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Case Number: T 1958/18 - 3.4.03

Application Number: 06782838.4

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Language of the proceedings: EN

Title of invention:
SEMICONDUCTOR LAYERED STRUCTURE AND ITS METHOD OF FORMATION, AND LIGHT EMITTING DEVICE

Applicant:
NGK Insulators, Ltd.

Relevant legal provisions:
EPC 1973 Art. 56
EPC Art. 123(2)

Keyword:
Inventive step - main request, first and second auxiliary requests - (no)
Amendments - extension beyond the content of the application as filed - third auxiliary request (yes)

Beschwerdekammern

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Case Number: T 1958/18 - 3.4.03

DECISION
of Technical Board of Appeal 3.4.03
of 17 May 2021

Appellant: (Applicant)	NGK Insulators, Ltd. 2-56, Suda-cho Mizuho Nagoya-shi, Aichi 467-8530 (JP)
Representative:	Mewburn Ellis LLP Aurora Building Counterslip Bristol BS1 6BX (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 22 February 2018 refusing European patent application No. 06782838.4 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	M. Stenger
Members:	M. Ley C. Heath

Summary of Facts and Submissions

I. The appeal lies against the decision of the examining division to refuse European patent application No. 06 782 838.4 pursuant to Article 97(2) EPC.

The decision cited *inter alia* the following documents:

D1	EP 1 211 737 A2
D2	EP 1 211 736 A2
D6	XP 000922737
D7	JP H10 79501 A
D8	XP 012061596

II. The examining division decided that claim 6 according to a main request lacked clarity (Article 84 EPC 1973), that the subject-matter of claims 1 and 6 according to the main request and of claim 1 according to first and second auxiliary requests did not involve an inventive step (Article 56 EPC 1973). Claim 1 according to a third auxiliary request was found not to comply with Article 123(2) EPC.

III. The appellant requested that the decision be set aside and that a European patent be granted based on a main request or on first to third auxiliary requests, all filed with the statement of grounds of appeal; the requests corresponding to those underlying the contested decision.

Oral proceedings were requested if the Board "intends not to remit the application for grant or further prosecution on the basis of the main request, or intends to reject this appeal as inadmissible".

IV. In a communication pursuant to Article 15(1) RPBA 2020, the Board informed the appellant about its provisional opinion that the independent claims according to the main request and to the first auxiliary request lacked clarity (Article 84 EPC 1973) and that their subject-matter did not involve an inventive step (Article 56 EPC 1973). Regarding the second auxiliary request, the Board provisionally found that, in addition, claim 1 did not comply with Article 123(2) EPC. With respect to the third auxiliary request, the Board took the provisional view that it did not meet the requirements of Articles 84 EPC 1973 and 123(2) EPC.

V. In a short letter dated 1 April 2021, the appellant withdrew its request for oral proceedings and informed the Board that the applicant would not be represented at the oral proceedings in the event the Board decided "to continue with the oral proceedings". No further requests or submissions were made and no further arguments were provided.

VI. The Board cancelled the oral proceedings.

VII. Claim 1 according to the main request has the following wording:

A method of forming a semiconductor layered structure (10) by epitaxial growth, comprising the steps of:
(a) forming an n-type conductive layer (4) of a second group III nitride doped with a predetermined n-type dopant, said second group III nitride being $Al_xGa_{1-x}N$ $(0 < x \leq 1)$*, on an underlying substrate which is obtained by forming an underlying layer (2) of a first group III nitride on a predetermined base material (1), said first group III nitride being AIN; and*

(b) forming a functional layer (5) with a quantum dot structure on said n-type conductive layer by repetition of the steps of:
(b-1) forming a plurality of quantum dots (51d, 52d, 53d) of a third group III nitride, said third group III nitride layer being $Ga_yIn_{1-y}N$ *(*$0 < y \leq 1$*), by self-organization; and*
(b-2) forming a matrix layer (51m, 52m, 53m) of a fourth group III nitride, said fourth group III nitride being $Al_zGa_{1-z}N$ *(*$0 < z \leq 1$*),*
wherein a single unit layer is formed each time steps (b-1) and (b-2) are repeated;
said step (a) and said step (b) being sequentially performed by MBE,
said n-type conductive layer (4) and said matrix layer (51m, 52m, 53m) forming a matrix region (5m),
each unit layer forming said matrix region being formed so as to maintain alignment of said matrix region with said underlying layer and thereby to have a lattice constant which is smaller than an ideal lattice constant that a substance with the same composition has under non-stress conditions.

Claim 1 according to the first auxiliary request is identical to claim 1 of the main request.

Claim 1 according to the second auxiliary request differs from claim 1 of the main request by the addition, at its end, of the feature

wherein during step (a) and (b), In is supplied to serve as a surfactant on the crystal growth surface.

Claim 1 of the third auxiliary request differs from claim 1 according to the main request in that the feature *said step (a) and said step (b) being sequentially performed by MBE*

is replaced by the feature

said step (a) and said step (b) being sequentially formed by MBE with no intervening step

and by the addition, at the end of the claim, of the feature

wherein during step (a), In is supplied to serve as a surfactant on the crystal growth surface.

VIII. The appellant's relevant arguments can be summarized as follows:

(a) Main request and first auxiliary request

In the statement of grounds of appeal, pages 5 and 6, "Patentability D1 and D2", the appellant discussed inventive step taking D1 as the closest prior art.

The appellant argued that D1 did not disclose a matrix layer made of $Al_zGa_{1-z}N$ with $0 < z \leq 1$ (see statement of grounds of appeal, page 6, fourth and sixth paragraphs), but used GaN. Claim 1 of D1 stated that the composition of each layer was "a semiconducting nitride material including at least one element selected from the group consisting of Al, Ga and In", while paragraph [0032] defined a required relationship between the bandgaps of the cladding layer (4), the island layers (13-1, ..., 13-5, 14-1, ..., 14-5, 15-1, ..., 15-5) and the base layer (18) in order to obtain light emission (reference signs added by the Board, see statement of grounds of appeal, page 6, second and fourth paragraphs).

Moreover, D1 did not disclose the "alignment" of the matrix region with the underlying layer and the skilled person "motivated in some way to try to exhibit compression stress by the alignment of the matrix layer with the cladding layer" would not consider the materials used in D1 (see statement of grounds of appeal, page 6, first to third paragraphs).

Starting from D1 as the closest prior art, the objective technical problem would be achieving "the technical effects related to the alignment of the matrix layer with the underlying growth layer, and the formation of quantum dot structures by self-organization and having suitable device conductivity", see the statement of grounds of appeal, page 6, eighth paragraph.

(b) Second auxiliary request

Regarding the feature "wherein during step (a) and (b), In is supplied to serve as a surfactant on the crystal growth surface" in claim 1 of the second auxiliary request, the appellant indicated page 12, lines 3 to 7 of the application as originally filed as a basis.

The appellant argued that the effect of indium would be to improve the crystal quality of each layer and thus to provide "further advantageous alignment of the matrix region with respect to the underlying layer due to a reduction in crystalline defects promoting such alignment". In D6 or D7, other surfactants (e. g. $Si(C_2H_5)_4$) were used in the context of the MOCVD technique.

(c) Regarding the amendments made to claim 1 of the third auxiliary request, the appellant argued that the wording "formed sequentially" already implied that no intervening steps were performed between steps (a) and (b). Moreover, the appellant referred to example 1, page 24, lines 9 to 16. Regarding the supply of indium as a surfactant, the appellant referred to page 12, lines 3 to 7, example 1, page 24, lines 4 to 16.

Reasons for the Decision

1. The appeal is admissible.

2. Procedural matters

The Board informed the appellant in its communication pursuant to Article 15(1) RPBA 2020 that none of the requests was allowable. In its letter dated 1 April 2021, the appellant did not provide any further arguments or submissions. The Board thus has no reasons to deviate from its provisional opinion.

Hence, the case is ready for decision which is taken in written proceedings without holding oral proceedings in accordance with Article 12(8) RPBA 2020.

3. The invention

The present invention relates to light emitting devices including group III nitrides with quantum dot structures provided in light emitting layers.

An n-type conductive $Al_xGa_{1-x}N$ $(0 < x \leq 1)$ layer 4 is formed onto an AlN underlying layer 2, which forms with a predetermined base material 1 an underlying substrate.

$Ga_yIn_{1-y}N$ (with $0 < y \leq 1$) quantum dots 5d are formed by self-organization and are capped by a $Al_zGa_{1-z}N$ (with $0 < z \leq 1$) matrix layer 5m. A layer of quantum dots 5d and its associated matrix layer 5m form a single "unit layer". A functional layer 5 is formed by repeating the steps of forming the quantum dots and the matrix layer. The matrix layers 5m, 51m, 52m, 53m and the n-type conductive layer 4 form together a "matrix region".

The last four lines of claim 1 of the main request read "each unit layer forming said matrix region being formed so as to maintain alignment of said matrix region with said underlying layer and thereby to have a lattice constant which is smaller than an ideal lattice constant that a substance with the same composition has under non-stress conditions". The skilled person might understand from the term "to maintain alignment of said matrix region with said underlying layer" that each unit layer (i. e. the quantum dots 5d made of $Ga_yIn_{1-y}N$ and the matrix layers 5m made of $Al_zGa_{1-z}N$) and the n-type $Al_xGa_{1-x}N$ conductive layer 4 all have the lattice constant of the underlying AlN layer 2.

However, the description clarifies how the last lines of claim 1 should be understood. Page 15, line 11 to page 16, line 6 disclose that the stress conditions in the n-type conductive layer 4 are relaxed during growth, but not completely until its thickness exceed a predetermined value. In other words, the uppermost surface portion of the as-grown n-type conductive layer

4 has a smaller a-axis length than under non-stress conditions. Nevertheless, it does not have the lattice constant of the underlying AlN layer 2, see also figure 2, page 16, lines 7 to page 17, line 8. It follows that the lattice constant of matrix layers 5m, 51m, 52m, 53m is not the same as the one of the underlying AlN layer 2, either.

That is, the term "to maintain alignment of said matrix region with said underlying layer" in claim 1 does not imply that each unit layer and the n-type $Al_xGa_{1-x}N$ conductive layer all have the lattice constant of the underlying AlN layer, but only that these layers are under compressive stress.

The appellant's submissions confirm the Board's interpretation of the last four lines of claim 1 of the main request. According to the appellant's explanations in the statement of grounds of appeal, page 3, second to sixth paragraph, the matrix region (i. e. the n-type conductive layer 4 and the matrix layers 5m) does not have the same lattice constant as the underlying layer throughout its thickness, so that claim 1 covers "a partially relaxed matrix region". The growth of the n-type layer 4 "progressively relaxes the compressive stress caused by the lattice mismatch at the interface of the layer 3 and 4".

Hence, the Board takes the view that the feature defined in the four last lines of claim 1 of the main request merely requires that the n-type conductive layer (4) and the matrix layers (51m, 52m, 53m) of each unit layer forming said matrix region have an a-axis lattice constant which is smaller than an ideal a-axis lattice constant that a substance with the same composition has under non-stress conditions. In other words, the n-type conductive layer 4, the matrix layers 51m, 52m, 53m and, hence, the "matrix region" are under compressive stress as a result of their deposition on the underlying AlN layer 2.

4. Main request

The Board is of the view that the subject-matter of claim 1 does not involve an inventive step (Article 56 EPC) for the following reasons.

4.1 The examining division considered either D6 or D7 as the closest prior art.

D6 discloses growing an AlN "buffer layer" on a silicon carbide (SiC) substrate, growing an $Al_xGa_{1-x}N$ cladding layer and growing a layer of self-organized GaN quantum dots in $Al_xGa_{1-x}N$ by metalorganic chemical vapour deposition (MOCVD). As a possible application, light emitting diodes are mentioned.

D7 discloses growing an AlN "buffer layer" 32 on a substrate 31, growing an AlGaN cladding layer 33 and growing a layer of self-organized GaN quantum dots 34 in an AlGaN cap layer 35 by molecular beam epitaxy (MBE).

In view of the fact that claim 1 of the main request is directed to a structure having a functional layer with at least two unit layers with quantum dots and that D1 concerns this type of structures (see e. g. figure 3), the Board considers document D1 as a more promising springboard in order to arrive at the subject-matter of claim 1.

4.2 D1 discloses (in the wording of claim 1 according to the main request):

A method of forming a semiconductor layered structure (figures 1 and 3) by epitaxial growth, comprising the steps of:
(a) forming an n-type conductive layer (3, 4, [0035]: n-AlGaN, [0069]: "Si-doped n-AlGaN", [0070]: Si doped n-$Al_{0.2}Ga_{0.8}N$) of a second group III nitride doped with a predetermined n-type dopant ([0035], [0070]), said second group III nitride being $Al_xGa_{1-x}N$ ($0 < x \leq 1$), on an underlying substrate which is obtained by forming an underlying layer (2, [0035]: AlN, [0066]: AlN) of a first group III nitride on a predetermined base material (1, [0065]: "sapphire single crystal substrate"), said first group III nitride being AIN ([0035], [0066]); and
(b) forming a functional layer (5) with a quantum dot structure on said n-typ conductive layer (3, 4) by repetition of the steps of:
(b-1) forming a plurality of quantum dots (13-1 to 13-5, 14-1 to 14-5, 15-1 to 15-5) of a third group III nitride ([0070]: $In_{0.1}Ga_{0.9}N$), said third group III nitride layer being $Ga_yIn_{1-y}N$ ($0 < y \leq 1$), by self-organization (implicit in view of the fact that MBE is used, see [0068] to [0070]); and
(b-2) forming a matrix layer (base layer 18, [46]) of a fourth group III nitride ([0070]: "GaN as a base layer"), said fourth group III nitride being <u>GaN</u> (instead of $Al_zGa_{1-z}N$ ($0 < z \leq 1$)),
wherein a single unit layer is formed each time steps (b-1) and (b-2) are repeated (figure 3, [0046] to [0048]);
said step (a) and said step (b) being sequentially performed by MBE ([0068] to [0070], [0046] to [0048], figure 3),

said n-type conductive layer (3, 4) and said matrix layer (18) forming a matrix region (3, 4, 18; see [0046] and figure 3).

4.3 Similar to the application (see page 11, lines 11 to 20), the n-type conductive layer made of AlGaN 3, 4 in D1 is formed by MBE on an AlN underlying layer 2 and has a thickness of e. g. 2 micrometer (D1, see [0069] and [0070], layers 3 and 4 in combination). As, according to page 11, lines 19 and 20 of the application, an AlGaN n-type conductive layer 4 grown with a thickness of several micrometers on AlN is not relaxed, but under the claimed compressive stress (see page 15, lines 8 to 14 of the application), this must also be the case for the 2 µm thick AlGaN layer in D1. Hence, the uppermost surface of the n-type conductive layer (3, 4) in D1 necessarily presents a compressive stress like the one discussed in the context of figures 2 and 3 of the present application.

Each respective matrix layer in D1 has a thickness of only 20 nm (see D1, [0070]: 200Å = 20 nm) so that the total thickness of the three matrix layers of figure 3 is 3 x 20 = 60 nm. The example of figure 1 of the application shows at least five matrix layers 51m, 52m, 53m with a total thickness of 60 nm or more, as each one has a thickness of 12 nm (see page 18, lines 14 to 19, "a dozen nm"). As the compressive stress present at the uppermost surface of layer 4 in figure 1 of the application is maintained until the uppermost of the matrix layers, this must also be the case for the uppermost matrix layer 18 in D1.

Hence, the n-type conductive layer 4 and the matrix layers 18 of each unit layer forming said matrix region in D1 have an a-axis lattice constant which is smaller than an ideal a-axis lattice constant that a substance with the same composition has under non-stress conditions. In other words, using the wording of claim 1, D1 also discloses (see figure 3)

"each unit layer forming said matrix region being formed so as to maintain alignment of said matrix region with said underlying layer and thereby to have a lattice constant which is smaller than an ideal lattice constant that a substance with the same composition has under non-stress conditions".

Thus, the Board does not agree with the appellant (see VIII.(a) above, third paragraph) and takes the view that the claimed "alignment" and "smaller lattice constant" must also be present for a matrix layer made of GaN. As figure 3 of the present application shows, the difference in lattice constant between GaN ($Al_zGa_{1-z}N$ with $z = 0$, 3.19 Å, as used in D1) and the AlN underlying layer 2 (3.11 Å) is even higher than the corresponding difference of the embodiments according to claim 1 with $Al_zGa_{1-z}N$ ($0 < z \leq 1$). It is not plausible that the claimed "alignment" and "smaller lattice constant" can be achieved with $Al_zGa_{1-z}N$ with an infinitely small content of Al, e. g. $Al_{0.001}Ga_{99.999}N$, but not with GaN (i. e. $Al_zGa_{1-z}N$ with $z = 0$).

4.4 Therefore, the only difference between the subject matter of claim 1 and D1 is that the base layer 18 in D1 is made of GaN, whereas claim 1 requires in step b-2 that the matrix layer be made of $Al_zGa_{1-z}N$ (with $0 < z \leq 1$, i. e. z can be infinitely small), see also point VIII.(a) above, second paragraph.

4.5 In view of this distinguishing feature, the Board does not agree with the appellant's formulation of the objective technical problem, see VIII.(a), fourth paragraph above.

The objective technical problem cannot be formulated as how to achieve the "alignment of the matrix region" or any technical effect related thereto, because the claimed "alignment" is already obtained in the method according to D1 as set out above.

The objective technical problem cannot be formulated as how to achieve any effect related to the formation of the quantum dot structures by self-organization, either, because in D1 the quantum dots are formed by self-organization due to the difference in lattice constant between the matrix region and the quantum dots and the compressive stress.

As D1 discloses a functional light-emitting element, it necessarily has a "suitable device conductivity". The Board is also not convinced that the distinguishing feature would necessarily have any beneficial effect on the "device conductivity".

The appellant argued that the effect of the claimed composition of the matrix region was explained on page 12, line 20 to page 13, line 4 of the application, see the statement of grounds of appeal, seventh paragraph, last sentence. The Board is of the opinion that this passage of the application merely describes the matrix layer as a doped $Al_zGa_{1-z}N$ layer without disclosing any particular effect obtained by the presence of (an infinitely small amount of) Al as compared to the GaN layer used in D1.

Thus, the objective technical problem has to be formulated in a less ambitious way as how to provide an alternative matrix material for the base layer 18 in D1.

4.6 In view of D6 or D7 (see D6, abstract, "$Al_xGa_{1-x}N$ confined layer structures" or D7, abstract "AlGaN cap layer", [0028]: $Al_xGa_{1-x}N$ cap layer 35), it is known for the skilled person that AlGaN is used as matrix material for a layer comprising quantum dots. Hence, it would be obvious for the skilled person wishing to solve the objective technical problem to select AlGaN in place of GaN as the base layer 18 in the device of D1 ([0046], figure 3). In particular, D7 makes it clear (see paragraph [0013]) that molecular beam epitaxy (MBE) can be used for this kind of material.

Therefore, it would be obvious for the skilled person to use matrix layers 18 made of $Al_zGa_{1-z}N$ ($0 < z \leq 1$), while still selecting the respective bandgaps such that the requirement of paragraph [0032] of D1 is met and light emission is possible.

Thus, the subject-matter of claim 1 is rendered obvious by a combination of D1 with D7 or D6 and does not involve an inventive step (Article 56 EPC 1973).

5. First auxiliary request

As claim 1 of the first auxiliary request is identical to claim 1 of the main request, the requirements Article 56 EPC 1973 are not met for the first auxiliary request, either.

6. Second auxiliary request

Regarding an inventive merit related to the use of In as a surfactant, the Board shares the examining division's position, see the contested decision, page 10 to page 11.

Page 12, lines 3 to 7 of the published application cited by the appellant describe that indium may be supplied for serving as a surfactant on the crystal growth surface during the formation of the n-type conductive layer 4 and "other subsequent layers". Page 24, lines 4 to 8 describes indium as a surfactant when growing n-$Al_{0.5}Ga_{0.5}N$ layer 4 only.

According to the application, page 12, lines 3 to 7, the related technical effect is only to improve the crystal quality of the layer to be grown. The Board is not convinced that an improved crystal quality necessarily produces an "advantageous alignment" of the matrix region with respect to the underlying layer, as argued by the appellant, see VIII.(b). The objective technical problem therefore is to modify the process known from D1 such that an improved crystal quality of the group III nitride layers is obtained.

As shown by D8, it is known to use indium as a surfactant when growing GaN by MBE (see page 4322, left column, lines 1 to 15). The Board shares the examining division's view that it would be obvious to use indium as a surfactant in the growth of n-type conductive layer 4 and other subsequent layers, e. g. the matrix layers 18 and the quantum dots. The argument that in D6 or D7 other surfactants (e. g. $Si(C_2H_5)_4$) might be used in order grow the quantum dots is not relevant for the skilled person starting from D1 as the closest prior art and wishing to solve the objective technical problem.

Thus, the subject-matter of claim 1 according to the second auxiliary request does not involve an inventive step (Article 56 EPC 1973).

7. Third auxiliary request

The Board shares the examining division's view that the added feature that no intervening step is performed between step (a) and step (b) is neither disclosed in the application as originally filed nor can it be directly and unambiguously derived therefrom.

On the contrary, as both layers 4 and 5 have a different composition, it is inevitable that intervening steps are present. For example, the provision of Si, B, Ge n-type dopants used on layer 4 has to be stopped after growing layer 4 and the provision of Eu, Tb, Tm used in quantum dots 51d, 52d, 53d has to be initiated before starting the growth of functional layer 5.

Further, in the example of figure 4, page 19, line 16 to page 23, line 5, and example 2, page 25, line 16 to page 27, line 13, a step of forming the first cladding layer 18 is performed between the steps (a) and (b) so that an "intervening step" is even explicitly disclosed for this example.

Thus, the addition of "with no intervening step" introduces subject-matter that was not present in the application as originally filed, contrary to the requirements of Article 123(2) EPC.

8. As no allowable request is on file, the appeal must fail.

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 ✦

B. Atienza Vivancos M. Stenger

Decision electronically authenticated