

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

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
27 October 2011 (27.10.2011)

PCT

(10) International Publication Number
WO 2011/133015 A2

(51) International Patent Classification:
G01N 27/40 (2006.01) **B01D 35/00** (2006.01)

(21) International Application Number:
PCT/MY2010/000264

(22) International Filing Date:
10 November 2010 (10.11.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PI2010001857 23 April 2010 (23.04.2010) MY

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

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

Published:

— with declaration under Article 17(2)(a); without abstract; title not checked by the International Searching Authority

(54) Title: SILICON NANOWIRE BASED FILTER AND METHOD OF FABRICATING THEREOF

(57) Abstract:



WO 2011/133015 A2

SILICON NANOWIRE BASED FILTER AND METHOD OF FABRICATING THEREOF**FIELD OF INVENTION**

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The present invention generally relates to fluidic filters, and more particularly to a fluidic filter comprising silicon nanowires with controlled attributes.

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BACKGROUND

The conventional and well-known methods which are widely implemented in regards to sensing in the electrochemical analysis of fluidic samples would comprise the use of fluidic channels incorporated with at least one sensing device.

Generally, for an attempt of sensing chemical elements or molecules for fluidic samples using a device as briefly described above, the common challenges in producing an accurate result based on the sensing are prominently influenced by external factors such as, but not limiting to, temperature, humidity, light, motion and pressure. In order to partially resolve this increasingly unsettling drawback, users have started to incorporate filters or filtering apparatus within the apparatus in effort to reduce disruptions to obtain better sensing outcome.

The number of studies conducted in order to further develop the efficiency and enhance the capability of fluidic sensing with the aid of filtering apparatus has tremendously increased over the
5 past few years. Such studies may become solutions for complications or undesirable characteristics as discussed previously and may further include such sensing capabilities being time drift and temperature dependence, and thus reduce the precision of sensing which is quite significant in relation to
10 producing an accurate output.

Another significant drawback which relates to fluidic sensing is in regards to the presence of superfluous constituents which would in many occasions result to creation of noises thus
15 interrupting the measured signals.

Whilst many prior art and technology substitutions may be expedient and considerably enhanced in regards to the utilization of fluidic filters, the current condition or challenge of
20 filtering unwanted materials to obtain better sensing clarity has yet to be thoroughly resolved. A great majority of devices or methods which may be able to provide at least half of the clarity in sensing are more often prohibitively expensive.

Proceeding from the above, there is a need to provide a device and method that is able to resolve the abovementioned drawbacks in regards to the utilization of fluidic filter technology.

5 The present invention is particularly developed to overcome the aforementioned complications.

It is therefore a primary object of the present invention to provide a device and method thereof for use in fluid or fluidic
10 filter devices, said device and method provides the capability of selective filtering thereby producing an enhanced sensing clarity.

It is further an object of the present invention to provide a
15 device and method thereof for use in fluid or fluidic filter devices, said device and method allows the circumvention of a purification step in filtering signals during use.

It is yet another object of the present invention to provide a
20 device and method thereof for use in fluid or fluidic filter devices, said device comprising silicon nanowires grown therein.

Further objects and advantages of the present invention may become apparent upon referring to the preferred embodiments of
25 the present invention as shown in the accompanying drawings and as described in the following description.

SUMMARY OF INVENTION

There is disclosed a method for use in fabricating a filtering

5 device, said method comprising the steps of:

i) forming a trench structure on a support material;

ii) providing a predetermined amount of silicon
nanowires within said trench structure for use in
controlling the flow of particles and collecting
10 the particles of interest within said filtering
device;

iii) confining the trench structure;

wherein said silicon nanowires is provided by way of
in-situ growth within said trench structure.

15

In another aspect of the present invention there is disclosed a
device (100) for use in filtering, said device comprising: a
substrate (20); at least one trench structure (60); at least one
layer (80) for confining the trench structure; a predetermined
20 amount of silicon nanowires (40) provided within the trench
structure for controlling particles which flow through the device
(100) and collect the desired particles within the device (100);
characterized in that the silicon nanowires (40) are grown in-
situ thus directly within the trench structure in a manner such
25 that the nanowires (40) are permitted to free stand and self
align therein.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

5 In order to provide a comprehensive understanding of the nature of the invention, reference should be made to the accompanying drawings and the subsequent description. Briefly, the drawings are:

10 **FIG 1** shows the filter device in accordance with a preferred embodiment of the present invention;

FIG 2 shows a flowchart for fabrication of the filter device in accordance with a preferred embodiment of the present invention;

15

FIG 3 shows the variety of cross sections for a trench structure in accordance with a preferred embodiment of the present invention;

20 **FIG 4** shows the steps involved in preparing the filter in accordance with a preferred embodiment of the present invention;

FIG 5 shows the steps involved in preparing the filter in accordance with another preferred embodiment of the present
25 invention;

FIG 6 shows the steps involved in preparing the filter in accordance with another preferred embodiment of the present invention;

- 5 **FIG 7** shows the steps involved in preparing the filter in another preferred embodiment of the present invention.

DETAILED DESCRIPTION

- 10 In addition to the drawings, further understanding of the object, construction, characteristics and functions of the invention, a detailed description with reference to the embodiments is given in the following.

- 15 It should be noted that the preferred embodiments which will be described in detail herein are provided to assist in further understanding of the invention. The steps involved in attaining the outcome based on the scope of the appended claims are described in their best mode and sequential order, said
20 sequential order may vary and thus the best mode which will be described herein should not be construed as restricting the scope of the invention.

- In accordance with one aspect of the present invention for
25 achieving the above discussed objects, there is provided a fluidic filter device comprising silicon nanowires grown therein

and method thereof. The silicon nanowires in accordance to the present invention are grown in-situ by an accurate and precise process which will be described herein, thus providing a filtering device with controllable pore sizes. The use of silicon nanowires is preferred owing to its low temperature process thereby allowing compatibility with most substrates.

FIG 1 shows the filter device (100) embodying the present invention, whereby the essential or vital section of the filter (100) is a channel supporting free standing nanowires.

The aim of the filter (100) of one embodiment in accordance with the present invention is to segregate the constituents of a fluid based on the pore size of the filter mesh or by means of functionalized sites. It is further described that the filtered outflow of the fluid of the constituents gathered at the filter can be analyzed with better precision. As previously mentioned, the filter mesh incorporated for the filter device (100) of the present invention is based on silicon nanowires which are grown therein as part of the fluidic channel fabrication.

The filter device (100) of the present invention therefore comprises at least one channel (60) or trench structure formed within a substrate (20) for accommodating or supporting a predetermined amount of silicon nanowires (40) which are provided

by means of in-situ growth within said channel (60). These nanowires are grown in a free standing manner within the channel (60). An encapsulation layer (80) which functions primarily to confine the trench structure (60) is further disposed therein. A catalyst permits the growth of nanowires, whereby the catalyst may be deposited within the channel by means of physical vapour deposition, chemically or by means of self assembly.

FIG 2 provides a flowchart showing the imperative steps involved for the fluidic filter fabrication in accordance with a preferred embodiment of the present invention. As evident in the flowchart the first step is providing a suitable substrate (S200) and followed by the formation of trenches or trench structures (S300). The next step is deposition of catalyst or starting material for nanowire growth (S400). This is then followed by in-situ deposition of silicon nanowire by, but not limiting to, chemical vapour deposition (S500). Finally, the formed trench is encapsulated thus forming embedded channel by means of waferbonding (S600).

The trench structures of the present invention may be formed by means of etching and lithography. It is understood that the cross sections of the trench structures may vary, as shown, but not limiting to the types in **FIG 3**. The cross sections may include rectangular, triangular, V-shape and circular forms.

Now referring to **FIG 4** containing steps (a) to (e) accompany the description to show that the trench may be formed by means of etching into a substrate. Suitably, the trenches may be formed in the substrate by means of dry or wet etching followed by
5 lithographic patterning. In this approach, the first step involves the deposition of suitable catalyst materials for the deposition or growth of silicon nanowires at the bottom portion of the channel. Such deposition may be carried out by means of physical vapour deposition including sputtering and evaporation.
10 In the next step, a lift off is preferably used to remove the excess catalyst material, after which the silicon nanowires is then suitably deposited in -situ within the formed channel. In the final step of this process, the channel is accordingly encapsulated by mean of waferbonding.

15

FIG 5 accompanies the description in the event that the trench is formed by means of lithography. As seen in **step 5 (a)**, a polymer is involved. Similar to that of the previously discussed etching method, the starting or catalyst material may be deposited within
20 the channel by means of physical vapour deposition. However for the removal of excess catalyst, physical polishing is preferred. Then the silicon nanowires are deposited within the channel and encapsulated by means of waferbonding.

25 **FIG 6** accompanies the description in the event that the trench structure is formed comprising deliberately underdeveloped

polymer. This embodiment involves forming of trenches by means of lithography, whereby the channel is deliberately underdosed in order to ensure that the depth is not developed straight to the supporting substrate. In **step 6 (b)** and similar to that of the previously discussed methods, the catalyst for the growth of the silicon nanowires may be suitably deposited within the formed channel by means of physical vapour deposition. The excess catalyst is then removed by means of physical polishing prior to deposition of silicon nanowires within the channel. The channel is then suitably encapsulated by means of waferbonding. For this method, the polymer containing the channel is removed from the supporting substrate.

In another preferred embodiment of the present invention and as shown in **FIG 7** the silicon nanowires is deposited at desired sites with the aid of a chemical affinity to the silicon nanowires catalyst precursor. For this embodiment, the trenches are defined by lithography whereby the filter region or channel is provided with a thin layer of material with chemical affinity to the catalyst material. Subsequently, the channel containing this material is suitably encapsulated by means of waferbonding, after which a solution containing the catalyst material is then channeled through the trench. The silicon nanowires are then deposited in-situ within the formed channel or trench by means of process gas.

It should be noted that the filter device (100) comprising silicon nanowires which is preferably grown at a temperature of 350 to 500 °C in accordance to the present invention allows controllable pore size based on the spacing between the silicon nanowires and thereby the capacity to make the filter application specific and selective by way of functionalizing the silicon nanowires.

In accordance to a preferred embodiment of the present invention and as discussed briefly in the preceding paragraphs, the growth of silicon nanowires are preferably done in-situ, specifically within the formed channel of the device (100). Such deposition thereby results to self-aligning process, as well as ordered morphology and thus reducing the number of required steps of the prior art methods.

In another preferred embodiment of the present invention, the formation of the silicon nanowires within the channel is based on a clean and controlled process which therefore does not necessitate further purification step.

It is noted that the pore size of the filter channel can vary from 50nm to 5µm, subject to its application, which may include biomedical purposes such as, but not limiting to, insulating bacteria and virus for analysis. It is further observed that the filter as described may aid in the separation of materials that

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may impede the operation of other devices within the fluidic cell such as sensors and filtering materials to be channeled independently to different areas of the fluidic cell.

5 Although the present invention has been described in terms of the presently preferred embodiments, it is to be understood that such disclosure is not to be interpreted as limiting. Various alterations and modifications will no doubt become apparent to those skilled in the art after having read the above disclosure.

10 The appended claims should be interpreted as covering all alterations and modifications as fall within the scope of invention.

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CLAIMS

1. A method for use in fabricating a filtering device, said method comprising the steps of:

- 5 a) forming a trench structure (S300) on a support material;
- b) providing a predetermined amount of silicon nanowires (S500) within said trench structure for use in controlling the flow of particles and
- 10 collecting the particles of interest within said filtering device;
- c) confining (S600) the trench structure;
- wherein said silicon nanowires is provided by way of in-situ growth within said trench structure.

- 15 d) The method as claimed in Claim 1 wherein the method further comprising the step of providing a form of catalyst for the growth of silicon nanowires (S400).

- 20 e) The method as claimed in Claim 1 wherein the step providing a predetermined amount of silicon nanowires (S400) comprises providing said nanowires directly in the trench structure and thus allowing
- 25 self alignment of the silicon nanowires.

f) The method as claimed in Claim 1 wherein the trench structure is confined in a manner such that a capping or encapsulating layer is provided on said structure.

5

g) The method as claimed in Claim 1 wherein the supporting material comprises a substrate.

10

h) The method as claimed in Claim 1 wherein the temperature for growth of silicon nanowires is between 350-500°C.

15

i) The method as claimed in Claim 1 wherein the trench structure has a cross-section generally in the form of either a rectangular, circular, V-shape or triangular shape.

20

j) The method as claimed in Claim 1 wherein the silicon nanowire has a pore size of between 50nm to 1.5 µm, whereby the pore size can be varied subject to the desired particles to be filtered.

25

k) The method as claimed in Claim 1 wherein the trench structure may be formed by etching or lithography.

l) The method as claimed in Claim 3 wherein the catalyst is provided by means of physical vapour deposition, chemically or by means of self assembly.

m) The method as claimed in Claim 1 wherein the silicon nanowires may be grown by means of chemical vapour deposition or flowing a process gas.

5

n) The method as claimed in Claim 2 wherein the step providing a catalyst further comprising the step of removing excess catalyst from the trench structure.

10

o) The method as claimed in Claim 4 wherein the encapsulation may be provided by means of anodic bonding, silicon bonding, adhesive bonding or polymer bonding.

15

p) The method as claimed in Claim 1 wherein the filtering device is for use in fluid and gases.

20

q) A device (100) for use in filtering, said device comprising:

a substrate (20);

at least one trench structure (60);

at least one layer (80) for confining the trench structure;

25

a predetermined amount of silicon nanowires (40) provided within the trench structure for controlling particles which flow through the device (100) and collect the desired particles within the device (100);

characterized in that the silicon nanowires (40) are grown in-situ thus directly within the trench structure in a manner such that the nanowires (40) are permitted to free stand and self align therein.

5 r) The device (100) as claimed in Claim 15 wherein the device is used in series or parallel for filtering fluid at different stages.

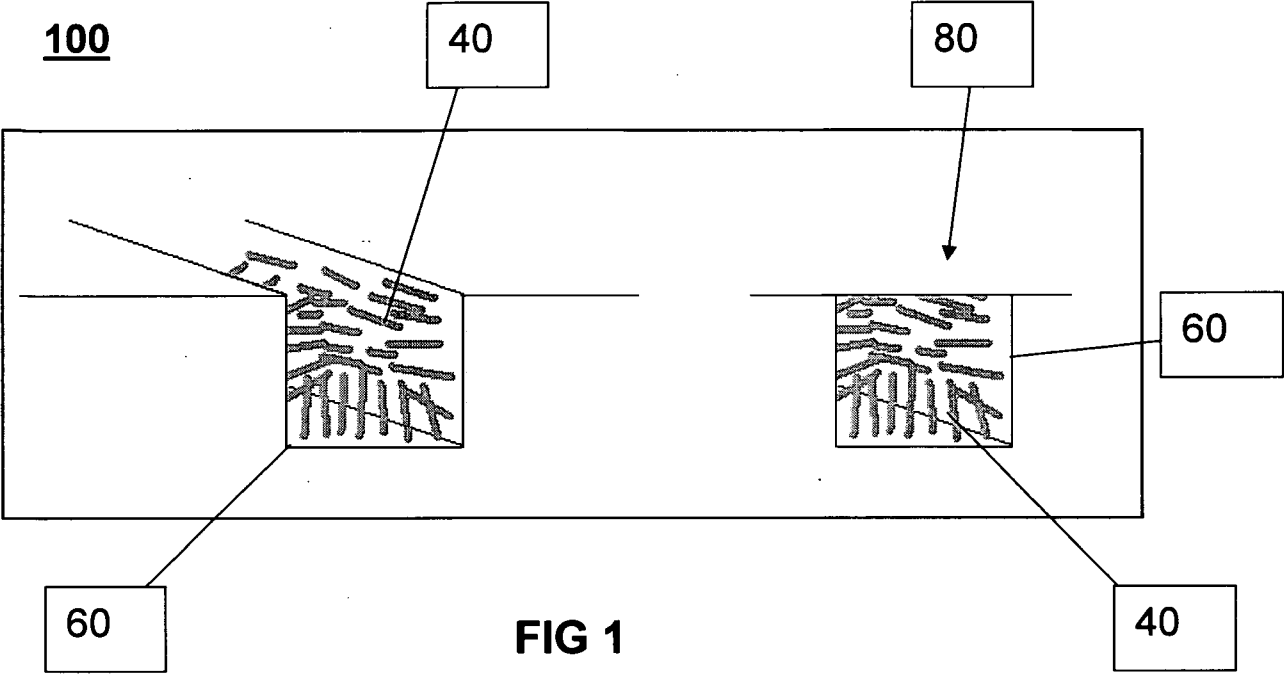
s) The device (100) as claimed in Claim 15 for use in filtering fluid and gases.

10

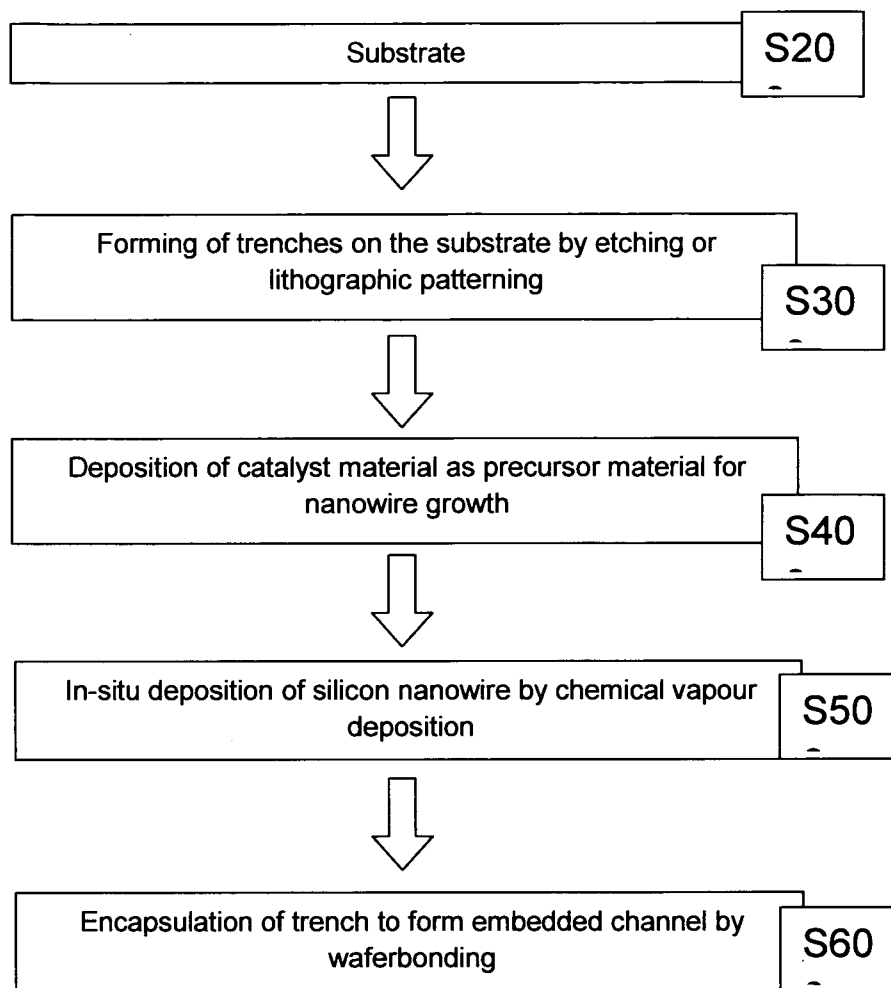
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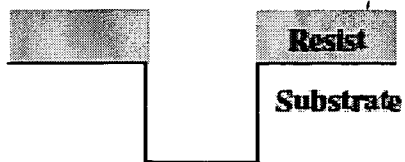


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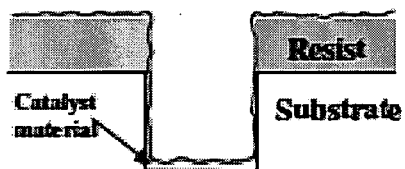
**FIG 2****FIG 3**

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a) Etching of Trench



b) Deposition of SiNW catalyst



c) Lift off/Resist removal



d) SiNW Deposition



e) Channel encapsulation (Waferbond)

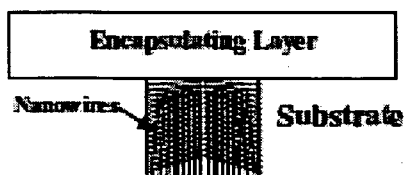
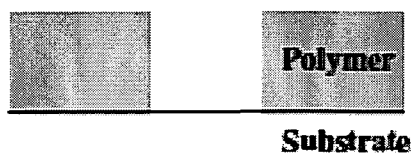


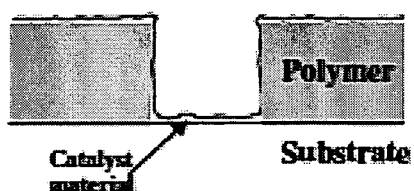
FIG 4

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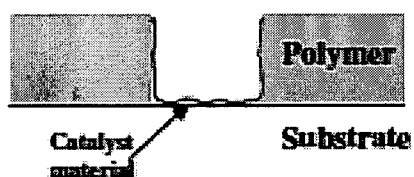
a) Trench formation via lithography



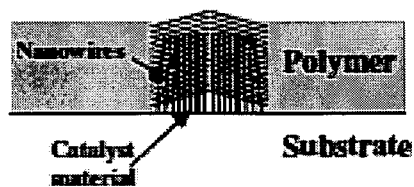
b) Deposition of SiNW catalyst



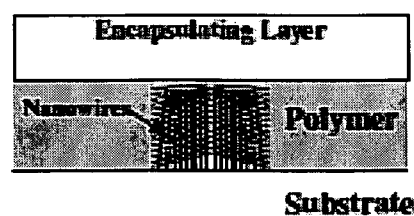
c) Wafer polishing



d) SiNW Deposition

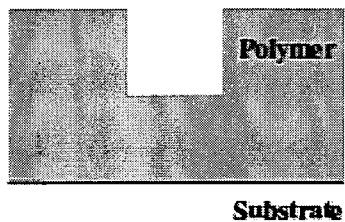


e) Channel encapsulation (Waferbond)

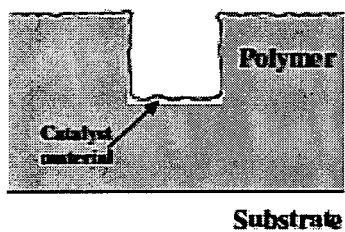
**FIG 5**

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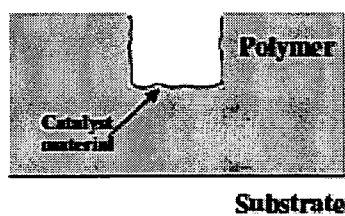
a) Trench formation via lithography



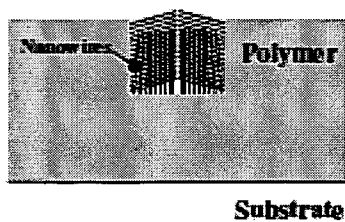
b) Deposition of SiNW catalyst



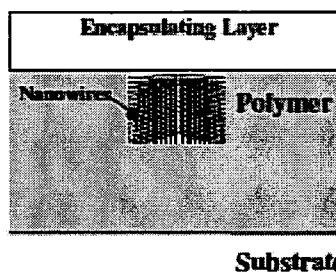
c) Wafer Polishing



d) SiNW Deposition



e) Channel encapsulation (Waferbond)



f) Removal from substrate

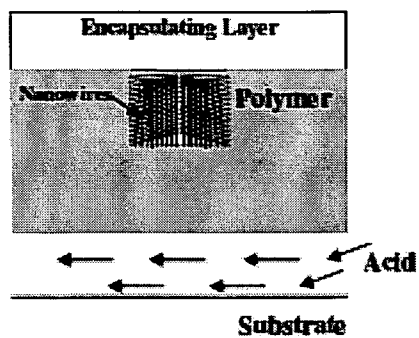
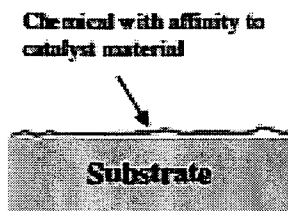


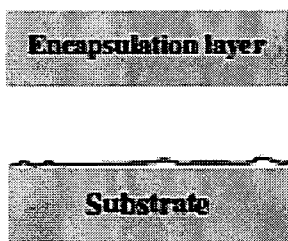
FIG 6

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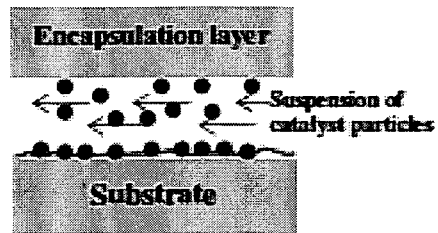
- a) Deposition of material with chemical affinity



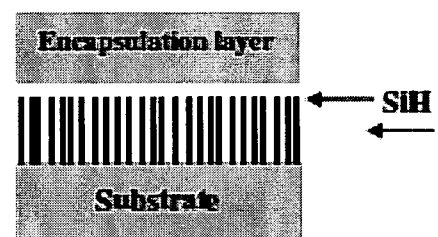
- b) Channel encapsulation (Waferbond)



- c) Deposition of Catalyst material



- d) SiNW deposition

**FIG 7**

PATENT COOPERATION TREATY

PCT

DECLARATION OF NON-ESTABLISHMENT OF INTERNATIONAL SEARCH REPORT
(PCT Article 17(2)(a), Rules 13ter.1(c) and (d) and 39)

Applicant's or agent's file reference Mimos60Yan	IMPORTANT DECLARATION	Date of mailing (<i>day/month/year</i>) 28 SEPTEMBER 2011 (28.09.2011)
International application No. PCT/MY2010/000264	International filing date (<i>day/month/year</i>) 10 NOVEMBER 2010 (10.11.2010)	(Earliest) Priority date (<i>day/month/year</i>) 23 APRIL 2010 (23.04.2010)
International Patent Classification (IPC) or both national classification and IPC <i>G01N 27/40(2006.01)i, B01D 35/00(2006.01)i</i>		
Applicant Mimos Berhad et al		

This International Searching Authority hereby declares, according to Article 17(2)(a), that **no international search report will be established** on the international application for the reasons indicated below.

1. ☐ The subject matter of the international application relates to:
 - a. ☐ scientific theories.
 - b. ☐ mathematical theories.
 - c. ☐ plant varieties.
 - d. ☐ animal varieties.
 - e. ☐ essentially biological processes for the production of plants and animals, other than microbiological processes and the products of such processes.
 - f. ☐ schemes, rules or methods of doing business.
 - g. ☐ schemes, rules or methods of performing purely mental acts.
 - h. ☐ schemes, rules or methods of playing games.
 - i. ☐ methods for treatment of the human body by surgery or therapy.
 - j. ☐ methods for treatment of the animal body by surgery or therapy.
 - k. ☐ diagnostic methods practised on the human or animal body.
 - l. ☐ mere presentation of information.
 - m. ☐ computer programs for which this International Searching Authority is not equipped to search prior art.
2. ☒ The failure of the following parts of the international application to comply with prescribed requirements prevents a meaningful search from being carried out:

☐ the description
 ☒ the claims
 ☐ the drawings
3. ☐ A meaningful search could not be carried out without the sequence listing; the applicant did not, within the prescribed time limit:

☐ furnish a sequence listing on paper complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
☐ furnish a sequence listing in electronic form complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
☐ pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rule 13ter.1(a) or (b)
4. Further comments:

Name and mailing address of ISA/KR  Korean Intellectual Property Office Government Complex-Daejeon, 189 Cheongsaro, Seo-gu, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer Noh Dae Hyun Telephone No. 82-42-481-5637 
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