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

Datasheet for the decision of 23 April 2015

Case Number:	T 2255/10 - 3.4.03
Application Number:	01998993.8
Publication Number:	1345262
IPC:	H01L21/322
Language of the proceedings:	EN

Title of invention:
METHOD FOR PRODUCING SILICON WAFER AND SILICON WAFER

Applicant:
SUMCO CORPORATION

Headword:

Relevant legal provisions:
EPC Art. 52(1), 123(2)
EPC 1973 Art. 56, 84
RPBA Art. 13(3)

Keyword:
Inventive step - closest prior art - auxiliary request (yes)

Decisions cited:
T 0482/92

Catchword:

In accordance with the established case law of the Boards of Appeal the closest prior art for assessing inventive step is normally a prior art document disclosing subject-matter conceived for the same purpose as the claimed invention and having the most relevant technical features in common. (Reasons, point 2.2.2, citing T 482/92, Reasons, point 4.1, third paragraph.)

In establishing the closest prior art, the determination of the purpose of the invention is not to be made on the basis of a subjective selection from among statements of purpose which may be set out in the description of the application, without any reference to the invention as defined in the claims. On the contrary, the question to be asked is, what, in the light of the application as a whole, would be achieved by the invention *as claimed*.

For this reason, statements of purpose must be read in conjunction with the claims. Merely inserting such a statement into the description does not entitle an applicant effectively to "veto" any inventive step objection based on a document which is unrelated to this purpose, if it is not plausible that the invention as claimed would actually achieve the stated purpose. (Reasons, point 2.2.4.)

European Patent Office
D-80298 MUNICH
GERMANY
Tel. +49 (0) 89 2399-0
Fax +49 (0) 89 2399-4465

Case Number: T 2255/10 - 3.4.03

DECISION
of Technical Board of Appeal 3.4.03
of 23 April 2015

Appellant: (Applicant)	SUMCO CORPORATION 2-1, Shibaura 1-chome Minato-ku, Tokyo (JP)
Representative:	Hoffmann Eitle Patent- und Rechtsanwälte PartmbB Arabellastraße 30 81925 München (DE)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 21 June 2010 refusing European patent application No. 01998993.8 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	G. Eliasson
Members:	S. Ward
	T. Karamanli

Summary of Facts and Submissions

I. The appeal is against the decision of the Examining Division refusing European patent application No. 01 998 993 on the grounds that the claimed subject-matter of the main request and of the first and second auxiliary requests all filed with the letter of 24 February 2010 was not clear (Article 84 EPC) and did not involve an inventive step (Articles 52(1) and 56 EPC).

II. At the end of the oral proceedings held before the Board the appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of one of the following requests:

Main Request
Claims 1 to 4 according to the main request, filed with letter dated 20 March 2015;

1st Auxiliary Request
Claims 1 and 2 according to the 1st Auxiliary Request, filed during oral proceedings before the Board;

2nd Auxiliary Request
- Claims 1 and 2 according to the 2nd Auxiliary Request, filed during oral proceedings before the Board;

- Description pages 1 to 22, filed during oral proceedings before the Board; and

- Drawing sheets 1/10 to 10/10, filed on 4 June 2003;

3rd Auxiliary Request

Claims 1 and 2 according to the 3rd Auxiliary Request, filed with letter dated 20 March 2015;

4th Auxiliary Request
Claims 1 and 2 according to the 4th Auxiliary Request, filed with letter dated 20 March 2015;

5th Auxiliary Request
Claims 1 to 3 according to the 5th Auxiliary Request, filed with letter dated 20 March 2015.

III. The following documents cited by the Examining Division are referred to in this decision:

D1: WO 00/67299 A2
D2: WO 00/13211 A2.

Reference is also made to the following document submitted by the appellant:

D3: A "declaration by Yoshinobu Nakada, who is one of the Inventors of the present application ... prepared during the examination proceedings of the corresponding US application".

The declaration refers to five "Reference Figures" and one "Reference Table", which were also enclosed with said letter and are considered to be comprised in document D3.

IV. Claim 1 of the main request reads as follows:

"A production method for silicon wafers, comprising:
a step for slicing a silicon wafer from an ingot composed of perfect area where no agglomerate of

interstitial type point defects and no agglomerate of vacancy type point defects exist;
a step for thinning or stripping an oxide film on a surface of the silicon wafer in case where the thickness of the oxide film is 2 nm or more, wherein the oxide film is thinned so as to be less than 2 nm thick; and
a thermal annealing step for thermal-annealing the silicon wafer in an atmosphere to nitride the surfaces of the silicon wafer; thereby, forming vacancies therein,
wherein the step for thinning or stripping an oxide film is performed before the thermal annealing step,
the atmosphere used in the thermal annealing step comprises a nitride gas comprising NH_3 *having a lower decomposition temperature than a decomposable temperature of* N_2*,*
the NH_3 *in the nitride gas is 0.5% or more in concentration, or 10 sccm or more in flow rate, and*
the temperature in the thermal annealing step is 900°C to 1200°C and the time in the thermal annealing step is 60 seconds or less."

Apart from minor editorial changes, claim 1 of the 1st auxiliary request differs from claim 1 of the main request only in that the following features have been added as the final features of the claim:

"the thermal annealing step comprises:
providing the silicon wafer in a reaction chamber for the thermal annealing,
carrying out a purging treatment for removing oxygen contained in an atmosphere in the reaction chamber, and
supplying an atmosphere containing the nitride gas into the reaction chamber."

Claim 1 of the 2nd auxiliary request reads as follows:

"A production method for silicon wafers, comprising:
a step for slicing a silicon wafer from an ingot composed of perfect area where no agglomerate of interstitial type point defects and no agglomerate of vacancy type point defects exist;
a step for thinning or stripping an oxide film on a surface of the silicon wafer in case where the thickness of the oxide film is 2 nm or more, wherein the oxide film is thinned so as to be less than 2 nm thick;
a first thermal annealing step for thermal-annealing the silicon wafer in an atmosphere to nitride the surfaces of the silicon wafer, thereby, forming vacancies therein; and after the first thermal annealing step,
a second thermal annealing step, wherein a non-defect layer is formed in a surface layer of the silicon wafer at lower temperature than that in the first thermal annealing step and at the same time oxygen atoms are precipitated by utilizing the vacancies in the silicon wafer,
wherein the step for thinning or stripping an oxide film is performed before the first thermal annealing step,
the atmosphere used in the first thermal annealing step comprises a nitride gas comprising NH_3 *having a lower decomposition temperature than a decomposable temperature of* N_2*,*
the NH_3 *in the nitride gas is 0.5% or more in concentration, or 10 sccm or more in flow rate,*
the temperature in the first thermal annealing step is 900°C to 1200°C and the time in the first thermal annealing step is 60 seconds or less, and
the first thermal annealing step comprises:

providing the silicon wafer in a reaction chamber for the thermal annealing,
carrying out a purging treatment for removing oxygen contained in an atmosphere in the reaction chamber; and
supplying the atmosphere containing the nitride gas into the reaction chamber."

V. In the contested decision, the Examining Division found essentially as follows:

Claim 1 of the main request was unclear (Article 84 EPC), as the term "stripping" (in "an oxide film stripping step") was normally used in the art with reference to the complete removal of the oxide layer, whereas what appeared to be intended, at least for some of the embodiments, was only a partial removal, i.e. a thinning, of the oxide. Moreover, reducing the thickness to zero would not explain the formation of the claimed "silicon oxynitride film" during the nitridation step.

The subject-matter of claim 1 of the main request also did not involve an inventive step (Article 56 EPC). Document Dl was the closest prior art, and the subject-matter of claim 1 differed from the method disclosed in this document in that:

"i) the wafer is sliced from an ingot composed of perfect area where no agglomerate of interstitial type point defects and no agglomerate of vacancy type point defects exist; and

"ii) the oxide film is thinned so as to be less than 2 nm thick in the oxide film stripping step."

The problem underlying the invention might be regarded as obtaining a high quality wafer.

Concerning point i), since Dl dealt with a gettering process, the use of an ideal precipitation wafer was obvious and belonged to the general knowledge of the skilled person.

Concerning point ii), no technical advantage could be seen in a step of reducing an oxide thickness to below 2 nm compared to already having a native oxide layer with a thickness in that range (1.3 to 1.5 nm) as in D1. Moreover, for an HF stripped wafer (total oxide removal), a very thin native oxide would immediately re-form on contact with the atmosphere. Hence no inventive merit could be recognised in such a process, and the subject-matter of claim 1 was thus not inventive.

The subject-matter of claim 1 of the 1st auxiliary request and of claim 1 of the 2nd auxiliary request was similarly unclear and also did not involve an inventive step.

VI. In the section "ADDITIONAL COMMENTS" the Examining Division argued essentially as follows:

Claim 1 of the main request could also not be considered as inventive in view of document D2. The subject-matter of claim 1 differed from the disclosure of document D2 in that the oxide film was thinned so as to be less than 2 nm thick in the oxide film stripping step. Document D2 instead specified an interval between 2 and 3 nm (page 12, lines 15-23) for the oxide layer prior to the ammonia annealing. The thickness range of claim 1 (less than 2 nm) was so close to the known range (2 to 3 nm) that claim 1 could not justifiably be regarded as inventive.

VII. The appellant's arguments, insofar as they remain relevant to the present decision and the current requests, may be briefly summarised as follows:

As a result of the amendments made to the claims of the current requests, the clarity requirement of Article 84 EPC was met. It was not necessary to specify the origin of the oxide film; silicon wafers were commonly subjected to processes which might result in their formation.

In relation to inventive step, the Examining Division had been mistaken to regard document D1 as the closest prior art, as the purpose of the method of document D1 (using vacancies for controlling the distribution of dopant elements) was quite different to that of the present invention.

In the first and second embodiments of document D2, a thermal oxidation step S_1 was carried out (page 12, lines 15-23) resulting in an oxide layer which could be inferred to have a thickness preferably greater than at least about 2 nm. It would be an unrealistic approach to choose as a starting point for a production method for silicon wafers comprising a step for thinning or stripping an oxide film, an embodiment in which the formation of an additional oxide layer was envisaged (emphasis added by the appellant). Accordingly the Examining Division's argumentation starting from the first embodiment of D2 amounted to an artificial and unrealistic approach.

The third embodiment of document D2 [it was argued in the statement of grounds of appeal] described on page 18, line 16 to page 19, line 16 was therefore to be regarded as the closest prior art.

The distinguishing features of claim 1 over this embodiment of document D2 could be identified as: the thinning or stripping of an oxide layer to less than 2 nm, the use of a nitride gas comprising NH_3 (as opposed to nitrogen with a small partial pressure of oxygen), the concentration and flow rate of NH_3, and the temperature (900°C to 1200°C) and time (60 seconds or less) of the thermal annealing step.

All of these distinguishing features contributed to the efficient and uniform injection of vacancies into a perfect wafer, thereby increasing BMD density. There was no apparent reason for one of average skill in the art to modify the third embodiment of the method of manufacturing the handle wafer in D2 in the direction of the claimed production method with a reasonable expectation to inject vacancies into the perfect wafer efficiently and uniformly.

The purging step of claim 1 of the 1st auxiliary request and the oxygen precipitation step of the 2nd auxiliary request further distinguished the claimed subject-matter from document D2.

Alternatively [it was argued in the letter of 20 March 2015] one of the concrete examples of document D2 should be selected as closest prior art, such as Example 5 (pages 44 and 45) or, most suitably, "Sample 3-14" of "Example 1" (pages 38 and 39, Table I).

The process according to claim 1 of the main request differed from the said sample 3-14 at least in that it used a lower temperature for the thermal annealing step (900 to 1200°C vs. 1250°C), in the use of an atmosphere comprising NH_3, and in the use of a perfect wafer being free of any agglomerates of intrinsic point defects. This allowed for uniform formation of a high number of vacancies, good surface roughness and a significantly reduced slip length. This was further confirmed by the declaration by Mr. Nakada [document D3].

Document D2 did not teach how the surface roughness of a silicon wafer could be improved, nor the advantages of NH_3 over a nitrogen atmosphere. Furthermore, document D2 clearly taught that higher temperatures and increased annealing times would lead to an increased concentration of vacancies (page 16, lines 21-25), the preferred temperature range being 1200 to 1275°C (page 13, line 2).

Since the number of defects was very low in a perfect wafer, the skilled person had no expectation that a high number of vacancies could be introduced therein. Moreover, such wafers could only be obtained under precise control of the pulling conditions in the Czochralski method; perfect wafers were thus more expensive. The skilled person would naturally choose a wafer containing predominantly vacancies rather than a wafer that is basically free of any defects.

The process of claim 1 of the main request was thus inventive over document D2, and over a combination of document D2 with document D1.

Claim 1 of the first auxiliary request added a step for forming a non-defect layer at a lower temperature than the thermal annealing step, and a step for precipitating oxygen atoms.

The method of sample 3-14 did not result in a sufficient DZ layer. Document D2 suggested the possibility of an oxygen annealing step after the thermal annealing using a nitriding atmosphere (page 19, line 25 to page 20, line 14), but this treatment was conducted at a temperature of at least 1150°C, and preferably at a higher temperature than in step S_2 (page 21, lines 1-5). Such a process would lead away from the process of claim 1, according to which a temperature that is lower than the temperature of the thermal annealing step is used.

The additional features of the 2nd to 5th auxiliary requests further distinguished the respective claimed subject-matter from document D2.

Reasons for the Decision

1. The appeal is admissible.

2. Main request

2.1 Amendments (Article 123(2) EPC)

2.1.1 Claim 1 of the main request is based on a combination of claims 1-3 and 5-7 as originally filed. The feature relating to the "perfect area" is based on the passages from page 17, line 8 to page 19, line 17. The feature "to nitride the surfaces of the silicon wafer" may be seen as being based on numerous passages throughout the description, for example page 12, lines 7-11. Hence, the subject-matter of claim 1 of the main request is considered to meet the requirements of Article 123(2) EPC.

2.2 Closest prior art

2.2.1 The Examining Division considered document Dl to be the closest prior art. The appellant regards this as an unsuitable choice for the reason that the purpose of the present invention and that of document D1 are different. The first question to examine, therefore, is whether document D1 represents an appropriate starting point.

2.2.2 The Boards of Appeal have considered the question of the selection of the closest prior art in numerous decisions, the conclusions being summarised in Case Law of the Boards of Appeal, 7th edition 2013, I.D.3.

In T 482/92, for example, the position is stated as follows:

- *"in accordance with the established case law of the Boards of Appeal the 'closest prior art' for assessing inventive step is normally a prior art document disclosing subject-matter conceived for the same purpose as the claimed invention and having the most relevant technical features in common."* (T 482/92, Reasons, point 4.1, third paragraph.)

2.2.3 The Board therefore agrees with the appellant that a comparison of the purpose of the invention and that of a potential closest prior art document is an important consideration in this regard. However, this leads to the question of how, precisely, the purpose of an invention is to be determined.

Typically, a patent application may comprise numerous statements of aims, ambitions and alleged advantages, the present application being no exception. In the first paragraph on page 1 (where one would normally expect to find the application described in its most general aspect) the invention is said to relate to "forming vacancies in a silicon wafer" and "forming a denuded zone (DZ) just under the surface of the silicon". Later, more specific aims are mentioned, for example providing a layer with a high density of BMDs (which the appellant apparently regards as the purpose of the invention), suppressing the generation of slips, providing satisfactory surface roughness etc.

The question is, therefore, which of these goals is to be considered as the purpose of the invention for the determination of the closest prior art? The answer, in the opinion of the Board, is provided in the passage quoted from T 482/92, in which it is stated that the closest prior art should relate to "the same purpose as the *claimed* invention" (emphasis added by the Board).

2.2.4 In establishing the closest prior art, the determination of the purpose of the invention is not to be made on the basis of a subjective selection from among statements of purpose which may be set out in the description of the application, without any reference to the invention as defined in the claims. On the contrary, the question to be asked is, what, in the light of the application as a whole, would be achieved by the invention *as claimed*.

For this reason, statements of purpose must be read in conjunction with the claims. Merely inserting such a statement into the description does not entitle an applicant effectively to "veto" any inventive step objection based on a document which is unrelated to this purpose, if it is not plausible that the invention as claimed would actually achieve the stated purpose.

2.2.5 It must be borne in mind that Article 113(2) EPC guarantees that the manner in which the invention is defined in the claims of a European patent application is entirely in the hands of the applicant.

Where a specific purpose of the invention is stated in the description, the applicant is free to include in an independent claim those features by means of which this purpose is achieved. In this case a document unrelated to this purpose (or at least a similar purpose) would generally not be a suitable choice of closest prior art, for the reasons indicated above.

Alternatively, the applicant may decide to seek protection for the invention according to a broader definition by omitting from the claim one or more of the features mentioned above so that the claimed invention would no longer achieve the specific purpose referred to. In this case a different purpose must be sought by asking what would in fact be achieved by the invention as claimed.

It will often be the case that a more general purpose will have to be ascribed to the broader claim, and that the number of prior art documents relating to this more general purpose is correspondingly greater. By defining the invention in broader terms the applicant aims for a larger scope of protection, but at the same time exposes the claimed invention to possible inventive step attacks based on a larger number of potential candidates for closest prior art. As noted above, the choice is entirely in the hands of the applicant.

2.2.6 Turning to the present main request, the appellant stresses the aspect of providing a high density of oxygen precipitates (BMDs). The Board accepts that this aim is mentioned in the application, the invention being described, for example, as providing a "high quality silicon wafer having a DZ layer, which is suitable for forming a device, as the surface layer, and also having a high BMD density area having a proximity gettering effect" (see page 6, lines 9-12, and in general, page 6, line 2 to page 7, line 11; page 19, lines 4-8 etc.).

The appellant concludes that document D1 is not a suitable choice of closest prior art, as the purpose of the method disclosed in this document is different, namely to control the distribution of dopant elements in the silicon wafer, thereby controlling resistivity.

2.2.7 The Board notes that the method disclosed in the present application comprises at least two steps, as follows:

- a first step involving subjecting a silicon wafer to rapid thermal annealing in an atmosphere comprising NH_3 to inject vacancies into the wafer (page 3, line 5 – page 4, line 20; page 10, line 21 – page 12, line 11), and

- a second step involving a second thermal anneal at a lower temperature in an atmosphere comprising O_2 resulting in a denuded zone at the wafer surface

> and a layer having a high density of oxygen precipitates (BMD layer) suitable for proximity gettering (page 6, lines 2-12; page 12, lines 12-21).

The purpose highlighted by the appellant (a high density BMD layer) is therefore achieved by carrying out *both* steps of this procedure.

In claim 1 of the main request, however, the appellant has chosen to define the invention in terms of the first step only. The result achieved by carrying out this claimed method would be a silicon wafer with injected vacancies. There would be no denuded zone and no BMD layer.

In the light of the analysis above, it cannot be legitimately asserted that the purpose of the invention as claimed is to provide a silicon wafer having BMD layer with high density, or for that matter having a denuded zone. The purpose of the claimed invention can only be defined in terms of what would be objectively achieved by carrying out the claimed method, namely providing a silicon wafer with injected vacancies. It follows, therefore, that any document which describes a process having the purpose of injecting vacancies into a silicon wafer, for whatever reason, is a potentially suitable choice as closest prior art, or at least cannot be excluded on the grounds that it relates to a different purpose.

There has never been any dispute that document D1 discloses a method by which vacancies are injected into a silicon wafer. Moreover, the method of document D1 has many technical features in common with the claimed invention (see point 2.3.2, below). The Board therefore considers that document D1 is a perfectly suitable choice as closest prior art for the main request.

2.3 *Main request: inventive step starting from document D1*

2.3.1 Document D1 discloses a production method for silicon wafers (see e.g. page 6, line 8), and it is implicit to a skilled person that such wafers would be sliced from an ingot.

Moreover, the use of "in case where" in claim 1 means that two alternatives are defined: when the thickness of the oxide film is 2 nm or more, it is thinned or stripped, and when it is not 2 nm or more, it is not thinned or stripped. The wafers of document D1 have only a natural oxide layer with a thickness of about 13 Angstroms (1.3 nm, see page 6, line 19; page 7, second paragraph), and this is generally not stripped (although as an alternative it could be - see page 7, second paragraph). Hence, document D1 discloses the second claimed alternative in relation to thinning/stripping.

2.3.2 Document D1 therefore discloses the following features of claim 1 of the main request:

A production method for silicon wafers, comprising:
a step for slicing a silicon wafer from an ingot;
a step for thinning or stripping an oxide film on a surface of the silicon wafer in case where the thickness of the oxide film is 2 nm or more, wherein the oxide film is thinned so as to be less than 2 nm thick (see point 2.3.1, above); and
a thermal annealing step for thermal-annealing the silicon wafer in an atmosphere to nitride the surfaces

of the silicon wafer; thereby, forming vacancies therein (see e.g. page 2, line 9 to page 3, line 19), wherein the step for thinning or stripping an oxide film is performed before the thermal annealing step (see point 2.3.1, above),
the atmosphere used in the thermal annealing step comprises a nitride gas comprising NH_3 having a lower decomposition temperature than a decomposable temperature of N_2 (page 8, second paragraph),
the NH_3 in the nitride gas is 0.5% or more in concentration, or 10 sccm or more in flow rate (page 8, second paragraph, 10000 ppm corresponds to 1%), and
the temperature in the thermal annealing step is 900°C to 1200°C and the time in the thermal annealing step is 60 seconds or less (page 8, second paragraph).

2.3.3 The method of claim 1 therefore differs from that of document D1 in that the ingot is composed of perfect area where no agglomerate of interstitial type point defects and no agglomerate of vacancy type point defects exist.

According to the application the wafer can be sliced from an ingot grown by a "normal CZ method" (page 17, lines 8-9), or alternatively from an ingot according to the above distinguishing feature (page 17, line 9 *et seq.*), i.e. corresponding to the region [P] of figure 5.

The appellant essentially argued that if the aim were to produce a wafer with a significant number of vacancies, a skilled person would naturally consider it advantageous to start from a wafer already containing vacancies (region [V]), rather than a wafer that is basically free of any defects (region [P]).

However, if this argument were to be considered valid, it would have to be asked why it would not apply with equal force to the claimed invention. Why, in other words, in the context of an invention which aims to provide a silicon wafer with injected vacancies, is a feature included in the claim which, according to the appellant, is disadvantageous in precisely this respect? Which technical effect (other than the adverse one pointed out by the appellant) would it provide? Which problem would it solve?

During the oral proceedings the appellant conceded that this choice might appear counter-intuitive, especially as the process for forming such ingots involved extra cost and effort. Nevertheless, the appellant asserted that it had been found worthwhile to start from such an ingot. When pressed on this point, however, the appellant did not offer any specific technical effects provided by such a choice.

2.3.4 The Board notes that there is no dispute that the technical content of figure 5 of the present application and of the associated text is well-known, and essentially summarises the relationship (first pointed out by Voronkov in the 1980s) between the levels of vacancy and interstitial type defects and the ratio of the pulling rate to the temperature gradient (V/G). It is also not in dispute that a skilled person would, at the priority date, have been well able to produce ingots corresponding to any of the regions depicted in the figure.

Given the aim of injecting vacancies into the wafer of document D1, the skilled person would clearly not be tempted to select the region [I] depicted in figure 5, in which interstitial type point defects predominate.

Choosing the "perfect area [P]" would result in a low number of vacancy type point defects (admittedly a disadvantage when injecting vacancies is the aim), but also in a low incidence of *agglomerates* of point defects, i.e. macroscopic defects such as COPs (see page 19, lines 4-8) which are generally harmful. Alternatively, working in the area [V] would result in a greater number of desirable vacancy type point defects, but also in a correspondingly greater number of undesirable agglomerates of point defects.

The skilled person would make a selection from this very limited number of alternatives on the basis of the well-known advantages and disadvantages of each, and without exercising any inventive activity.

The subject-matter of claim 1 of the main request does not, therefore, involve an inventive step within the meaning of Article 56 EPC 1973.

3. *1st auxiliary request*

3.1 *Amendments (Article 123(2) EPC)*

3.1.1 In addition to the features of claim 1 of the main request, claim 1 of the 1st auxiliary request comprises the features of dependent claim 8 as filed. Hence, the subject-matter of claim 1 of the 1st auxiliary request is considered to meet the requirements of Article 123(2) EPC.

3.2 *Closest prior art*

3.2.1 Claim 1 of the 1st auxiliary request also omits the second thermal annealing step necessary to produce a denuded zone and a BMD layer, and hence document D1 is seen as the closest prior art for the same reasons as mentioned in connection with the main request, *mutatis mutandis*.

3.3 1st auxiliary request: inventive step starting from document D1

3.3.1 In addition to the features of claim 1 of the main request, claim 1 of the 1st auxiliary request comprises the following features:

"the thermal annealing step comprises:
providing the silicon wafer in a reaction chamber for the thermal annealing;
carrying out a purging treatment for removing oxygen contained in an atmosphere in the reaction chamber; and supplying an atmosphere containing the nitride gas into the reaction chamber."

3.3.2 The first and third of these features (thermal annealing of the silicon wafer taking place in a reaction chamber and the atmosphere containing the nitride gas being supplied into the reaction chamber) are implicit in document D1.

3.3.3 Moreover, document D1 discloses embodiments in which the thermal treatment takes place in an atmosphere comprising NH_3 and argon; oxygen, if present at all, is seen as an impurity (see e.g. page 6, lines 6-22; page 8, lines 8-16). Hence, in the normal case where the reaction vessel contained air prior to the commencement of the thermal treatment, it would clearly be necessary to remove oxygen from the chamber.

In the opinion of the Board, any such method to remove oxygen from the chamber could quite properly be referred to as a "purging method". However, even if this term were considered to refer to the specific method adopted in the description, i.e. flushing the chamber with argon, such a procedure would be entirely familiar to the person skilled in the art.

The subject-matter of claim 1 of the 1st auxiliary request does not, therefore, involve an inventive step within the meaning of Article 56 EPC 1973.

4. 2nd auxiliary request

4.1 Article 123(2) EPC

4.1.1 Claim 1 of the 2nd auxiliary request is based on claim 1 of the 1st auxiliary request (the thermal annealing step for nitriding the surfaces now being referred to as the "first thermal annealing step") with the following feature added:

"and after the first thermal annealing step, a second thermal annealing step, wherein a non-defect layer is formed in a surface layer of the silicon wafer at lower temperature than that in the first thermal annealing step and at the same time oxygen atoms are precipitated by utilizing the vacancies in the silicon wafer".

4.1.2 The basis for this feature may be seen as follows:

Two possibilities for forming the non-defect layer (denuded zone) and for precipitating oxygen are disclosed in the application as filed. According to a first possibility, these processes are performed separately and sequentially (e.g. claim 9 as filed, and page 6, lines 2-12). According to a second possibility a single thermal treatment at a lower temperature than that of the first thermal annealing step produces the non-defect layer and required oxygen precipitation at the same time (page 10, lines 9-13; page 12, lines 12-21; page 14, lines 5-12; and page 17, lines 5-7).

It is the second possibility which has been incorporated into claim 1 of the 2nd auxiliary request, and this has a satisfactory basis in the application as filed as indicated above.

Claim 2 is based on claim 4 as originally filed, and the description has been amended only to the extent necessary to achieve consistency with the amended claims.

The 2nd auxiliary request is therefore considered to satisfy the requirements of Article 123(2) EPC.

4.2 *Article 84 EPC 1973*

4.2.1 The additional feature of the 2nd auxiliary request is partly defined in a functional manner, in terms of achieving the formation of a denuded zone and oxygen precipitation in a single thermal treatment. The Board has therefore carefully considered whether this formulation meets the clarity requirements of Article 84 EPC 1973, or whether it would be necessary to re-formulate this feature in terms of concrete parameters. Given that the only such parameters disclosed in the application as filed appear to be the specific combinations mentioned in lines 12-21 of page 12 (800°C for 4 hours under an N_2/O_2 atmosphere, or 1000°C for 16 hours), the choice is a stark one.

On balance, the Board finds the formulation of the present request acceptable.

4.2.2 Firstly, there is at least one feature which would be implicit to the skilled person in the claimed formulation, namely that the atmosphere must comprise some component of O_2 to provide oxidation thereby injecting interstitial defects into the surface layer to annihilate with the vacancies there. Without this no denuded layer would form.

Moreover, whether a denuded zone has been formed and whether oxygen has been precipitated may be determined experimentally, and according to the claim, both results are achieved at the same time in a thermal annealing step. Hence, a thermal annealing step involving a combination of temperature, annealing time, atmosphere etc. which results, at the same time, in both the formation of a denuded zone and oxygen precipitation, falls within the ambit of the claim. Thermal annealing steps resulting in only a denuded zone or oxygen precipitation or neither do not fall within the ambit of the claim. The Board therefore finds that claim 1 meets the requirements of Article 84 EPC 1973.

4.3 Closest prior art

4.3.1 Unlike the previous requests, claim 1 of the 2nd auxiliary request includes both a first thermal annealing step for injecting vacancies into the silicon wafer, and a second thermal annealing step for producing a non-defect layer (denuded zone) and oxygen precipitation (a BMD zone). For this request, therefore, the purpose of the claimed invention can be seen as providing a silicon wafer having a DZ layer and a BMD layer for internal gettering, essentially as set out under point 2.2.6 above. This is not the purpose of the method disclosed in document D1, and hence document D1 is not a suitable choice as the closest prior art for this request.

Document D2, which also deals with the creation of a denuded zone, internal gettering etc., clearly represents a more promising choice.

4.3.2 In relation to thermal annealing, three principal embodiments are disclosed in document D2 (page 12, line 15 to page 22, line 12).

The first embodiment includes an initial step (referred to as "S_1") in which the wafer is heat-treated in an oxygen-containing atmosphere with the express purpose of growing an oxide layer with a thickness preferably in the range 20–30 Angstroms (2–3 nm). Choosing this as a starting point for an invention which advocates that such an oxide layer should be stripped or thinned so as to be less than 2 nm was described by the appellant in the statement of grounds of appeal as "an artificial and unrealistic approach". The Board entirely agrees.

In the letter dated 20 March 2015 the appellant suggested that sample 3-14 of Example 1 (see Table I, page 39) was the most suitable starting point. Although step S_1 is omitted in sample 3-14, it appears to be more in the nature of a comparative example, as no denuded zone is formed. For this reason, this also appears an unlikely choice.

The second embodiment appears also to include step S_1 and hence is no more suitable than the first embodiment (in fact less, as a non-nitriding atmosphere is used).

Starting from the third embodiment (page 18, line 16 *et seq.*), in which the step S_1 "is omitted and the starting wafer has no more than a native oxide layer" would avoid the artificiality referred to above.

The third embodiment discloses two alternative possibilities in relation to the formation of the denuded zone: a first alternative in the form of a one step process (page 19, lines 7-24) in which annealing takes place "in a nitride atmosphere containing a small partial pressure of oxygen" and a second alternative in the form of a two step process (page 19, line 25-page 22, line 12) in which the wafer is "subjected to a thermal anneal, or rapid thermal anneal, treatment under an oxygen atmosphere after annealing under a nitrogen atmosphere or a neutral atmosphere" (page 19, lines 25-29). Clearly this second alternative is closer to the two-step method of claim 1.

Moreover, Example 5 (pages 44-45) is an example which corresponds to the second alternative of the third embodiment (no prior oxidation step S_1, two step annealing etc.) and further specifies that the nitriding treatment takes place in an atmosphere of ammonia.

Hence, Example 5 together with the general explanation of the second alternative of the third embodiment (page 18, line 16 to page 19, line 6; and page 19, line 25 to page 22, line 12) is seen as the closest prior art for claim 1 of the second auxiliary request.

4.4 Second auxiliary request: inventive step starting from Example 5 of document D2

4.4.1 Claim 1 of the second auxiliary request differs from Example 5 in at least the following features indicated in bold type:

a) a step for slicing a silicon wafer from an ingot **composed of perfect area where no agglomerate of interstitial type point defects and no agglomerate of vacancy type point defects exist;**

b) a second thermal annealing step, wherein a non-defect layer is formed in a surface layer of the silicon wafer **at lower temperature than that in the first thermal annealing step** and **at the same time oxygen atoms are precipitated** by utilizing the vacancies in the silicon wafer,

c) the NH_3 in the nitride gas is **0.5% or more in concentration, or 10 sccm or more in flow rate,**

d) the time in the first thermal annealing step is **60 seconds or less**, and

e) carrying out a **purging treatment for removing oxygen** contained in an atmosphere in the reaction chamber.

4.4.2 The feature listed under point a) cannot be considered to confer an inventive step. Although this feature is not expressly mentioned in relation to Example 5, it is disclosed in document D2 as a clear preference in relation to the formation of the device layer (page 23, lines 10-20). It is also mentioned in lines 17-25 of page 34 which describe an ion implantation process for the formation of SOI structures, according to which the "handle wafer" (which is subjected to the thermal annealing) and the wafer comprising the device layer (which is substantially free of agglomerated defects) are in fact the same wafer.

4.4.3 The feature listed under point b) – a second thermal annealing step at a lower temperature – provides a non-defect layer and oxygen precipitation in a single step. The problem may therefore be seen as providing a simple method of arriving at a DZ and BMD layer.

The second thermal annealing step of Example 5 of document D2 takes place at the *same* temperature (1180°C) as the first (nitriding) annealing step for 3 minutes. This choice is not arbitrary, but is seen in document D2 as being necessary to avoid a decrease in the peak concentration of vacancies in the BMD region 17 (page 21, lines 1-8).

However, this treatment is not, apparently, suitable for producing oxygen precipitation, and further treatments are required, in particular an "oxygen stabilization and growth step (S_4)" (page 44, lines 21-22) which is in fact a lower temperature heat-treatment for oxygen precipitation (page 15, line 26 to page 16, line 14).

According to the present invention, for a wafer produced according to the process conditions of claim 1, a single second thermal annealing step taking place at a lower temperature than that of the first thermal annealing step has been found sufficient to produce simultaneously a denuded zone suitable for device formation and oxygen precipitation providing a BMD layer having high density for proximity gettering (page 14, lines 5-12). On the basis of the available prior art, the Board sees no reason to believe that a skilled person would find it obvious to arrive at this solution.

4.4.4 There are, moreover, numerous other differences between claim 1 and the closest prior art.

The method of claim 1 requires that the NH_3 in the nitride gas is "0.5% or more in concentration, or 10 sccm or more in flow rate". This feature is said to lead to nitride films each having the same film thickness, and hence resulting in the same concentration of vacancies being introduced (page 15, lines 2-13), and the Board sees no reason to question the plausibility of this observation. Document D2 does not provide any guidance on NH_3 concentration or flow rate, nor does the problem of equalizing nitride film thicknesses appear to be recognized.

In document D1 a concentration range for NH_3 of 2500 to 10000 ppm (0.25% to 1%) is mentioned (page 8, line 8). Elsewhere other ranges are mentioned (e.g. 2500 to 5000 ppm, i.e. 0.25% to 0.5% on page 9, line 28), and in any event, these ranges appear to be discussed entirely in terms of the resultant resistance of the doped oxide layers produced, which is clearly a different problem. Hence, document D1 does not render the presently claimed range obvious.

4.4.5 Furthermore, the annealing time of 60 seconds or less for the first thermal annealing step, in combination with the temperature range, is not only chosen to achieve sufficient vacancy generation, but also to suppress the generation of slips (page 4, lines 12-17). Again, the Board has no reason to doubt the plausibility of this observation. The corresponding time in example 5 of document D2 is 3 minutes, and the problem of the generation of slips is not mentioned.

4.4.6 In the light of the above, the Board concludes that the skilled person would not arrive at the combination of features of claim 1 in an obvious manner, and hence the subject-matter of claim 1 of the 2nd auxiliary request is considered to involve an inventive step within the meaning of Article 56 EPC 1973.

5. *3rd to 5th auxiliary requests*

5.1 As the 2nd auxiliary request is judged to be allowable, it is not necessary for the Board to consider the 3rd to 5th auxiliary requests.

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 in the following version:

   - Claims 1 and 2 according to the 2nd auxiliary request, filed during oral proceedings before the Board;

   - Description pages 1 to 22, filed during oral proceedings before the Board; and

   - Drawing sheets 1/10 to 10/10, filed on 4 June 2003.

The Registrar: The Chairman:

Beschwerdekammern des Europäischen Patentamts
Boards of Appeal of the European Patent Office
Chambres de recours de l'Office européen des brevets

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated