Internal distribution code:

(A) [-] Publication in OJ
(B) [-] To Chairmen and Members
(C) [-] To Chairmen
(D) [X] No distribution

Datasheet for the decision of 20 September 2018

Case Number: T 0404/14 - 3.4.03

Application Number: 09164802.2

Publication Number: 2104137

IPC: H01L21/762, H01L21/20

Language of the proceedings: EN

Title of invention:
Glass-based soi structures

Applicant:
Corning Inc.

Headword:

Relevant legal provisions:
EPC 1973 Art. 56

Keyword:
Inventive step - (no) - common general knowledge

Decisions cited:

Catchword:

Beschwerdekammern
Boards of Appeal
Chambres de recours

Boards of Appeal of the
European Patent Office
Richard-Reitzner-Allee 8
85540 Haar
GERMANY
Tel. +49 (0)89 2399-0
Fax +49 (0)89 2399-4465

Case Number: T 0404/14 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 20 September 2018

Appellant: Corning Inc.
(Applicant) 1 Riverfront Plaza
Corning, NY 14831 (US)

Representative: Isarpatent
Patent- und Rechtsanwälte Behnisch Barth Charles
Hassa Peckmann & Partner mbB
Postfach 44 01 51
80750 München (DE)

Decision under appeal: **Decision of the Examining Division of the European Patent Office posted on 10 October 2013 refusing European patent application No. 09164802.2 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman G. Eliasson
Members: M. Stenger
C. Heath

Summary of Facts and Submissions

I. The appeal concerns the decision of the Examining Division to refuse European patent application no. 09164802 which is a divisional of parent application no. 04809284 for lack of compliance with Articles 76, 84 and 56 EPC.

II. At the end of the oral proceedings before the Board, the appellant requested the grant of a patent according to a main request and 4 auxiliary requests, all filed with the grounds for appeal. The main request corresponds to the main request of the first instance procedure.

III. The following prior art documents will be referred to in this decision:

D1: US 6413135 B1
D2: DE 10042590 A1
D4: Albaug K.B.: "Electrode Phenomena during Anodic Bonding of Silicon to Sodium Borosilicate Glass", J. Electrochem. Soc., Vol. 138, No. 10, pages 3089-3094; XP 248020
D5: Nitzsche P. et al.: "Ion Drift Processes in Pyrex-Type Alkali-Borosilicate Glass during Anodic Bonding", J. Electrochem. Soc., Vol. 145, No. 5, pages 1755-1762; XP 2534765
D6: US 6823693 B1
D7: Schmidt B. et al.: "In situ investigation of ion drift processes in glass during anodic bonding", Sensors and Actuators A 67, pages 191-198; XP 22713629
D8: US 2002/0069960 A1
D9: Shoji S. et al.: "Low-temperature anodic bonding using lithium aluminosilicat-β-quartz glass ceramic", Sensors and Actuators A 64, pages 95-100; XP 4102143

IV. Claim 1 of the main request has the following wording (labeling added by the Board):

A semiconductor-on-insulator structure comprising

(a) *a part (15) of a first substrate (10) comprising a substantially single-crystal semiconductor material (material S),*
(b) *wherein the thickness (Ds) of the part (15) of the first substrate (10) of material S (15) is in the range of 10 nm to 500 nm*

and

(c) *a second substrate (20) comprising an oxide glass or an oxide glass-ceramic which comprises positive ions (material G),*
(d) wherein the thickness (D2) of the second substrate (20) is in the range of 0,1 mm to 10 mm,

(e) *and wherein at least a part of the structure comprises in order:*

(e1) *a first region of material S;*
(e2) *a second region (16) of material S with an enhanced oxygen content compared to the first region;*
(e3) *a third region (23) of material G with a reduced positive ion concentration for at least one type of positive ion compared to a fifth region of material G;*
(e4) *a forth region of material G with an enhanced positive ion concentration compared to the fifth region of material G for at least one type of positive ion, including at least one alkaline earth modifier ion from the material G of the third*

region (23) with a reduced positive ion concentration; and
(e5) *the fifth region of material G.*

V. Claim 1 of auxiliary request 1 differs from claim 1 of the main request in that feature (e2) is replaced by the following feature (e2'), comprising at its end an additional sub-feature (labeling added by the Board):

(e2') *a second region (16) of material S with an enhanced oxygen content compared to the first region,*
wherein a thickness (δ_H) of the second region (16) is between 50 nm to 100 nm and a concentration of oxygen (C_O) within the second region (16) is at least 50%;

VI. Claim 1 of auxiliary request 2 differs from claim 1 of auxiliary request 1 in that features (e3) and (e4) are replaced by the following features (e3') and (e4'), respectively (labeling added by the Board):

(e3') *a third region (23) of material G with a reduced positive ion concentration for at least potassium, sodium or barium compared to a fifth region of material G;*

(e4') *a forth region of material G with an enhanced positive ion concentration compared to the fifth region of material G for at least potassium, sodium or barium from the material G of the third region (23) with a reduced positive ion concentration; and*

VII. Claim 1 of auxiliary request 3 differs from claim 1 of auxiliary request 1 by the additional features (f), (g) and (h) as follows (labeling added by the Board):

(f) *wherein the oxide glass or oxide glass-ceramic has a 250 °C resistivity p which satisfies the relationship:* $\rho < 10^{16}$ *Q-cm, and*

(g) *wherein CTE2 is the 0-300 °C coefficient of thermal expansion of the oxide glass or oxide glass-ceramic, which satisfies the relationships:* $5x10^{-7}$ */°C ≤ CTE <* 75×10^{-7} */°C, and*

(h) *wherein the part (15) of a first substrate (10) of the semiconductor-on-insulator structure is under compression of the contracted second substrate (20) of the semiconductor-on-insulator structure.*

VIII. Claim 1 of auxiliary request 4 differs from claim 1 of auxiliary request 2 in that it additionally comprises features (f), (g) and (h) as defined above.

IX. The main arguments of the appellant concerning the different requests may be summarised as follows.

(a) Main request
The invention involved a substantially single-crystal semiconductor first substrate, whereas D7 disclosed a coating of aluminium or silicon on glass. D7 did not relate to joining of two different substrates and would thus not lead the skilled person to the invention.

(b) Auxiliary request 1
The silica layer shown in D7 had a thickness of only 8 nm. The thicker second region of the

invention provided a better protection of the semiconductor substrate from the positive ions.

(c) Auxiliary request 2
The specific elements sodium, potassium and barium were introduced into claim 1 to overcome clarity objections made by the examining division.

(d) Auxiliary request 3
The resistivity and thermal coefficient values were added to claim 1 mainly in order to avoid objections concerning added subject-matter.
The compression exerted by the second contracted substrate, on the other hand, provided a better fixing or bonding of the two substrates. This compression could not be achieved by the CTE value of the glass alone. Instead, the description comprised further information indicating that a temperature gradient during anodic bonding was necessary to obtain that effect.

(e) Auxiliary request 4
Auxiliary request 4 was a combination of auxiliary requests 2 and 3. It was referred to the previous arguments concerning inventive step.

Reasons for the Decision

1. Anodic bonding
Anodic bonding is a process in which an oxide glass substrate is joined/bonded to an oxidisable substrate by putting both substrates into contact, heating them

and applying an electric field gradient perpendicular to the contact surface.
The Board notes that the procedure consisting of steps A, B and C described in the application in relation to figures 1A to 1C corresponds to an anodic bonding process, although the application does not mention the term "anodic bonding" proper.

2. Main request

2.1 Closest state of the art
The Examining Division used document D7 as representing the closest state of the art (section E 1.2.1 of the communication dated 12 July 2013, which was referred to in the contested decision).

Document D7 is a scientific article investigating the ion drift processes occurring during anodic bonding by means of the non-destructive quantitative depth profiling method ERDA (see "Introduction"). For this purpose, an experimental set-up is used in which a glass (PYREX or TEMPAX, see page 194, left column, second paragraph) coated with aluminium or silicon anode and cathode layers is subjected to the same heating and electrical field conditions as used in an anodic bonding process (see, for example, figure 1(a) and page 192, left column).

Thus, the experimental set-up employed in D7 does not involve joining two substrates, as pointed out by the appellant (see section IX.(a) above), and is directed at a different aim than the application. Therefore, D7 is not optimal for representing the closest prior art.

However, anodic bonding is a well-known standard process for joining substantially single-crystal silicon substrates to glass substrates.
This was not disputed by the appellant during oral proceedings and is also apparent from the prior art on file (see, for example D1: column 3, line 55 to column 4, line 7; D2: page 1, lines 7 to 9; D4: page 3089, left column, first sentence of last paragraph; D5: introduction; D6: column 1, line 5 to column 2, line 13; D7: introduction, first sentence; D8: paragraph 2; D9: introduction).

Further, the glasses commonly used for this standard process are borosilicate or aluminosilicate glasses, because their coefficient of thermal expansion is close to that of silicon (examples are PYREX and TEMPAX). They comprise alkali and/or alkaline earth positive ions like potassium or sodium (see, for example, D1: column 3, line 58 to column 4, line 7; D2: page 2, lines 29 to 37 and page 3, lines 4 to 10; D4: title and page 3090, left column, last paragraph of the section "Experimental"; D5: title and page 1756, first sentence of the section "Experimental"; D6: column 1, lines 16 to 19; D7: page 191, right column, last paragraph; D8: paragraph 2, D9: introduction).

Thus, a semiconductor-on-insulator structure comprising a part of a first substrate comprising a substantially single-crystal semiconductor material according to feature (a) which is joined to a second substrate comprising a borosilicate or aluminosilicate oxide glass which contains alkali and/or earth alkaline positive ions according to feature (c) by means of an anodic bonding process must be seen in combination as being part of the common general knowledge of the skilled person.

This generally known combination of features is suitable to be taken as a starting point representing the closest state of the art.

2.2 Implicit features

The experimental results presented in D7 indicate that under the conditions occurring during anodic bonding, oxygen ions are attracted by the anode and oxidise a part of it, resulting in a silicon dioxide (or silica) layer at the interface between the silicon anode and the glass (page 194, right column, paragraphs 1 and 2). This silica layer corresponds to the second region/ feature (e2) of claim 1, while the unoxidised part of the anode corresponds to the first region/feature e1 of claim 1.

Further, under these conditions, positive ions like sodium and potassium are attracted by the cathode, resulting in a positive ion depletion layer (page 191, left column, lines 10 to 15; page 193, right column, second paragraph) as well as a pile-up layer with increased density (of positive ions) relative to the bulk density at the depletion layer edge (page 193, right column, second paragraph).
The depletion layer and the pile-up layer correspond to the third region/feature (e3) and the fourth region/ feature (e4) of claim 1, respectively.

Finally, the bulk glass near the cathode layer (for example, the right part of figure 4) corresponds to the fifth region/feature (e5) of claim 1.

Thereby, according to the results presented in D7, joining a silicon substrate to an alkali or alkaline earth containing glass using the anodic bonding process will *inevitably* result in the creation of the five regions as defined in claim 1 and corresponding to features (e) and (e1) to (e5).

In view of the argument of the appellant that D7 would not lead the skilled person to the invention (see section IX.(a) above), the Board notes that D7 describes the physical and chemical processes occurring during anodic bonding that will automatically lead to the presence of features (e) and (e1) to (e5) even without the knowledge of D7.

It must be concluded that the generally known combination of features representing the closest state of the art as defined above comprises not only features (a) and (c), but also features (e), (e1), (e2), (e3), (e4) and (e5).

2.3 Difference

It follows from the above that the subject-matter of claim 1 differs from the closest state of the art as defined above only by the thickness ranges defined for the substrates and thus by features (b) and (d).

2.4 Inventive step

The thickness ranges defined in these features, however, are very large and generally correspond to values that can normally be found in standard micro-electronic or micro-mechanical applications using SOI structures and do not provide any particular technical effect per se.

Thicknesses in these ranges would thus be selected by the skilled person according to the circumstances (i.e., according to the specific application using the SOI structure in question), without the exercise of an inventive step.

For these reasons, the subject-matter of claim 1 of the main request does not involve an inventive step according to Article 56 EPC 1973 in view of the common general knowledge of the skilled person.

3. Auxiliary request 1

Feature (e2') requires, in addition to what is defined in feature (e2), that the second region has a specific thickness and an oxygen concentration of at least 50%.

The second region corresponds to the silica layer that is inevitably formed when a silicon substrate is joined to a glass substrate by anodic bonding as argued above. That is, the oxygen concentration of this layer is by definition 66,67% and thereby higher than 50%. This was not disputed by the appellant. Therefore, the oxygen concentration specified in feature (e2') is implicitly present in the generally known combination of features defined above as representing the closest state of the art.

The Board acknowledges that the thickness of the silica layer in D7 is thinner than the thickness of the second region according to feature (e2'), as argued by the appellant (see section IX.(b) above).

However, D7 relates essentially to ion drift processes in an already coated glass substrate and is not directed at a micro-electronic or micro-mechanical application for which the quality of the silicon layer would be crucial. Thus, there is no need to specifically protect the silicon coating and a thin silica layer is sufficient for the purposes of D7.

This document would therefore not incite the skilled person to provide only a very thin silica layer during a standard process of anodic bonding used to join two substrates. For this reason, D7 can not be seen as leading the skilled person away from the feature (e2').

Further, the Board notes that the application as a whole only generally states that the thickness of the second region will be typically *substantially smaller than 200 nm, e.g., on the order of 50 - 100 nm* (see paragraphs 79 and 80 of the application as published). It does not mention any particular technical effect achieved by a specific thickness of the second region (the Board notes that paragraph 55 relates to oxide layers present *before* the bonding step). The appellant did not indicate a corresponding passage, either.
The layer thickness of 50 nm to 100 nm defined in feature (e2') therefore has to be seen as an arbitrary choice not involving an inventive step.

Therefore, the subject-matter of claim 1 of auxiliary request 2 is not inventive according to Article 56 EPC 1973, either.

4. Auxiliary request 2

At least potassium and sodium defined in features (e3') and (e4') are elements that are contained in borosilicate glasses like TEMPAX or PYREX generally used in connection with silicon for anodic bonding (see, e.g., D7, first sentence of section 2. Experimental; see also the antepenultimate paragraph of section 2.1 of the present decision).

This was not disputed by the appellant who indicated that features (e3') and (e4') had been introduced only to overcome clarity issues (see section IX.(c) above).

Thus, the subject-matter of claim 1 of the second auxiliary request is not inventive, either.

5. Auxiliary request 3

5.1 Features (f) and (g)

In examples 7 and 12 of the application, the glass type Corning No. 7740 is used, with resistivity and CTE (Coefficient of Thermal Expansion) values according to features (f) and (g) (see paragraph 128 of the description).

The Board notes that Corning No. 7740 and PYREX are two different names for the same glass type (see D7, first sentence of section "2. Experimental"), which is one of the types commonly used for anodic bonding, as argued above (see antepenultimate paragraph of section 2.1 of the present decision).

On a more general level, the resistivity and CTE values defined in features (f) and (g) correspond to standard values for borosilicate glasses.

This was not disputed by the appellant, who indicated that these features had mainly been introduced together with feature (h) to avoid objections with respect to Article 123(2) EPC (see section IX.(d) above).

Features (f) and (g) can thus not provide a basis for the acknowledgement of an inventive step.

5.2 Feature (h)

The Board accepts the argument of the appellant that putting the silicon substrate under compression of the contracted glass substrate (feature (h)) improves the bond between the two materials (see section IX.(d) above).

However, the Board notes that the CTE of silicon is roughly 24×10^{-7} /°C, while the CTE of the borosilicate glasses normally used for anodic bonding is approximately 33×10^{-7} /°C (see e.g. D4, page 3090, left column, last paragraph, and D2, table 1).

Anodic bonding is performed at higher temperatures than room temperature and thus requires cooling of the bonded structure after the bonding step. Since the CTE of borosilicate glasses is higher than the CTE of silicon, cooling down a structure created by anodically bonding silicon on such a glass inevitably puts the silicon part of the structure under compression by the glass which contracts when cooling down.

Thus, the effect mentioned by the appellant is *inevitable* in any structure created by anodically bonding silicon on a borosilicate glass.

The Board concedes that such an effect might possibly also be achieved by a temperature differential as described in paragraph 70 of the application (see last argument of the appellant mentioned in section IX.(d) above). Such a temperature differential is, however, not apparent from the wording of claim 1 which is directed at a structure/device and the Board is not aware how a compression created by a temperature differential could be distinguished from a compression created by different CTEs in a completed SOI structure.

5.3 It follows from the above that the subject-matter of claim 1 of auxiliary request 3 is not inventive according to Article 56 EPC 1973, either.

6. Auxiliary request 4

Since claim 1 of the fourth auxiliary request is a combination of the features of the independent claims of auxiliary requests 2 and 3, corresponding considerations concerning inventive step apply.

The appellant did not submit any additional arguments concerning auxiliary request 4, beyond the arguments relating to the previous requests.

Therefore, the subject-matter of claim 1 of auxiliary request 4 is not inventive according to Article 56 EPC 1973.

7. Conclusion

None of the requests satisfies the requirements of Article 56 EPC 1973. Thus, the appeal has to be dismissed.

The contested decision also comprised objections with respect to Articles 76(1), 123(2) and 84 EPC. However, since none of the requests complies with the EPC as set out above, it is not necessary to discuss these objections here.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated