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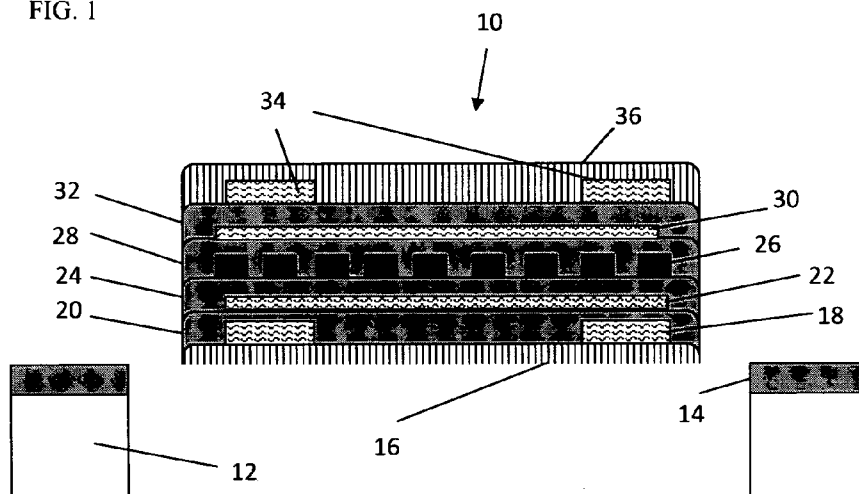
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(54) Title: MICRO-HOTPLATE BASED GAS SENSOR

FIG. 1



(57) Abstract: The present invention provides a chemo-resistive gas sensor in which consists of two chemo-resistive sensor elements (16, 36) placed on both sides of a micro-hotplate array (26). It is capable of providing lower power consumption compared to existing one-side sensing membrane gas sensor. An embodiment of the invention has the two sensor elements to be of same material to increase the sensitivity of the device. Another embodiment of the invention has two sensor elements of different material to allow different gas to be monitored. The proposed two membranes may be arranged to provide multiple gas solution for remote application and device miniaturization.

MICRO-HOTPLATE BASED GAS SENSOR

The present invention relates to gas sensor. More particularly, the invention relates to gas sensor, integrated on a micro-hotplate platform, and methods for making such
5 integration.

BACKGROUND ART

Chemo-resistive gas sensors basically operate on principles of bulk changes sensitive to
10 oxygen partial pressure and its oxide defect chemistry, and surface changes mechanism which involve adsorption and desorption of oxygen on the sensor surface. It has a high operation temperature, in the range of 700 °C and above. High surface temperature of sensor promotes oxidation process on the sensor surface. Oxygen adsorbents will build a space-charge region in the semiconductor layer. Reversible change in resistant of the
15 semiconductor layer based on O₂ adsorption-desorption can be used to detect impurity/minority gases. The temperature dependence is due to differing stabilities of O₂ species and different oxidizing temperature of gases.

Currently, metal oxide semiconductor (MOS) gas sensor is a mature innovation and has
20 many advantageous feature such as high sensitivity, fast response and recovery, versatile selectivity through operational temperature and sensor material, as well as good capabilities for low-cost mass production and small size mobile applications. It has been widely applied in measuring various volatile organic compounds, toxic chemical vapours as well as gases such as NO₂, CO, CH₄ and H₂S.

25 Good desirable gas sensors with good sensitivity have features of fast time sequence to apply variable operation temperature using micro-hotplate structure. Micro-hotplate structure functions as integrated resistor heater for the sensor layer.

30 However, existing gas sensors have drawbacks. The gas sensor has high power consumption due to the limited micro-hotplate surface which results in waste heat. Existing gas sensor has a fixed structure of integrating one sensor layer to one micro-hotplate structure which is not suitable for multi sensor integration and the device is too big for mobile or wireless application.

The present invention is made in view of the need to reduce the power consumption of micro-hotplate surface.

SUMMARY OF INVENTION

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The aim of the present invention is to provide a gas sensor structure with lower power consumption compared to existing gas sensor structure. Within this aim, the present invention provides a gas sensor structure consisting of chemo-resistive sensor layer on top and bottom surface of micro-hotplate layer.

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The gas sensor structure improves the overall sensitivity of gas sensor and allows further device miniaturization of the sensor. Another embodiment of the present invention provides a gas sensor structure with two different type sensors which offer multiple gas sensor solutions. The present invention allows a multiple gas sensor solution by forming two different sensing membranes on both sides of micro-hotplate array.

15

A method of making such gas sensor structure is also provided.

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The gas sensor structure according to the present invention includes a top layer of chemo-resistive sensor coupled with electrical contacts, a top layer of thermal distribution element, a layer of micro-hotplate array, a bottom layer of thermal distribution element and a bottom layer of chemo-resistive sensor. The sensor layers are heated to desired temperature by the layer of micro-hotplate array. The heat is equally distributed by the layers of thermal distribution element. The present invention reduces the power consumption of proposed sensor compared with sensors of existing structure as only one side of the micro-hotplate array is utilized and the other side's heat is wasted.

25

By forming two similar sensing membranes on both sides of micro-hotplate array, the sensitivity of the sensor is improved. Therefore the present invention also reduces the space required for sensors of similar sensitivity and enables device miniaturization.

30

Additional objects and advantages of the invention will become apparent to those skilled in the art upon reference to the detailed description taken in conjunction with the provided figures.

5 BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic diagram of a gas sensor for minority gas detection, according to the invention.

FIG. 2 is a diagram of gas sensor structure.

10 FIG. 3 is a schematic top view of sensor device according to the present invention.

FIG. 4 is a series of diagram of formation of a sensor element.

FIG. 5 is a series of diagram of formation of a micro-hotplate platform.

FIG. 6 is a series of diagram of formation of another sensor element above micro-hotplate.

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DESCRIPTION OF EMBODIMENTS

Reference will now be made in detail to the preferred embodiments of the invention which is intended to provide a thorough understanding of the present invention. However,
20 well known methods, procedures, components, and circuits have not been described in detail as not to unnecessarily obscure aspects of the present invention.

In an embodiment of the present invention, a schematic diagram of gas sensor [10] fabricated on a substrate, such as silicon, is shown in FIG. 1. A gas sensor [10]
25 comprising a substrate [12], an insulating layer [14] such as silicon nitride forming on the substrate [12], a bottom chemo-resistive sensor membrane layer [16] forming on insulating layer [14], a layer of electrical contacts [18] coupled to bottom sensing membrane layer [16], an insulating layer [20] forming on bottom sensing membrane layer [16] and its electrical contacts [18], a bottom thermal distribution layer [22] forming
30 on insulating layer [20], an insulating layer [24] forming on bottom thermal distribution layer [22], a micro-hotplate array [26] forming on insulating layer [24], an insulating layer [28] forming on micro-hotplate array [26], a top thermal distribution layer [30] forming on insulating layer [28], an insulating layer [32] forming on top thermal distribution layer [30], a layer of electrical contacts [34] forming on insulating layer [32] in which coupled with

top chemo-resistive sensing membrane layer [36], and a top sensing membrane layer [36] forming on insulating layer [32] and electrical contacts [34]. A brief outline of the structure is shown in Fig. 2.

- 5 When current is applied to micro-hotplate array [26], the micro-hotplate array [26] is heated to desirable temperature for chemical reactions of gas and sensors surface. The top [30] and bottom thermal distribution layer [22] are used to distribute the heat transferred from the micro-hotplate array [26] evenly to the top [36] and bottom sensing membrane layer [16]. The conducting layers are insulated by insulating layers such as
10 silicon nitride or silicon dioxide to prevent short circuit in the structure.

- As such, the top [36] and bottom sensing membrane layer [16] fully utilized the heated area of micro-hotplate array [26] and results in less power consumption than existing gas sensors. The micro-hotplate structure is of a material selected from a group consisting
15 and not limited to silicon, platinum, gold, silver, nickel and tungsten. The sensing membranes is of metal oxide selected from a group consisting but not limited to tin oxide, tungsten oxide, tantalum pentoxide, aluminium oxide, copper oxide, iron oxide, titanium oxide, neodymium oxide, indium oxide, vanadium pentoxide and zinc oxide. Different sensing element enables detection of different minority gas species. The gas sensor [10]
20 using same sensing element for both side sensors will increase the sensors [10] sensitivity and enables device miniaturization. These features enable the sensor [10] of present invention more favourable for mobile sensing device and wireless-remote sensing device than existing gas sensor.

- 25 FIG. 3 shows a top view of sensor device [10], where the contact pads are all on the top surface. Contact pads [38] are coupled to top sensing layer [36], contact pads [40] are coupled to micro-hotplate array [26], and contact pads [42] are coupled to bottom sensing layer [16]. An active area [44] of the sensing membranes is shown.

- 30 A method of fabricating a gas sensor of present invention involves the step of depositing an insulating layer [14] such as silicon nitride onto both sides of silicon substrate [12] surfaces, as shown in FIG. 4. The back insulating layer is etched to form a mask for etching silicon. A layer of bottom chemo-resistive sensing membrane [16] is deposited on one side of insulating layer [14]. A conductive layer is deposited on bottom sensing

membrane [16] and is etched to form electrical contacts [18] coupled with sensing membrane [16]. An insulating layer [20] is deposited on and covering bottom sensing membrane [16]. Next, a conductive layer is deposited on insulating layer [20] and is etched to form bottom thermal distribution layer [22]. An insulating layer [24] is deposited on and covering bottom thermal distribution layer [22]. A conductive layer is deposited on insulating layer [24] and is etched to form micro-hotplate array [26], as shown in FIG. 5. An insulating layer [28] is deposited on and covering micro-hotplate array [26]. Then, a conductive layer is deposited on insulating layer [28] and is etched to form top thermal distribution layer [30], as shown in FIG. 6. An insulating layer [32] is deposited on and covering top thermal distribution layer [30]. A conductive layer is deposited on insulating layer [32] and is etched to form electrical contacts [34]. A layer of top sensing membrane layer [36] is deposited on insulating layer [32] covering electrical contacts [34]. Silicon substrate and both insulating layer [14] are etched to form a cavity exposing bottom sensing membrane layer [16].

15

Accordingly, the invention disclosed a micro-hotplate based gas sensor. The micro-hotplate has gas detecting membrane on both sides of the micro-hotplate. This solution reduces problems in higher power consumption compared to existing structure, and device miniaturization.

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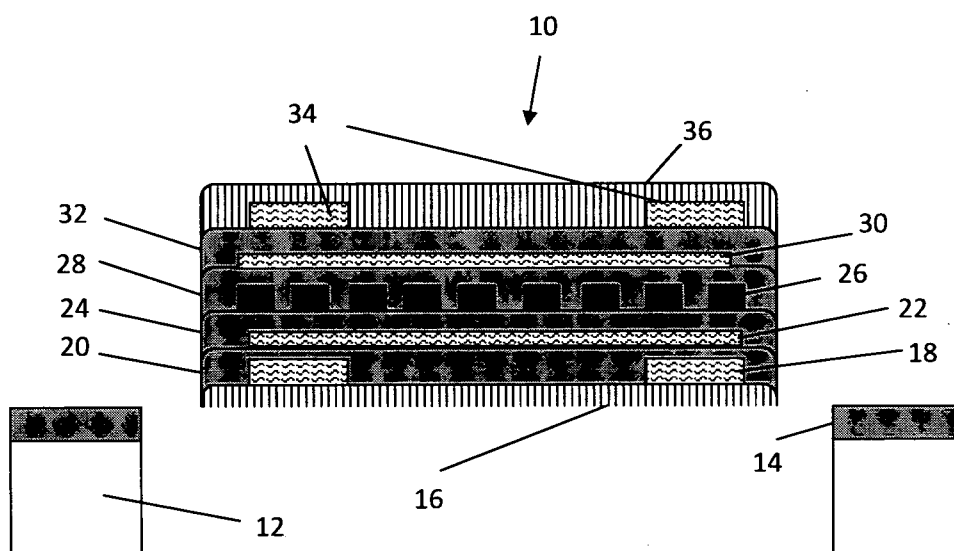
CLAIMS

1. A micro-hotplate based gas sensor [10], comprising:
 - a micro-hotplate layer [26];
 - 5 a chemo-resistive sensor element [36] on top of micro-hotplate layer;
 - characterized in that,
 - a chemo-resistive sensor element [16] below micro-hotplate layer and a cavity below said sensor element.
- 10 2. A sensor according to claim 1, further comprising a thermal distribution layer [22, 30] between micro-hotplate layer [26] and resistive sensor element [16, 36].
3. A sensor according to claim 1, wherein the cavity is bordered by substrates below resistive sensor element [16].
- 15 4. A sensor according to claim 1, wherein sensor elements [16, 36] are of same material.
5. A sensor according to claim 1, wherein sensor elements [16, 36] are of different
- 20 material.
6. A sensor according to claim 1, wherein sensor elements [16, 36] and micro-hotplate [26] has electrical contacts on the device surface.
- 25 7. A method of fabricating a micro-hotplate based gas sensor, comprising:
 - forming a chemo-resistive sensor element layer which is separated from substrate with insulating layer;
 - forming electrical contacts for the sensor element;
 - forming thermal distribution plate which is separated from electrical contact with
 - 30 insulating layer;
 - forming micro-hotplate platform which is separated from thermal distribution plate with insulating layer;
 - forming another thermal distribution plate separated from micro-hotplate structure with insulating layer;

forming another chemo-resistive sensor element layer with electrical contact, separated from thermal distribution layer with insulating layer; and etching a cavity through substrate to expose part of chemical resistive sensor element.

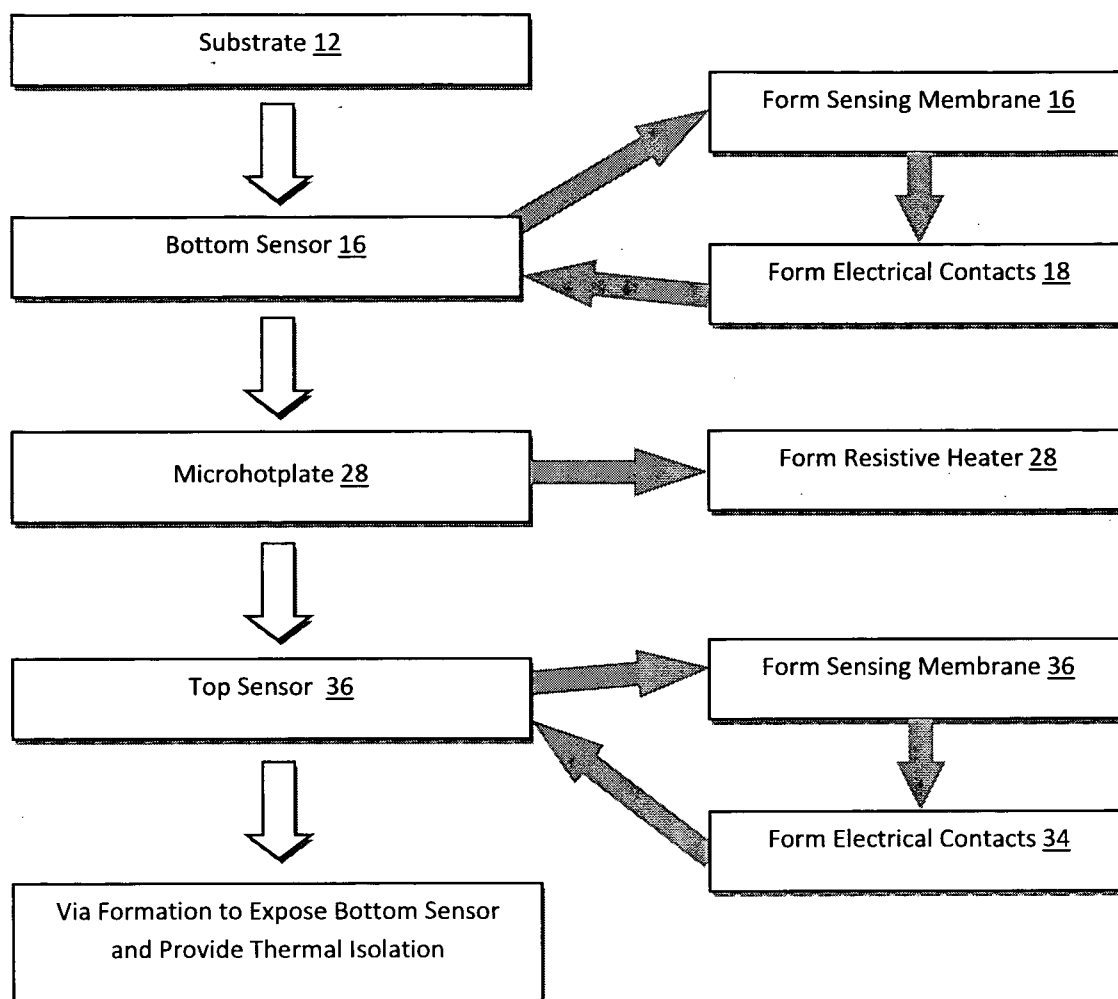
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FIG. 1



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FIG. 2



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FIG. 3

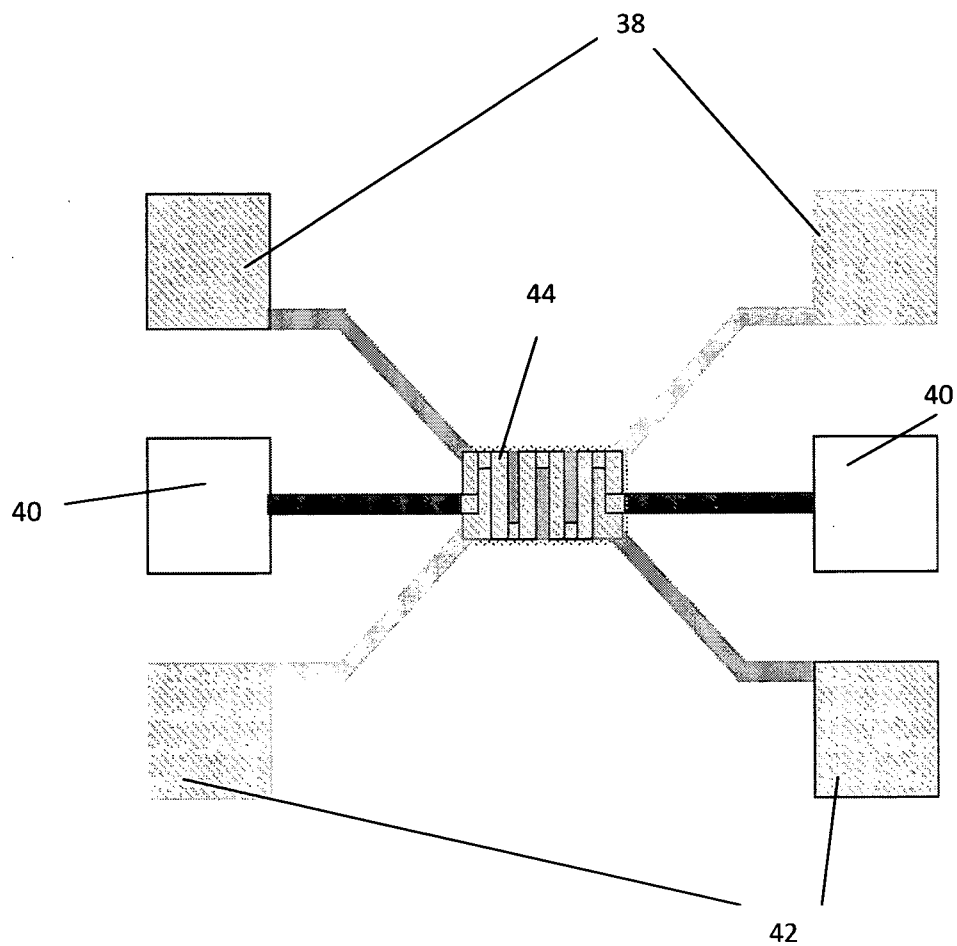


FIG. 4

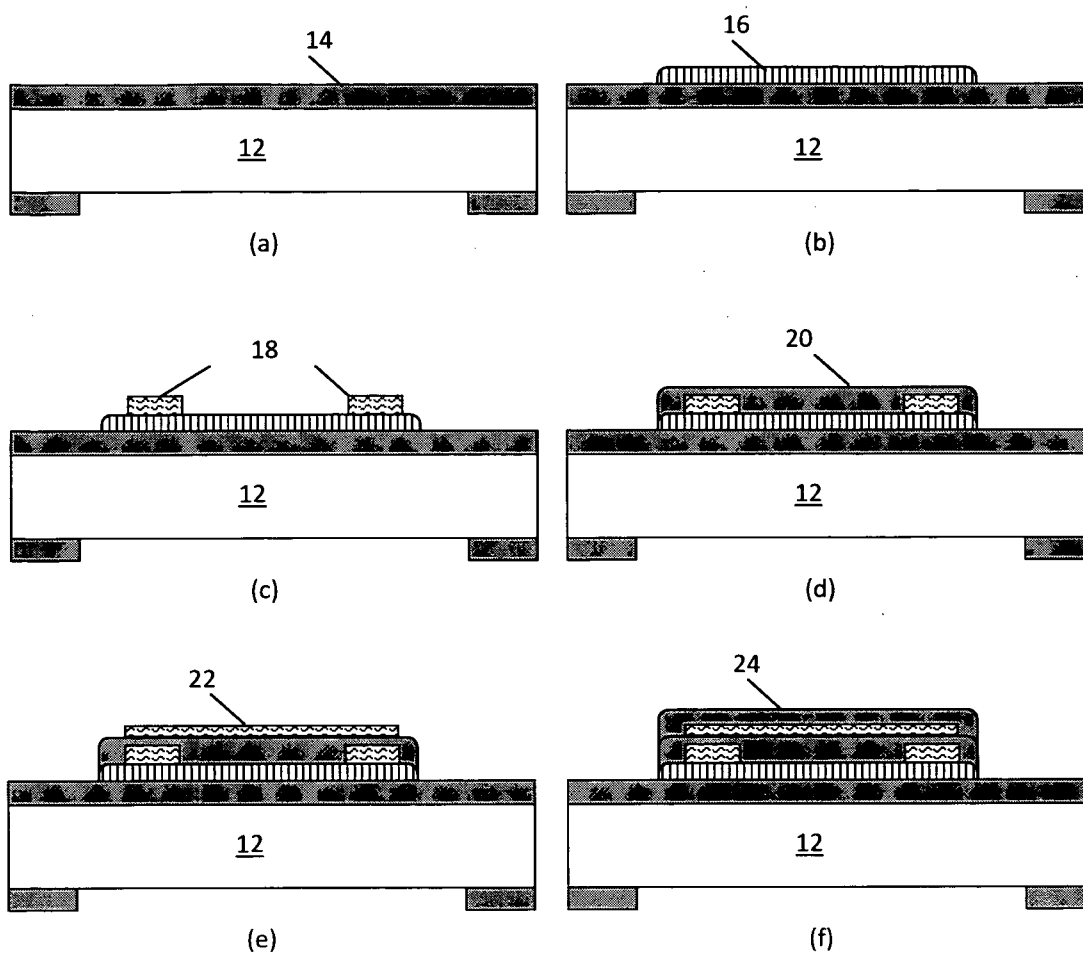


FIG. 5

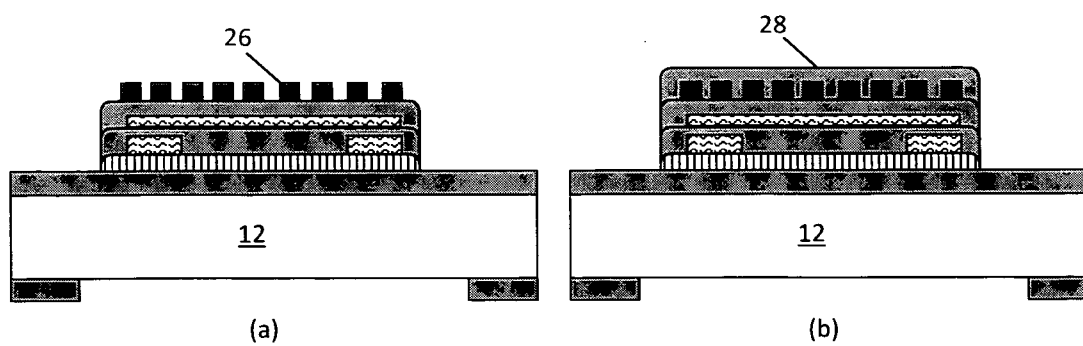
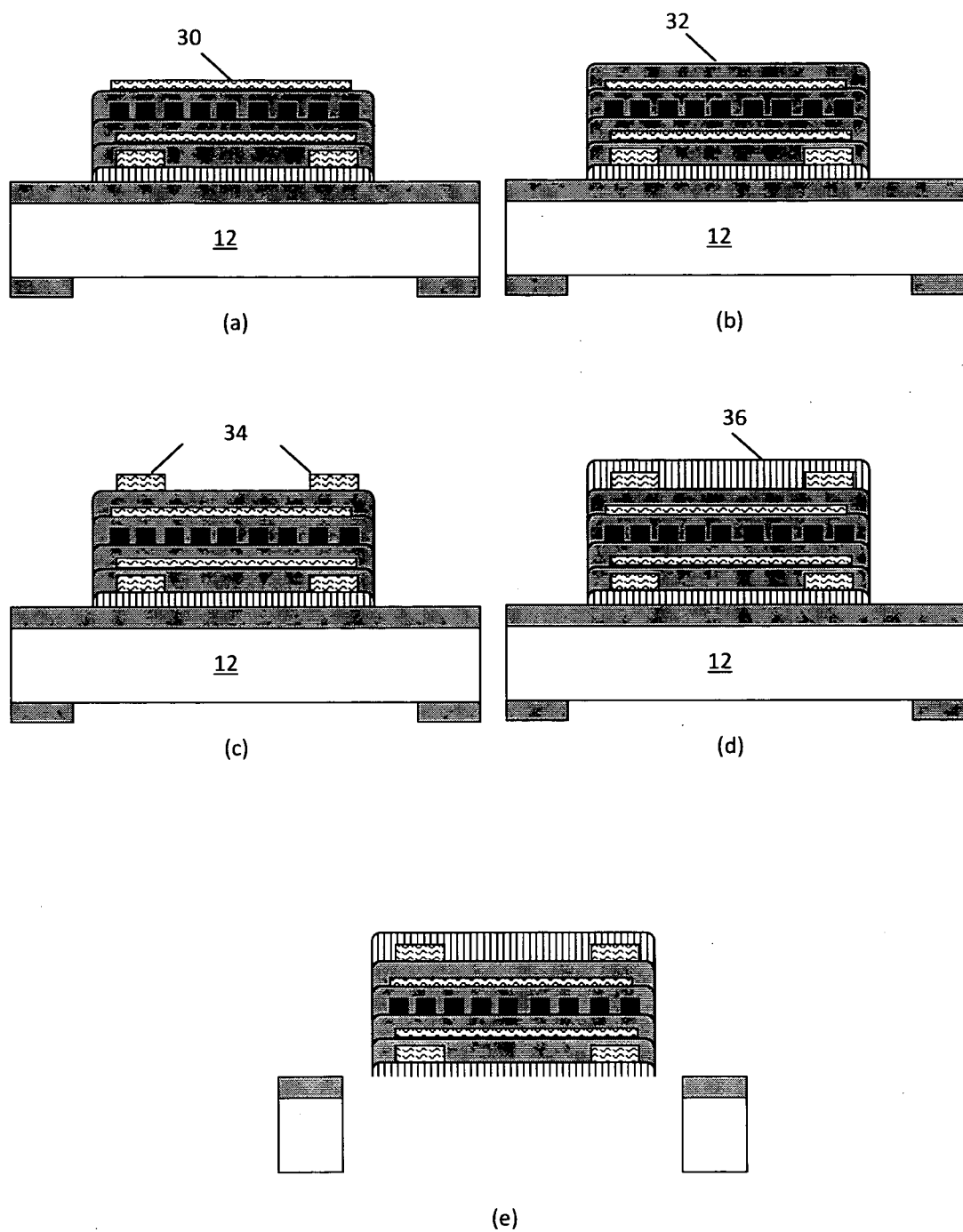


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/MY2011/000093

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

G01N 27/12 (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: hotplate, heat, thermal, chemical resist, sensor, membrane, gas, detect, miniature, micro.

Google: Mimos, gas, sensor; double sided chemo-resistive gas sensor

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2007/122287 A1 (ENVIRONICS OY) 1 November 2007 Abstract and page 10, line 29-page 11, line 10	
A	US 6596236 B2 (ADVANCED TECH MATERIALS) 22 July 2003 Abstract	



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	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
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10 NOVEMBER 2011

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/MY2011/000093

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Patent Document Cited in
Search Report

Patent Family Member

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

END OF ANNEX