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Datasheet for the decision of 28 April 2011

Case Number: T 2064/08 - 3.4.02

Application Number: 00923060.8

Publication Number: 1153291

IPC: G01N33/00, G01N27/12

Language of the proceedings: EN

Title of invention:
MICRO-MACHINED THIN FILM HYDROGEN GAS SENSOR, AND METHOD OF MAKING AND USING THE SAME

Applicant:
MST Technology GmbH

Relevant legal provisions:
EPC 1973 Art. 56

Keyword:
Inventive step (yes)

Europäisches Patentamt | European Patent Office | Office européen des brevets

Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 2064/08 - 3.4.02

D E C I S I O N
of the Technical Board of Appeal 3.4.02
of 28 April 2011

Appellant: (Applicant)
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 19 June 2008 refusing European application No. 00923060.8 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman: A. G. Klein
Members: F. J. Narganes-Quijano
B. Müller

Summary of Facts and Submissions

I. The appellant (applicant) lodged an appeal against the decision of the examining division refusing European patent application No. 00923060.8 based on the International application No. PCT/US00/00765 (published in a "Corrected version" with the International publication No. WO 00/43772).

II. In its decision the examining division referred to the following documents

D1: US-A-5635729

D3: "Tin oxide gas sensor fabricated using CMOS micro-hotplates and *in-situ* processing", J. S. Suehle *et al.*; IEEE Electron Device Letters (US) Vol. 14 (1993); pages 118 to 120

D4: "Fast temperature programmed sensing for micro-hotplate gas sensors", R. E. Cavicchi *et al.*; IEEE Electron Device Letters (US) Vol. 16 (1995); pages 286 to 288

D5: US-A-5356756

and held that the subject-matter of claim 1 then on file did not involve an inventive step (Article 56 EPC 1973).

III. With the statement setting out the grounds of appeal the appellant requested that the decision under appeal be set aside and a patent be granted. The appellant also submitted that the decision under appeal was tainted by a procedural violation.

IV. In a communication the Board drew the attention of the appellant to some deficiencies in the application

documents then on file and expressed its preliminary opinion that the allegations of the appellant were not sufficient to establish that the first-instance proceedings were tainted by a procedural violation.

V. With the letter of reply dated 29 March 2011 the appellant filed an amended set of claims 1 to 47 and amended pages 3, 4, 4a, 5 to 7, 9, 10, 13, 14, 33, 38 and 40 of the description and stated that, insofar as the appellant has pleaded a procedural violation and requested that the appeal fee be refunded, the request was withdrawn.

In response to a subsequent telephone consultation with the rapporteur, the appellant filed with its letter dated 6 April 2011 an amended page 32 of the description.

VI. Claim 1 amended according to the present request of the appellant reads as follows:

"A hydrogen sensor, comprising:
at least one hydrogen-interactive thin film sensor element comprising a rare earth metal or a rare earth metal dihydride,
at least one micro-hotplate structure coupled to said hydrogen-interactive sensor element for selective heating of the sensor element, and
a hydrogen-permeable material overlaying each hydrogen-interactive sensor element for selective permeation of hydrogen."

The claim request further includes independent claim 22 directed to a hydrogen sensor device comprising the hydrogen sensor defined in claim 1, independent claim 28 directed to a method of fabrication of the hydrogen

sensor defined in claim 1, independent claim 41 directed to a method of detecting hydrogen in an environment using the hydrogen sensor device defined in claim 22, and dependent claims 2 to 21, 23 to 27, 29 to 40 and 42 to 47 all referring back to claims 1, 22, 28 and 41, respectively.

VII. The arguments of the appellant in support of its requests can be summarised as follows:

The coupling of the sensor element with the micro-hotplate structure as claimed allows, on the one hand, heating the micro-plate structure already during the operation of the sensor so as to support the conversion of the dihydride to the trihydride compound in the presence of hydrogen, thereby increasing the sensitivity of the sensor, and, on the other hand, heating the sensor to a higher temperature so as to cause the reverse reaction from the trihydride to the dihydride compound to take place. It is therefore possible to specifically regulate the temperature of the sensor element depending on the desired operation, for instance by using a pulsed or variable cycle time operation or other time temperature schedule, thus improving the response and the recovery times of the sensor device.

The object of the invention is therefore to provide an improved sensor which responds to hydrogen within a shorter response time and with a higher sensitivity. The skilled person cannot gather in document D1 any hint to the fact that the temperature within a sensing process could play a role. As a matter of fact, document D1 deals only very generally with a switching device, and the use of the device as a sensor is only mentioned as one of several possible applications. In

the whole document D1, there is no hint that a temperature adjustment of the hydrogen sensor could probably have advantages, for instance on the sensor activity.

Document D3 describes a tin oxide gas sensor composed of a sensing film deposited on a silicon micromachined hotplate. This sensor element and the reactions taking place in it are completely different so that the application of a micro-hotplate structure on this SnO_2 film can in no way be transferred to other sensor films. In document D3 there is no hint to the general applicability of the micro-hotplate structure on any sensor film, nor is there any information concerning special sensor films of the rare-earth type.

Reasons for the Decision

1. The appeal is admissible.

2. The International application published under the PCT with the International publication No. WO 00/43772 was subsequently published in a "Corrected version" which differs from the previous publication only in the renumbering of the claims and in a clear copy of the drawings. The application documents according to the publication of the "Corrected version" will be referred to in the following as the application as filed.

3. *Amendments*

The application documents as amended according to the present request of the appellant satisfy the formal requirements of the EPC, and in particular those set

forth in Article 123(2) EPC. In particular, present claim 1 is based on claims 1 and 12, together with the passages in the description on page 13, third paragraph to page 14, last paragraph, page 17, last paragraph, page 26, fourth paragraph, page 30, first paragraph, and page 38, first paragraph of the application as filed, present independent claims 22, 28 and 41 are based respectively on claims 24, 34 and 51 of the application as filed, together with the amendments to present claim 1, and dependent claims 2 to 21, 23 to 27, 29 to 40 and 42 to 47 are respectively based on dependent claims 2 to 16, 19 to 23, 25 to 27, 30, 33, 35, 36, 39 to 41, 44 to 50, 53 and 55 to 59 of the application as filed. As regards the description, its text has been brought into conformity with the invention as defined in the amended set of claims (Article 84, second sentence and Rule 27(1)(c) EPC 1973) and the pertinent prior art has been acknowledged in the introductory part of the description (Rule 27(1)(b) EPC 1973).

4. *Inventive step*

4.1 Claim 1 is directed to a hydrogen sensor comprising a hydrogen-interactive thin film sensor element comprising a rare earth metal or a rare earth metal dihydride and a hydrogen-permeable material overlaying the element, and further comprising a micro-hotplate structure for selective heating of the sensor element.

4.2 The reasoning followed by the examining division in the decision under appeal in support of its finding of lack of inventive step is essentially the following:

- the hydrogen-activated thin film switching device disclosed in document D1 represents the closest state of the art,

- the switching device disclosed in document D1 comprises all the features of the hydrogen sensor defined in claim 1, with the only exception of the micro-hotplate structure,
- document D1 also teaches that the sensor film needs to be regenerated for re-use, e.g. by increasing the temperature, and the problem solved by the claimed invention is to be seen in the provision of an effective means for putting into practice the teaching of document D1, and
- the provision of a micro-hotplate structure was obvious in view of the teaching of document D3, or alternatively that of any of documents D4 or D5, relating to the use of a micro-hotplate for heating a thin film gas sensor.

The Board, however, cannot subscribe to the line of argument developed by the examining division in its decision for the following reasons:

4.2.1 Document D1 discloses a hydrogen-activated thin film device (Figure 1) comprising a film of yttrium overlayed by a palladium layer (column 2, lines 15 to 26) which - undisputed by the appellant - is permeable to hydrogen. The document also teaches the replacement of yttrium by other rare earth metals such as lanthanum and scandium (column 3, lines 1 to 6 and 44 to 52, and column 6, lines 15 to 19).

According to the disclosure of the document, in the presence of hydrogen the reflective film of yttrium is converted into a transparent, semiconductive film of trihydride of yttrium which in turn is converted by exposure to heat or by evacuation of hydrogen into a metallic, reflective film of dihydride of yttrium, the conversion of the reflective dihydride phase (YH_2) of

the film to the transparent trihydride phase (YH_3) being reversible (abstract, and column 1, line 34 to column 2, line 14).

The document also teaches that, while the transition from the metallic YH_2 phase to the transparent YH_3 phase takes place in the presence of hydrogen within a few seconds (column 2, lines 35 to 40, column 3, lines 38 to 44, and column 5, lines 27 to 36 and 44 to 47), the transition from the YH_3 phase to the YH_2 phase can be carried out by evacuation of hydrogen and/or by heating within seconds (column 1, lines 37 to 41 together with column 2, lines 40 to 50, column 4, lines 42 to 46, and column 5, lines 39 to 42).

In view of the different optical and electrical properties of the metallic, reflective YH_2 phase and of the semiconductive, transparent YH_3 phase (column 4, lines 17 to 21), the document primarily proposes the use of the thin film device as a switching element (title, abstract and column 1, line 1 to column 4, line 53), and more particularly

- as an electrical switching element in sensors, indicators or actuators (column 2, lines 27 to 33, and column 4, lines 46 to 53), or
- as an optical switching element in luminaries (column 4, lines 21 to 24), in thin displays and display screens (abstract and column 4, lines 31 to 40), in architectural glasses, sun roofs and rear-view mirrors (column 4, lines 21 to 30), and in recording layers of an optical recording medium (column 4, lines 40 to 46), or
- as a mechanical actuator (column 4, lines 58 to 62).

The document also discloses in the passage in column 4, lines 54 to 57 the use of the switching element as a sensor for organic compounds, such as methane, which eliminate hydrogen atoms when they are in contact with palladium.

4.2.2 It follows from the analysis in point 4.2.1 above, and in particular from the penultimate paragraph, that document D1 is primarily directed to a device the optical, electrical and mechanical properties of which can be controllably switched between two different states so that the device operates as an optical, electrical or mechanical switching device, and only in the passage in column 4, lines 54 to 57 is it taught to use the device as a sensor for organic hydrogen-containing compounds, without however giving any specific details as to the proposed use as a sensor. In these circumstances, even though the disclosure of document D1 relating to the use of the device as a sensor for hydrogen-containing organic compounds (point 4.2.1 above, last paragraph) can be considered to constitute the disclosure of a hydrogen sensor, the Board has doubts as to whether the skilled person would see in the single disclosure in the passage in column 4, lines 54 to 57 of the document a promising starting point for addressing the primary object considered in the application, i.e. the development of improved rare-earth based hydrogen sensors.

Having regard to the above, and also in view of the numerous prior art documents on file extensively describing hydrogen sensors of the rare-earth type (see for instance US-A-3732076 and the articles by J. N. Huiberts *et al*. cited in the International and in the Supplementary European search reports, respectively), the Board is rather reluctant to consider document D1

as representing an appropriate and realistic closest state of the art in the objective assessment of inventive step of the claimed invention according to the problem-solution approach.

4.2.3 In addition, the line of argument of the examining division relies on the view that document D1 discloses a hydrogen sensor constituted by the switching device mentioned in point 4.2.1 above in combination with the operation of heating the device.

However, in the Board's view there is no clear and unambiguous disclosure in document D1 towards heating the device when used as a hydrogen sensor. In particular, the operation of heating the device has been consistently disclosed in the document in the context of the use of the device as an optical, electrical or mechanical switching device, i.e. in connection with a device requiring a controllable and rapid switching of the optical, electrical and mechanical properties of the device and therefore a controllable and rapid conversion between the YH_2 and YH_3 phases of the switching film, and also consistently disclosed as an alternative to evacuating hydrogen for the purposes of reversing the YH_3 phase to the YH_2 phase in what appears to constitute a reset operation of the device when used as an optical, electrical or mechanical switching device (column 2, lines 40 to 50, and column 4, lines 43 to 46). As submitted by the appellant, however, in the disclosure relating to the use of the device as a hydrogen sensor there is no explicit disclosure pointing towards the need for heating the device or towards any advantageous technical effect that might result from heating the device when used as a sensor. In addition, contrary to the case when the device is used as an optical,

electrical or mechanical switching device requiring a reset operation or at least a rapid switching of the device, when using the device as a hydrogen sensor there is *a priori* no reason in the context of the disclosure of the document for resetting the device or speeding up the conversion between the YH_2 and YH_3 phases because the conversion between these two phases is said to be reversible depending on the presence of hydrogen (document D1, column 2, lines 40 to 44) and the operation of heating the device would rather interfere with the reaction of the film exposed to hydrogen and therefore with the detection of hydrogen by the hydrogen sensor.

Therefore, in the absence of any explicit disclosure of heating the device when used as a hydrogen sensor, or of any indication that would point implicitly to it, the Board concludes that there is no clear and unambiguous disclosure in document D1 leading the skilled person to consider the operation of heating the switching device when specifically used as a hydrogen sensor.

4.2.4 Even assuming that the skilled person would adopt the disclosure of document D1 as a promising starting point in the development of improved rare-earth based hydrogen sensors and also assuming that the skilled person would interpret the disclosure of the document as also teaching the operation of heating the device when used as a hydrogen sensor, the Board cannot follow the subsequent line of argument of the examining division that the objective problem solved by the claimed invention would be the provision of an effective means of putting into practice the teaching of document D1 that the sensor needs to be regenerated for re-use and that it would be obvious to solve this

problem by means of the micro-hotplate structure known from document D3, D4 or D5.

First, document D1 discloses that the conversion from the YH_3 phase to the YH_2 phase of the film already takes place when hydrogen is evacuated (column 2, lines 40 to 43), and in this respect the document would at the most teach heating the hydrogen sensor for the purposes of speeding up the phase conversion, but not as a need when the sensor is to be reused as assumed by the examining division in the formulation of the objective problem because according to the teaching of the document the conversion between the two phases is reversible depending on the presence of hydrogen (column 2, lines 36 to 50 and column 5, lines 39 to 47) and therefore the sensor can be reused even if no heating is applied to the sensor.

And second, assuming that the skilled person would be confronted with the problem of how to heat the switching device of document D1 when used as a hydrogen sensor, the Board notes that

- document D1 already specifies means for heating the device such as the use of a laser-light beam when the device is used as an optical recording medium (column 4, lines 42 to 44), that
- consideration of any of documents D3, D4 and D5 for the purposes of solving the problem in terms of a micro-hotplate structure as claimed presupposes that the skilled person would first consider the provision of the device disclosed in document D1 as a microstructured device for which no clear and unambiguous disclosure can be found in document D1, and that
- each of documents D3, D4 and D5 indeed teach the use of a micro-hotplate structure for the purposes

of heating a gas sensor fabricated by microstructure techniques (see abstract of each of the documents) and the gas sensors disclosed in documents D3 and D4 are suitable for sensing, among other gases, hydrogen (D3, abstract, and D4, sentence bridging the two paragraphs on the first page), but the disclosure of these documents is confined to gas sensors of the semiconductor oxide type such as SnO_2 (D3, abstract, D4, first page, first paragraph, and D5, column 13, lines 5 to 20) which, nonetheless, primarily require - contrary to the hydrogen sensors of the rare-earth type under consideration (point 4.2.4 above, second paragraph) - a thermal activation of the absorptive processes that produce the gas sensing response and thus require a high temperature to firstly activate the sensor device (D3, page 119, second column, lines 21 to 29, D4, first paragraph of the first page, and D5, column 1, lines 42 to 51 and column 13, lines 5 to 20).

4.3 In view of the considerations in points 4.2.2 to 4.2.4 above, the Board concludes that only hindsight knowledge of the invention defined in claim 1 would have led the skilled person, confronted with the primary problem of developing improved rare-earth based hydrogen sensors, to first consider as the starting point the proposal in document D1 of using the switching device disclosed in the document as a hydrogen sensor, then to consider the teaching in document D1 relating to heating the switching device as applying also to the use of the device as a hydrogen sensor, to subsequently see in the heating operation of the hydrogen sensor some technically advantageous effect, and finally consider heating the hydrogen sensor by means of a micro-hotplate structure as that

disclosed in documents D3 to D5 in the context of gas sensors of a different type requiring - contrary to the sensors of the rare-earth type under consideration - a high activation temperature.

In these circumstances, the Board cannot endorse the examining division's view that the subject-matter of claim 1 would result in an obvious way from the disclosure of documents D1 and D3 to D5.

4.4 In addition, after consideration of the disclosure of the remaining documents on file, the Board is satisfied that the subject-matter of claim 1 is novel and does not result in an obvious way from the available prior art (Article 52(1) EPC). In particular, none of the documents on file discloses or suggests the selective heating of a hydrogen sensor of the rare-earth type under consideration by means of a micro-hotplate structure, nor the technical improvements achieved therewith, i.e. taking advantage of the localized and rapid thermal response of a micro-hotplate not for primarily activating the sensor as it is the case in documents D3 to D5 (see point 4.2.4 above), but for controlling the rate of interaction and of regeneration of the sensor and thus improving the response time and the sensibility of the sensor (see page 11, last paragraph to page 12, second paragraph, page 15, second paragraph, and page 18, second and third paragraphs of the description of the application).

The same conclusion applies to the subject-matter of claims 2 to 47 all directed to an entity or to an activity involving the hydrogen sensor defined in claim 1 (see point VI above, last paragraph).

5. With the statement of grounds of appeal the appellant alleged that the decision under appeal was tainted by a procedural violation, and in its communication the Board expressed the preliminary opinion that no circumstance could be identified in the first-instance proceedings that would have amounted to a procedural violation, let alone to a substantial procedural violation that, in the present case, would justify the remittal of the case under Article 11 RPBA and/or the reimbursement of the appeal fee pursuant to Rule 67 EPC 1973.

In reply to the preliminary opinion of the Board, the appellant stated that, insofar as the appellant has pleaded a procedural violation and requested that the appeal fee be refunded, the request was withdrawn (point V above).

In the absence of any request relating to the procedural violation previously alleged by the appellant and since no counterargument was submitted by the appellant in response to the preliminary opinion of the Board in this respect, there is no need to address this issue any further in the present decision.

6. The Board is also satisfied that the application documents amended according to the present request of the appellant and the invention to which they relate meet the remaining requirements of the EPC within the meaning of Article 97(1) EPC. The Board therefore concludes that the decision under appeal is to be set aside and a patent to be granted on the basis of the amended application documents of the present request of the appellant.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance with the order to grant a patent on the basis of the following application documents:
   - claims 1 to 47 filed with the letter dated 29 March 2011,
   - description pages 1, 2, 8, 11, 12, 15 to 31, 34 to 37 and 39 of the application as published under the PCT in the "Corrected version", pages 3, 4, 4a, 5 to 7, 9, 10, 13, 14, 33, 38 and 40 filed with the letter dated 29 March 2011, and page 32 filed with the letter dated 6 April 2011, and
   - drawing sheets 1/5 to 5/5 of the application as published under the PCT in the "Corrected version".

The Registrar: The Chairman:

M. Kiehl A. G. Klein