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Datasheet for the decision of 3 June 2015

Case Number:	T 1123/11 - 3.4.03
Application Number:	03009850.3
Publication Number:	1363322
IPC:	H01L21/324, H01L21/20, C30B29/40, C30B25/02
Language of the proceedings:	EN

Title of invention:
GaN single-crystal substrate, nitride type semiconductor epitaxial substrate, nitride type semiconductor device, and methods of making the same

Applicant:
Sumitomo Electric Industries, Ltd.
Institute of Materials Research and Engineering

Headword:

Relevant legal provisions:
EPC 1973 Art. 56

Keyword:
Inventive step (no)

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Catchword:

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Case Number: T 1123/11 - 3.4.03

DECISION
of Technical Board of Appeal 3.4.03
of 3 June 2015

Appellant:
(Applicant 1)

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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted on 17 December 2010 refusing European patent application No. 03009850.3 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman G. Eliasson
Members: R. Bekkering
T. Bokor

Summary of Facts and Submissions

I. The appeal is against the refusal of application no. 03 009 850 for lack of an inventive step, Article 56 EPC (main request, first auxiliary request), over document

D3: WO 02 01608 A.

and for added subject-matter, Article 123(2) EPC (third auxiliary request).

The applicant's second auxiliary request was not admitted into the procedure pursuant to Rule 137(3) EPC.

II. With the statement setting out the grounds of appeal dated 27 April 2011, the appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of the following:

Main request:

Claims 1 to 8 according to the appellant's main request, filed with the statement setting out the grounds of appeal, and

First auxiliary request:

Claims 1 to 7 according to the appellant's first auxiliary request, filed with the statement setting out the grounds of appeal.

Oral proceedings were requested for the case the board would be unable to rectify the contested decision on the basis of the main request.

III. A summons to oral proceedings was issued by the board, provided with an annex in which a provisional opinion of the board on the matter was given.

In particular, the appellant was informed that it appeared that the subject-matter of claim 1 of both the appellant's main request and the first auxiliary request lacked an inventive step in the sense of Article 56 EPC 1973 over document D3.

IV. With a letter dated 27 April 2015 of the appellant, the request for oral proceedings was withdrawn. A decision according to the state of the procedure was requested instead.

Oral proceedings were held on 3 June 2015 in the absence of the appellant.

V. Claim 1 of the appellant's main request reads as follows:

"*A method of making a GaN single-crystal substrate, said method comprising the step of subjecting a GaN single-crystal having a polished surface to heat treatment for at least 10 minutes at a substrate temperature of at least 1020°C in a mixed gas atmosphere containing at least an* NH_3 *gas, so that said surface of said GaN single-crystal substrate has a root-mean-square roughness of 0.2 nm or less defined in a square measuring 2.0 µm per side, and after said heat treatment,* *epitaxially growing a nitride type compound semiconductor layer on said GaN single-crystal substrate without oxidizing said surface of said GaN single-crystal substrate, so that said nitride type compound semiconductor layer has a threading dislocation density of* 1×10^6 cm^{-2} *or less.*"

VI. Claim 1 of the appellant's first auxiliary request reads as follows:

"*A method of making a GaN single-crystal substrate, said method comprising the step of subjecting a GaN single-crystal having a polished surface to heat treatment within an apparatus for carrying out epitaxial growth for at least 10 minutes at a substrate temperature of at least 1020°C in a mixed gas atmosphere containing at least an* NH_3 *gas, so that said surface of said GaN single-crystal substrate has a root-mean-square roughness of 0.2 nm or less defined in a square measuring 2.0 µm per side, and after said heat treatment,*
epitaxially growing a nitride type compound semiconductor layer on said GaN single-crystal substrate within the same apparatus for carrying out epitaxial growth without oxidizing said surface of said GaN single-crystal substrate, so that said nitride type compound semiconductor layer has a threading dislocation density of 1×10^6 cm^{-2} *or less.*"

VII. The appellant submitted in substance the following arguments:

In document D3, cleaning processes were described, for instance to clean oxide or other non-GaN products of the epitaxial surface. Claim 1 of the main request, however, recited that after heat treatment (of a GaN single-crystal substrate), a nitride type compound semiconductor layer was epitaxially grown on said GaN single-crystal substrate without oxidizing said surface of said GaN single-crystal substrate. This was different from a cleaning process as described in document D3. Moreover, avoiding oxidation provided boundary conditions in terms of eg surface dislocation density and contaminants density so that the claimed method could achieve a threading dislocation density of 1×10^{6} cm^{-2} or less. The combination of features of claim 1 of the main request was neither disclosed by nor rendered obvious from the cited prior art and should therefore be allowable.

Regarding the first auxiliary request, the appellant argued that the added feature made clear, how an epitaxial growth could be realized without oxidizing the surface of the GaN single-crystal substrate. As pointed out for the main request, avoiding oxidizing was nowhere disclosed by or rendered obvious from the cited prior art.

Reasons for the Decision

1. The appeal is admissible.

2. *Main request*

2.1 *Amendments*

Claim 1 as amended is based on claims 12 and 14 as originally filed, on the description as originally filed (cf page 13, line 21 to page 20, line 16) and on figure 4 as originally filed.

Accordingly, the amendments comply with Article 123(2) EPC.

2.2 *Novelty*

Document D3 is concerned with the homo-epitaxial growth of GaN on a free standing (FS) GaN substrate (ie a self-supporting structure, eg, of wafer or plate form (cf page 22, lines 10 to 12)). For comparison, reference is also made to the growth on eg a GaN/ sapphire substrate.

According to D3, "*Figure 11 shows a typical set of epitaxial growth process steps, wherein the vertical axis loosely denotes temperature and the horizontal axis loosely denotes time. Such process flow involves the steps of wafer cleaning, purging of the reactor, heat-up of the substrate, in-situ cleaning of the growth surface, growth of epi on the growth surface, and cool-down. These steps are discussed in detail in the ensuing description*" (cf page 37, lines 4 to 9; figure 11).

In particular, under the header "*Mass Transport for improved smoothing of morphology*", D3 notes that "*The smoothing of FS GaN morphology is necessary for high quality homo-epitaxial growth. The undesirable surface texture of the unfinished HVPE FS GaN substrate is an issue in high quality homo-epitaxial GaN growth. There are typically large moundlike hillock textures, which need to be smoothed out prior to epitaxial growth, or other substrate processing damage arising from producing a finished substrate which needs to be smoothed*" (page 69, lines 6 to 11).

In particular, according to D3 a process step causing mass transport to smooth the surface of the FS GaN substrate is carried out prior to the epitaxial growth of the GaN layer. This step consists in annealing the substrate at higher temperature in an overpressure of eg ammonia (NH_3) and H_2 or N_2 (cf page 69, line 5 to page 70, line 19; figures 36 to 38).

Accordingly, document D3 discloses (using the terminology of claim 1) a method of making a GaN single-crystal substrate, said method comprising the step of:

subjecting a GaN single-crystal having a polished surface to heat treatment at higher temperature in a mixed gas atmosphere containing at least an NH_3 gas,

and after said heat treatment,

epitaxially growing a nitride type compound semiconductor layer on said GaN single-crystal substrate.

The following features of claim 1 are missing from document D3:

- the step above is specified to be done for at least 10 minutes at a substrate temperature of at least 1020°C,

- after the step above, the surface of the substrate has a root-mean-square roughness of 0.2 nm or less defined in a square measuring 2.0 µm per side,

- epitaxial growing is without oxidizing the surface of the GaN single-crystal substrate,

- the epitaxially grown layer has a threading dislocation density of 1×10^6 cm^{-2} or less.

Accordingly, the subject-matter of claim 1 is new over document D3 (Article 54(1) EPC 1973).

The subject-matter of claim 1 is also new over the remaining available, more remote prior art.

2.3 *Inventive step*

2.3.1 Having regard to the above missing features, the objective problem to be solved relative to document D3 is to define suitable process conditions.

Regarding the above first missing feature, determining the temperature and the amount of time of the heat treatment required for obtaining a suitably smoothened surface is considered to be a matter of straightforward experimental practice falling within the competence of a skilled person working in the technical field at issue in the present case, which is that of semiconductor technology.

It is noted in this respect that D3 already indicates that the smoothing treatment should be carried out at higher temperature. Accordingly, it would be obvious to carry out this step after the reactor purge and heat-up steps, and just before epitaxial growth (cf figure 11 and corresponding description). Moreover, from the statement that the mass transport process step "*can be performed ex-situ to enable higher reactor throughput*" it is clear that an in-situ process is common where throughput is not an issue (cf page 70, lines 1 to 2). For an in-situ process, ie carried out in the apparatus used for carrying out the epitaxial growth, it would be obvious to use temperatures corresponding to those used for the subsequent epitaxial growth. The epitaxial growth temperature is generally disclosed to be from about 500 $^{\circ}$C to about 1250 $^{\circ}$C (cf eg page 28, lines 1 to 22; page 55, lines 1 to 16; claim 1). A temperature of 1020 $^{\circ}$C as claimed would, thus, be obvious.

Similarly, determining a suitable degree of smoothness of the surface, as well as a suitable dislocation density is considered to lie within the competence of the skilled person.

In this respect it is noted that the features of claim 1 relating to the obtained roughness and dislocation density are only acceptable under the requirement of clarity of Article 84 EPC 1973, where they are taken to define the roughness and dislocation density merely as a direct result of the preceding method steps and not as a result to be achieved by varying process conditions of these method steps. Clearly, in the latter case guidance is missing as to how the result should be achieved.

Moreover, since, as discussed above, it would be obvious to carry out the heat treatment in D3 in-situ, at the growth temperature and prior to the epitaxial growth, as a result there would be no oxidizing of the surface at this point.

Furthermore, it is noted that it would at any rate be self-evident to a person skilled in the art that there should be no oxide on the surface when starting epitaxial growth, as this would prevent the substrate from acting as a seed crystal. Thus, in any case this measure would be obvious to the skilled person.

2.3.2 The appellant argued that document D3 did not disclose the feature of "*epitaxially growing a nitride type compound semiconductor layer on said GaN single-crystal substrate without oxidizing said surface, of said GaN single-crystal substrate*".

Document D3 disclosed (cf page 37, lines 4 to 9) the steps of wafer cleaning, purging of the reactor, heat-up of the substrate, in-situ cleaning of the growth surface, growth of epitaxial layer on the growth surface and cool-down. On page 37 to 40, cleaning processes were described, for instance to clean oxide or other non-GaN products of the epitaxial surface (page 39, lines 14 and 15). On the other hand, claim 1 of the main request recited that after heat treatment (of a GaN single-crystal substrate), a nitride type compound semiconductor layer was epitaxially grown on said GaN single-crystal substrate without oxidizing said surface of said GaN single-crystal substrate. This was different from a cleaning process as described in document D3.

The difference between "*without oxidizing*" and "*cleaning*" was specified in the last paragraph of page 18 of the specification. Therein it was pointed out that "*the GaN single-crystal substrate shall be kept from being exposed to atmosphere before epitaxial growth after the heat treatment. This is because of the fact that, when exposed to the atmosphere, the surface of the substrate may get oxidized or absorb organic matters and other contaminants, thereby adversely affecting the subsequent epitaxial growth. In this case, it is necessary to carry out surface treatment* *for purifying the surface of the substrate again before the epitaxial growth, which increases the number of steps*".

Avoiding oxidation provided boundary conditions in terms of eg surface dislocation density and contaminants density so that the method described in claim 1 of the main request could achieve a threading dislocation density of 1 x 10^6 cm^{-2} or less.

2.3.3 It is, however, noted that the cleaning processes in D3 referred to by the appellant are performed before the mass transport heat treatment and have no bearing on the processing conditions between the heat treatment and the epitaxial growth (cf pages 37 to 41; figure 11). In the board's judgement, as discussed above, it would be obvious for a person skilled in the art to carry out the heat treatment in D3 in-situ, in the apparatus for epitaxial growth, at the growth temperature and prior to the epitaxial growth. Accordingly, the epitaxial growth would be performed without oxidizing the surface of the substrate.

2.3.4 Accordingly, the subject-matter of claim 1 according to the main request, having regard to the state of the art, is obvious to a person skilled in the art and, therefore, lacks an inventive step in the sense of Article 56 EPC 1973.

The appellant's main request is, therefore, not allowable.

3. First auxiliary request

3.1 Amendments

Claim 1 according to the appellant's first auxiliary request differs from claim 1 of the main request in that it is defined that the heat treatment is carried out in the same apparatus for carrying out the epitaxial growth.

This further amendment is based on the description as originally filed (cf page 21, lines 9 to 22).

Accordingly, the amendments comply with Article 123(2) EPC.

3.2 *Inventive step*

The appellant argued that the added feature made clear how an epitaxial growth could be realized without oxidizing the surface of the GaN single-crystal substrate. As already pointed out in the main request avoiding oxidizing was nowhere disclosed by or rendered obvious from the cited prior art.

In the board's judgement, however, as discussed above, it would obvious to a person skilled in the art to carry out the mass transport heat treatment in D3 in-situ, ie in the same apparatus for carrying out the epitaxial growth.

3.3 Accordingly, also the subject-matter of claim 1 according to the first auxiliary request, having regard to the state of the art, is obvious to a person skilled in the art and, therefore, lacks an inventive step in the sense of Article 56 EPC 1973.

The appellant's first auxiliary request is, therefore, not allowable either.

Order

For these reasons it is decided that:

The appeal is dismissed.

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