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Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

[Continued on next page]

(54) Title: A METHOD FOR FORMING SILICON GRASS

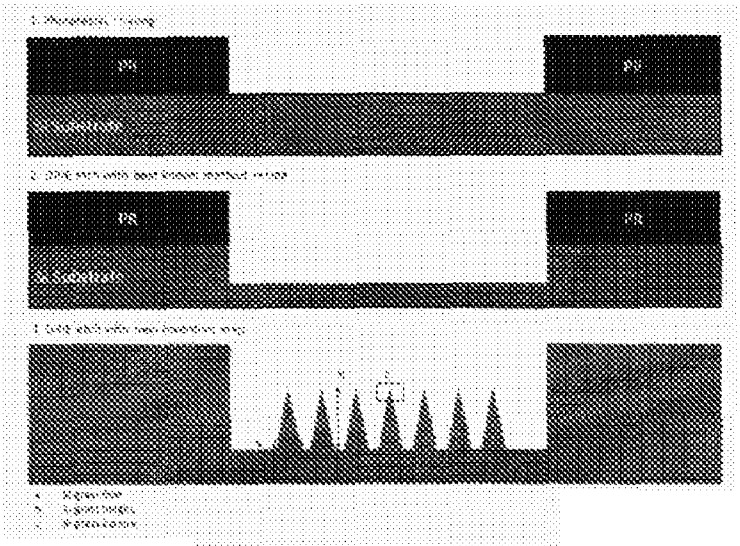

Figure 2

(57) Abstract: The present invention relates to a method for forming Si grass structure comprising: forming a silicon well (100); and etching the silicon well to form silicon grass structure (200); characterized in that the step of forming silicon well (100) is conducted using a standard deep reactive ion etching Bosch process using photoresist as the masking material. The present invention provides more surface area of the sensing membrane thus increasing the performance of a sensor.

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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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Description

Title of Invention: A METHOD FOR FORMING SILICON GRASS

[1] **FIELD OF INVENTION**

[2] The present invention relates to a method for forming a silicon grass structure which its application is in sensor technology.

[3] **BACKGROUND OF THE INVENTION**

[4] One of the most important feature in a sensor is a sensing membrane. Currently, the sensing membrane is fabricated in a form of flat surface. Theflat surface structure of a sensing membrane is limiting the reactivity of ions that would cause not enough surface potential for the sensor device to properly function. This would affect the performance of the sensor. While many had invented a method for forming a silicon sensing membrane such as inUS 2010/0092888, which construes : process for etching a silicon-containing substrate to form structures is provided. In the process, a metal is deposited and patterned onto a silicon-containing substrate (commonly one with a resistivity above 1-10 ohm-cm) in such a way that the metal is present and touches silicon where etching is desired and is blocked from touching silicon or not present elsewhere. The metallized substrate is submerged into an etchant aqueous solution comprising about 4 to about 49 weight percent HF and an oxidizing agent such as about 0.5 to about 30 weight percent H.sub.2O.sub.2, thus producing a metallized substrate with one or more trenches. A second silicon etch is optionally employed to remove nanowires inside the one or more trenches.

[5] However, the prior art still could not solve the above problem which isrelated to low surface-area-to-volume ratio of the sensing material structure.

[6] Therefore it is a need for an invention that can overcome the above mentioned problem.

[7] **SUMMARY OF THE INVENTION**

[8] According to an aspect of the present invention, the present invention providesmethod for forming Si grass structure comprising:forming a silicon well (100); etching the silicon well to form silicon grass structure (200); characterized in that the step of forming silicon well (100) is conducted using a standard deep reactive ion etching Bosch process using photoresist as the masking material. The above provision is advantageous as the present invention provides more surface area of the sensing material, thus increasing the performance of the sensor.The method for forming the silicon grass structure is invented using inductively coupled plasma (ICP) deep reactive ion etching (DRIE) process chamber. It was found that the diameter and height of silicon grass are controllable by varying the wafer chuck/silicon temperature process parameter. Bosch process is one type of silicon etching technology for high-aspect

ratio where silicon grass is one of the by-products. Previously, most of the studies have been focused on eliminating these silicon grasses. However, in the present invention, the optimized condition for obtaining silicon grasses is invented using inductively coupled plasma ICP DRIE system.

[9] **BRIEF DESCRIPTION OF THE DRAWINGS**

[10] **Figure 1**illustrates a flowchart of a method for forming a silicon grass of the present invention.

[11] **Figure 2**illustrates pictorialprocess flow for Si grass formation shielding wire surrounding the interdigitated electrodes.

[12] **Figure 3**illustrates SEM image for Si grass structure.

[13] **Figure 4**illustrates SEM image for Poly-Si grass structure.

[14] **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

[15] Generally, the present invention relates toa method for forming Si grass structure comprising:forming a silicon well (100); and etching the silicon well to form silicon grass structure (200); characterized in that the step of forming silicon well (100) is conducted using a standard deep reactive ion etching Bosch process using photoresist as the masking material. The flow of the present invention is depicted in **Figure 1** and **Figure 2** whereas the SEM images of the silicon grass is depicted in **Figure 3** and **Figure 4**.

[16] The step offorming a silicon well (100) further comprising: sequential etching (101) and passivation sub-cycle (103).The sequential etching (101) further comprising: exposing the silicon to SF_6 plasma for one second. Thepassivation sub-cycle (103) further comprising: exposing the silicon to a mixture of C_4F_8 and O_2 plasma for three seconds.

[17] The silicon well formation is created by using a standard deep reactive ion etching Bosh process using photoresist as the masking material. This step is based on a sequential passivation and etching sub-cycles where in the first sub-cycle passivation, a mixture of C_4F_8 and O_2 within time interval 1.8 second is used. In the etching sub-cycle, the sample is exposed to SF_6 plasma within time interval 1.9 second is used. This process step is performed at wafer chuck temperature of -10 °C.

[Table 1]

Process parameters	Unit	Value	Value
Distance source-chuck	mm	200	
Source power	W	1800	1800
SF6 flow	sccm		250
C4F8 + O2 flow	sccm	150 +10	
SF6 cycle time	sec		3
C4F8 cycle time	sec	1	
Process press. on SF6 cycle	Pa		3
Process press. on C4F8 cycle	Pa	2	
Chuck temperature (external probe)	°C	-10	
LF bias power	W	90W	
He backside pressure 1 / 2	mbar	10	

[18] Table 1: Deep silicon etch recipe parameters for silicon well formation

[19] The step of etching the silicon to form silicon grass (200) further comprising: first sequential etching and passivation (201); second sequential etching and passivation (203); and third sequential etching and passivation (205). The first sequential etching and passivation (201) further comprising: exposing the silicon to SF_6 plasma for one seconds at flow rate of 200 to 250sccm; exposing the silicon to a mixture of C_4F_8 and O_2 plasma for three seconds, with the C_4F_8 at a flow rate of 120 to 150 sccm and the O_2 at a flow rate of 8 to 10 sccm; wherein the silicon is at -4 to -5°C below pressure of 4 to 5 Pa for a predetermined time.The sequential etching and passivation process cycle is run for 45 minutes.

[Table 2]

Process parameters	Unit	Value	Value
Distance source-chuck	mm	200	
Source power	W	1800	1800
SF6 flow	sccm		250
C4F8 + O2 flow	sccm	150 +10	
SF6 cycle time	sec		3
C4F8 cycle time	sec	1	
Process press. on SF6 cycle	Pa		3
Process press. on C4F8 cycle	Pa	2	
Chuck temperature (external probe)	°C	-5	
LF bias power	W	90W	
He backside pressure 1 / 2	mbar	10	

[20] Table 2:First sequential etching and passivation (201)recipe parameters

[21] The second sequential etching and passivation (203) further comprising: exposing the silicon to SF_6 plasma for one seconds at flow rate of 200 to 250sccm; exposing the silicon to a mixture of C_4F_8 and O_2 plasma for three seconds, with the C_4F_8 at a flow rate of 120 to 150 sccm and the O_2 at a flow rate of 8 to 10 sccm; wherein the silicon is at 0°C below pressure of 4 to 5 Pa for a predetermined time.The sequential etching and passivation process cycle is run for 30 minutes.

[Table 3]

Process parameters	Unit	Value	Value
Distance source-chuck	mm	200	
Source power	W	1800	1800
SF6 flow	sccm		250
C4F8 + O2 flow	sccm	150 +10	
SF6 cycle time	sec		3
C4F8 cycle time	sec	1	
Process press. on SF6 cycle	Pa		3
Process press. on C4F8 cycle	Pa	2	
Chuck temperature (external probe)	°C	0	
LF bias power	W	90W	
He backside pressure 1 / 2	mbar	10	

[22] Table 3:Second sequential etching and passivation (203)recipe parameters

[23] The third sequential etching and passivation (205) further comprising: exposing the silicon to SF_6 plasma for one seconds at flow rate of 200 to 250sccm; exposing the silicon to a mixture of C_4F_8 and O_2 plasma for three seconds, with the C_4F_8 at a flow rate of 120 to 150 sccm and the O_2 at a flow rate of 8 to 10 sccm; wherein the silicon is at -4 to -5°C below pressure of 4 to 5 Pa for a predetermined time.The sequential etching and passivation process cycle is run for 30 minutes.

[Table 4]

Process parameters	Unit	Value	Value
Distance source-chuck	mm	200	
Source power	W	1800	1800
SF6 flow	sccm		250
C4F8 + O2 flow	sccm	150 +10	
SF6 cycle time	sec		3
C4F8 cycle time	sec	1	
Process press. on SF6 cycle	Pa		3
Process press. on C4F8 cycle	Pa	2	
Chuck temperature (external probe)	°C	5	
LF bias power	W	90W	
He backside pressure 1 / 2	mbar	10	

[24] Table 4:third sequential etching and passivation (205)recipe parameters

[25] Although the invention has been described with reference to particular embodiment, it is to be understood that the embodiment is merely illustrative of the principles and applications of the present invention. It is therefore to be understood that numerous modifications may be made to the illustrative embodiment that other arrangements may be devised without departing from the scope of the present invention as defined by the appended claims.

Claims

[Claim 1] A method for forming Si grass structure comprising:
forming a silicon well (100) using a standard deep reactive ion etching Bosch process;
etching the silicon well to form silicon grass structure (200);
characterized in that
the step of forming silicon well (100) is conducted using photoresist as the masking material.

[Claim 2] A method for forming Si grass structure as claimed in Claim 1, wherein the step offorming a silicon well (100) further comprising: sequential etching (101) and passivation sub-cycle (103).

[Claim 3] A method for forming Si grass structure as claimed in Claim 2, wherein the sequential etching (101) further comprising exposing the silicon to SF_6 plasma for one second.

[Claim 4] A method for forming Si grass structure as claimed in Claim 2, wherein thepassivation sub-cycle (103) further comprising exposing the silicon to a mixture of C_4F_8 and O_2 plasma for three seconds.

[Claim 5] A method for forming Si grass structure as claimed in Claim 1, wherein the step of etching the silicon to form silicon grass (200) further comprising:
first sequential etching and passivation (201);
second sequential etching and passivation (203); and
third sequential etching and passivation (205).

[Claim 6] A method for forming Si grass structure as claimed in Claim 5, wherein the first sequential etching and passivation (201) further comprising:
exposing the silicon to SF_6 plasma for one seconds at flow rate of 200 to 250sccm;
exposing the silicon to a mixture of C_4F_8 and O_2 plasma for three seconds, with the C_4F_8 at a flow rate of 120 to 150 sccm and the O_2 at a flow rate of 8 to 10 sccm; wherein the silicon is at -4 to -5°C below pressure of 4 to 5 Pa for a predetermined time.

[Claim 7] A method for forming Si grass structure as claimed in Claim 5, wherein the second sequential etching and passivation (203) further comprising:
exposing the silicon to SF_6 plasma for one seconds at flow rate of 200 to 250sccm;
exposing the silicon to a mixture of C_4F_8 and O_2 plasma for three seconds, with the C_4F_8 at a flow rate of 120 to 150 sccm and the O_2 at a

flow rate of 8 to 10 sccm; wherein the silicon is at 0°C below pressure of 4 to 5 Pa for a predetermined time.

[Claim 8] A method for forming Si grass structure as claimed in Claim 5, wherein the third sequential etching and passivation (205) further comprising:
exposing the silicon to SF_6 plasma for one seconds at flow rate of 200 to 250sccm;
exposing the silicon to a mixture of C_4F_8 and O_2 plasma for three seconds, with the C_4F_8 at a flow rate of 120 to 150 sccm and the O_2 at a flow rate of 8 to 10 sccm; wherein the silicon is at -4 to -5°C below pressure of 4 to 5 Pa for a predetermined time.

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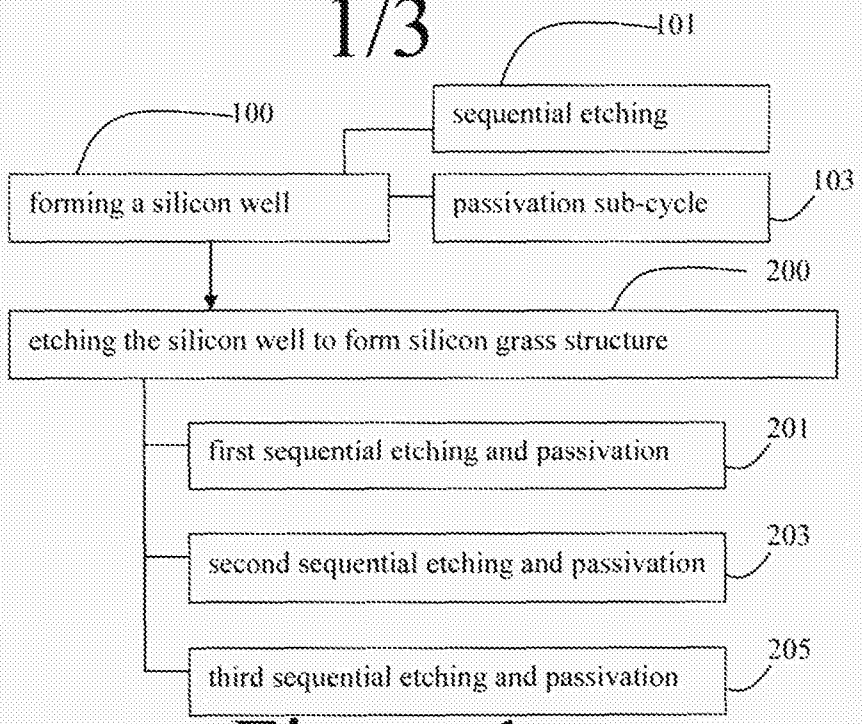

Figure 1

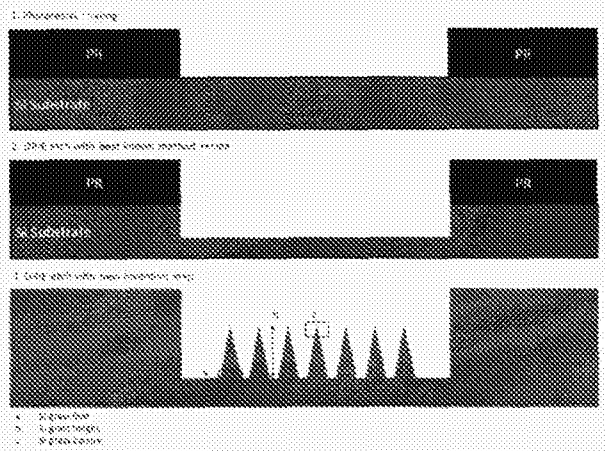

Figure 2

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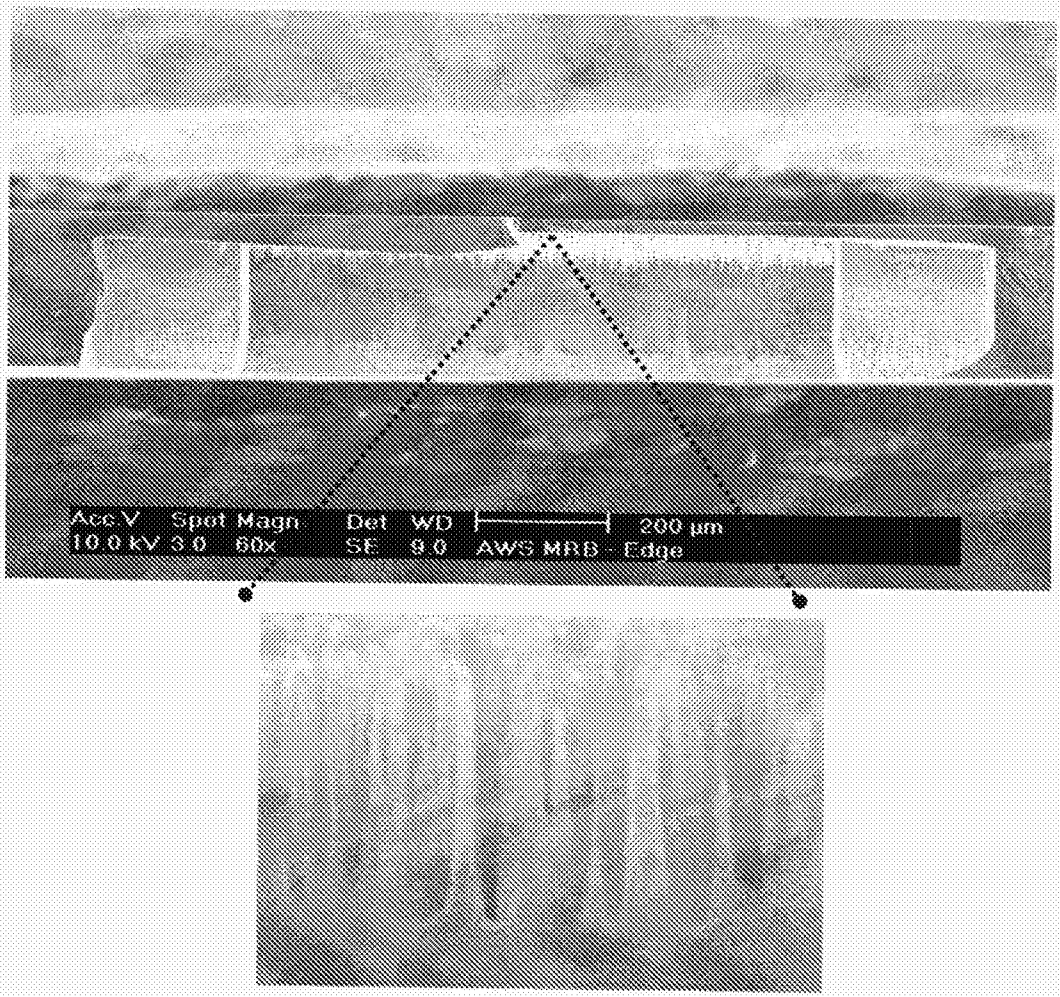

Figure 3

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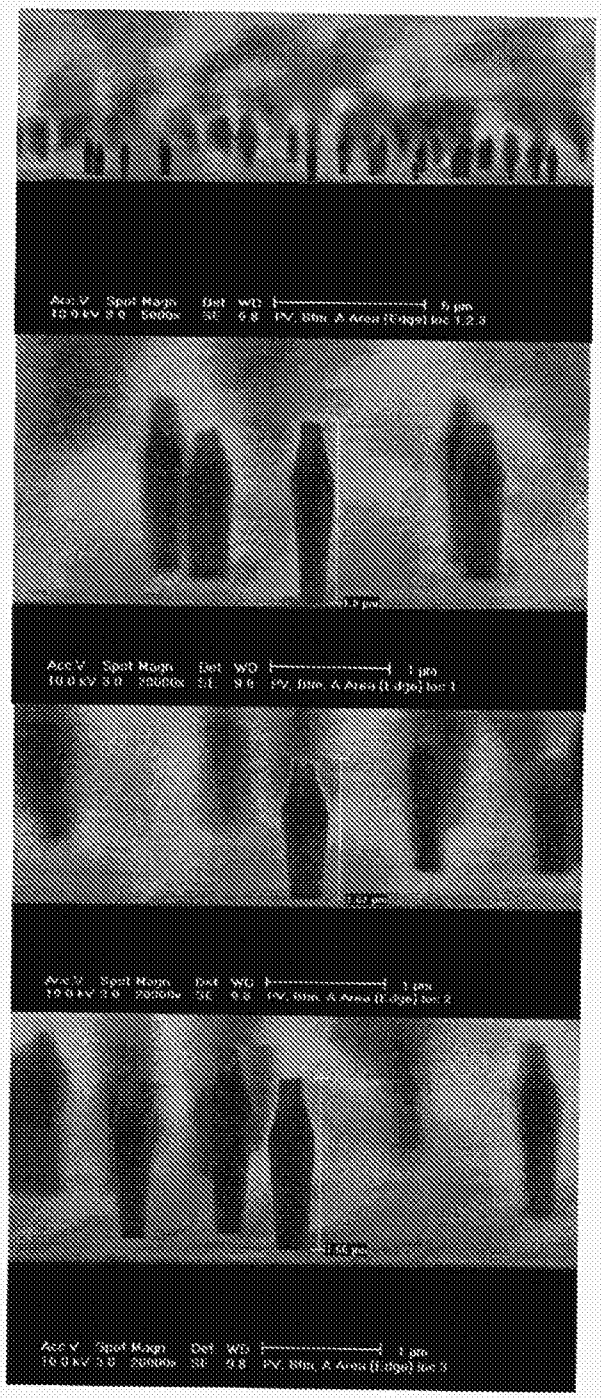

Figure 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/MY2014/000095

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L21/3065
ADD.

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)
H01L

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)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JUNG KYUBONG ET AL: "Parameter study for silicon grass formation in Bosch process", JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY: PART B, AVS / AIP, MELVILLE, NEW YORK, NY, US, vol. 28, no. 1, 15 January 2010 (2010-01-15), pages 143-148, XP012143916, ISSN: 1071-1023, DOI: 10.1116/1.3280131 EXPERIMENT ----- -/--	1-8

[X] 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

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"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
27 August 2014	04/09/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kenevey, Kester

INTERNATIONAL SEARCH REPORT

International application No
PCT/MY2014/000095

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CRAIGIE C J D ET AL: "Polymer thickness effects on Bosch etch profiles", JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY: PART B, AVS / AIP, MELVILLE, NEW YORK, NY, US, vol. 20, no. 6, 1 November 2002 (2002-11-01), pages 2229-2232, XP012009536, ISSN: 1071-1023, DOI: 10.1116/1.1515910 EXPERIMENTAL CONDITIONS; table 1 -----	1-8