 38; and
   a plurality of inter-digitated electrodes 40 with changing capacitance in accordance to change in humidity detected by the dielectric layer 38 embedded to the top membrane 36 wherein a plurality of trenches 42 are embedded to the bottom membrane 34 or to the substrate 32 thereby increasing area of exposure to humidity.

[Claim 2] 2. A humidity sensor 30 according to Claim 1, wherein the plurality of trenches 42 having a pattern of vertical, horizontal and/or criss-cross.

[Claim 3] 3. A humidity sensor 30 according to Claim 1, wherein the plurality of trenches 42 having a dimension ranges from 10^-4 to 10^-9 m.

[Claim 4] 4. A humidity sensor 30 according to Claim 1, wherein the dielectric layer 38 is selected from silicon dioxide, silicon nitride and polymer or the like.

[Claim 5] 5. A humidity sensor 30 according to Claim 1, wherein the dielectric layer 38 is a single or stacked type.

[Claim 6] 6. A flexible humidity sensor 30 comprising:
   a bottom membrane 34 and a top membrane 36 positioned above the bottom membrane 34 forming a dielectric layer 38; and
   a plurality of inter-digitated electrodes 40 with changing capacitance in accordance to change in humidity detected by the dielectric layer embedded to the top membrane 36 wherein a plurality of trenches 42 are embedded to the bottom membrane 34 thereby increasing area of exposure to humidity.

[Claim 7] 7. A method for fabricating a humidity sensor comprising:
   providing a substrate 82;
   depositing a first layer 84;
   etching the first layer forming an etched layer 86;
   forming a bottom membrane above the etched layer 88;
   depositing a conductive layer above the bottom membrane 90;
   etching the conductive layer forming a plurality of inter-digitated electrodes 92;
forming a top membrane above the plurality of inter-digitated electrodes 94; and
etching the etched layer forming a plurality of trenches 96.

[Claim 8]
8. A method according to Claim 7, wherein the etching the etched layer forming a plurality of trenches 96 is by material etch selectivity process.

[Claim 9]
9. A method according to Claim 7, wherein repeating step 84 to step 96 for obtaining a plurality of top membrane 36 and bottom membrane 34.

[Claim 10]
10. A method according to Claim 7, wherein additional step 83 of depositing an insulator layer above the substrate is for substrate made from silicon.

[Claim 11]
11. A method according to Claim 7, wherein the method further comprises additional step of separating the substrate from the bottom membrane using an etchant to obtain a flexible humidity sensor 30.

[Claim 12]
12. A method according to Claim 10, wherein the etchant is hydrofluoric acid.

[Claim 13]
13. A method for fabricating a humidity sensor comprising:
providing a substrate 82;
etching the substrate forming an etched substrate 87;
depositing a first layer on the etched substrate 89;
etching excessive of the first layer 91;
forming a bottom membrane above the etched substrate 93;
depositing a conductive layer above the bottom membrane 90;
etching the conductive layer forming a plurality of inter-digitated electrodes 92;
forming a top membrane above the plurality of inter-digitated electrodes 94; and
etching the etched layer forming a plurality of trenches 96.
FIGURE 3

FIGURE 4
Providing a substrate

Depositing a first layer

Etching the first layer forming an etched layer

Forming a bottom membrane above the etched layer

Depositing a conductive layer above the bottom membrane

Etching the conductive layer forming a plurality of inter-digitated electrodes

Forming a top membrane above the plurality of inter-digitated electrodes

Etching the etched layer forming a plurality of trenches

FIGURE 5a
FIGURE 5b
Providing a substrate

Depositing an insulator layer above the substrate

Depositing a first layer above the insulator layer

Etching the first layer forming an etched layer

Forming a bottom membrane above the etched layer

Depositing a conductive layer above the bottom membrane

Etching the conductive layer forming a plurality of inter-digitated electrodes

Forming a top membrane above the plurality of inter-digitated electrodes

Etching the etched layer forming a plurality of trenches

FIGURE 6a
Providing a substrate

Etching the substrate forming an etched substrate

Depositing a first layer on the etched substrate

Etching excessive of the first layer

Forming a bottom membrane above the etched substrate

Depositing a conductive layer above the bottom membrane

Etching the conductive layer forming a plurality of inter-digitated electrodes

Forming a top membrane above the plurality of inter-digitated electrodes

Etching the etched layer forming a plurality of trenches

FIGURE 7a
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)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI: G01N 27/22/low, capacitor, sensor, humidity, surface area, increase, membrane, trench and similar terms;

Google: interdigitated, sensor, humidity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>WO 2009/066992 A2 (MIMOS BERHAD) 23 May 2009 See fig 1, claim 3, pg 4 line 23-page 5 line 16.</td>
<td>1-6</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C

* 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
16 September 2011

Date of mailing of the international search report
04/10/2011

Name and mailing address of the ISA/AU
AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
E-mail address: pct@ipaustralia.gov.au
Facsimile No. +61 2 6283 7999

Authorized officer
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.

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WO 2009066992</td>
<td>NONE</td>
</tr>
<tr>
<td>WO 2010029507</td>
<td>CN 102150038 EP 2321632 US 2011185810</td>
</tr>
<tr>
<td>KR 100965835</td>
<td>KR 20090029383</td>
</tr>
</tbody>
</table>

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

END OF ANNEX