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Datasheet for the decision of 7 July 2021

Case Number: T 2587/16 - 3.4.03

Application Number: 06735699.8

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Language of the proceedings: EN

Title of invention:
ALUMINUM FREE GROUP III-NITRIDE BASED HIGH ELECTRON MOBILITY TRANSISTORS AND METHODS OF FABRICATING SAME

Applicant:
Cree, Inc.

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

Keyword:
Amendments - added subject-matter - main request (yes)
Inventive step - auxiliary requests 1 and 2 (no)

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Beschwerdekammern

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Case Number: T 2587/16 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 7 July 2021

Appellant: (Applicant)	Cree, Inc. 4600 Silicon Drive Durham, NC 27703 (US)
Representative:	Boult Wade Tennant LLP Salisbury Square House 8 Salisbury Square London EC4Y 8AP (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 19 July 2016 refusing European patent application No. 06735699.8 pursuant to Article 97(2) EPC.**

Composition of the Board:

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

Summary of Facts and Submissions

I. The appeal is against the decision of the examining division to refuse European patent application No. 06 735 699 pursuant to Article 97(2) EPC.

The examining division decided that claims 1 and 23 of the main request did not comply with Article 123(2) EPC and that their subject-matter lacked an inventive step (Article 56 EPC 1973), and that the subject-matter of claims 1 and 20 according to the first auxiliary request and of claims 1 and 17 according to the second auxiliary request lacked an inventive step (Article 56 EPC 1973).

The decision cited *inter alia* the following documents:

D1 WO 01/92428 A
D2 US 6 177 685 B1
D5 US 2002/185655 A1
D6 US 2004/061129 A1
D7 US 2002/096692 A1

II. The appellant requests that the decision be set aside and a European patent be granted based on either a main request, a first or a second auxiliary requests, all filed with the statements of grounds of appeal and all corresponding to those underlying the contested decision. In the statement of grounds of appeal, the appellant initially requested oral proceedings, unless the Board granted a patent based on the main request.

III. In a communication pursuant to Article 15(2) RPBA 2020, the Board informed the appellant about its provisional view that claims 1, 2, 4, 9, 17 to 23 according to the

main request, claims 2, 3, 9, 17 to 19 according to the first auxiliary request and claims 2, 3, 14 to 16 according to the second auxiliary request did not meet the requirements of Article 123(2) EPC. The subject-matter of claim 1 according to the first and second auxiliary requests did no involve an inventive step (Article 56 EPC 1973). Claims 1 and 17 of the second auxiliary request were found not supported by the description (Article 84 EPC).

IV. In a short letter dated 22 April 2021, the appellant withdrew its request for oral proceedings and informed the Board that it would not attend the oral proceedings. Not further requests were made and no further arguments were provided.

V. The Board cancelled the oral proceedings.

VI. Claim 1 of the main request has the following wording:

A high electron mobility transistor (HEMT), comprising:
i) an aluminium free barrier layer (212) including gallium nitride (GaN);
ii) an aluminium free channel layer (214) including GaN on the barrier layer;
iii) an aluminium free cap layer (216) including undoped GaN on the channel layer; and
iv) a doped GaN layer (250) between the cap layer and the channel layer, the doped GaN layer comprising a Tin (Sn), Oxygen (O) and/or Germanium (Ge) doped GaN layer.

Claim 1 of the first auxiliary request has the following wording:

A high electron mobility transistor (HEMT), comprising:
i) a substrate;

ii) an aluminium free gallium nitride (GaN) barrier layer (212),
iii) an aluminium free indium gallium nitride (InGaN) channel layer (214) on the barrier layer, the GaN barrier layer comprising a semi-insulating or insulating region proximate the substrate and an undoped region proximate the channel layer;
iv) an aluminium free GaN cap layer (216) on the channel layer; and
v) a doped GaN layer (250) disposed between the cap layer and the channel layer, the doped GaN layer comprising a Tin (Sn), Oxygen (O) and/or Germanium (Ge) doped GaN layer.

Claim 1 of the second auxiliary request has the following wording:

A high electron mobility transistor (HEMT), comprising:
i) a substrate;
ii) an aluminium free gallium nitride (GaN) barrier layer (212),
iii) an aluminium free indium gallium nitride (InGaN) channel layer (214) on the barrier layer, the GaN barrier layer comprising a semi-insulating or insulating region proximate the substrate and an undoped region proximate the channel layer;
iv) an aluminium free GaN cap layer (216) on the channel layer;
v) a first doped GaN layer (250) between the cap layer and the channel layer;
vi) a first undoped GaN layer (260) between the doped GaN layer (250) and the channel layer;
vii) a second doped GaN layer (230) between the GaN barrier layer and the channel layer; and

viii) a second undoped GaN layer (240) between the second doped GaN layer (230) and the channel layer (214).

VII. The appellant's relevant arguments will be discussed below, see sections 3.2, 5.1, 5.2.2, 5.3.1, 5.4.2, 7.1.2 and 7.2.1.

Reasons for the Decision

1. The appeal is admissible.

2. Procedural matters

In preparation for the oral proceedings the Board issued its preliminary opinion on the case raising objections against all requests under Articles 123(2) EPC, 84 EPC 1973 and 52(1) EPC in combination with Article 56 EPC 1973.

As the appellant chose not to comment on the preliminary opinion issued by the Board in preparation of the oral proceedings and as it withdrew its request for oral proceedings, the Board does not see any reasons to deviate from its preliminary opinion and concludes that the case is ready for decision.

Main request

3. Added subject-matter - Article 123(2) EPC

3.1 The examining division held that claims 1 and 23 do not meet the requirements of Article 123(2) EPC for three reasons. It essentially argued that the application as originally filed disclosed a device having the claimed

doped GaN layer (feature (v)) only in combination with a GaN barrier layer, a InGaN channel layer and a GaN cap layer, see e.g. original claims 8 and 17 or figure 3C. The wording of claim 1, however, encompassed embodiments with materials and combinations of materials not disclosed in the application as originally filed, see the contested decision, points 1.1 to 1.3.

3.2 In the statement of grounds of appeal, the appellant argued that figures 1 and 2 showed "base embodiments of the present inventive concept" and that figures 3A to 3D illustrated "various elements of embodiments of figures 1 and 2". The appellant cited page 12, lines 13 to 16 and concluded that the skilled person would understand that the features of figures 3A to 3D could "be readily combined with the more generic features shown in figures 1 and 2". Moreover, page 13, line 32 to page 14, line 3 made it clear that the features of figures 3A through 3D might "be combined with each other".

The appellant pointed out that page 6, line 27 to page 7, line defined the term "Group III-nitride" used in claim 1 as originally filed as "semiconducting compounds formed between nitrogen and the elements in Group III of the periodic table, gallium (Ga), and/or indium (In) [...] the Group III elements can combine with nitrogen to form binary (e.g., GaN), ternary (e. g., InGaN), and quaternary compounds." For the appellant, the skilled person would understand that the aluminium free Group III-nitride of original claims 1 and 31 can therefore be an aluminium free layer including GaN.

3.3 The Board agrees with the examining division's findings in section 1.1 of the contested decision. Whenever a doped GaN layer disposed between a cap layer and a channel layer is mentioned, said doped GaN layer is disposed between a aluminium free gallium nitride (or GaN) cap layer and an aluminium free indium gallium nitride (or InGaN) channel layer, see claims 1, 8, 17 and 18, figures 3C and 3D, page 13, lines 13 to 29, figure 3A and 3B in combination with page 13, line 30 to page 14, line 2 or page 3, lines 20 to 23. In this case, the barrier layer is always a gallium nitride (GaN) barrier layer. There is no indication for the skilled person that the doped GaN layer according to claim 1 could be used together with a channel layer merely comprising some sub-parts made of GaN. The subject-matter of claim 1 cannot be directly and unambiguously derived from page 12, lines 13 to 16, because this sentence clearly relates to an embodiment having a GaN cap layer, an InGaN channel layer and a GaN barrier layer, see figures 2 and 3C.

The Board agrees with the definition given on page 6, line 27 to page 7, line 2, but opines that it supports the examining division's view. Using the definition, a skilled person would understand that, for example, a Group III-nitride barrier layer is a barrier layer made of a Group III-nitride, e.g. a barrier layer "made of GaN" or a "GaN barrier layer". The wording of claim 1 according to the main request, however, encompasses any aluminium free barrier layer merely including GaN, e.g. a layer comprising GaN clusters or a stack comprising a GaN sub-layer like InGaAsSb/GaN or channel 14 shown in figure 4 of D2. Therefore, the Board agrees with the examining division's findings in sections 1.2 and 1.3 of the contested decision.

Claim 1 thus introduces subject-matter that extends beyond the content of the application as filed, contrary to the requirements of Article 123(2) EPC.

First auxiliary request

4. The Board concurs with the examining division that claim 1 of the first auxiliary request is based on original claims 1, 8, 17 and 18 and page 11, lines 1 to 3. The Board takes it that - although not explicitly defined in claim 1 - the stack formed by layers i) to v) is formed on the substrate, i. e. that it is the aluminium free gallium nitride barrier layer which is formed on the substrate.

5. Inventive step - Article 56 EPC 1973

5.1 Selection of the closest prior art

In the contested decision, the examining division selected document D2 as the closest prior art. The appellant stated on page 5, last paragraph that it believed that D1 or D2 could be equally valid choices for the closest prior art and presented its argumentation starting from D2. The Board has no reasons to select a different starting point for the assessment of an inventive step.

5.2 Distinguishing features

5.2.1 The examining division held in section 6.1 of the contested decision that D2 disclosed (in the wording of claim 1 according to the first auxiliary request) a high electron mobility transistor (figure 1), comprising:
i) a substrate (1);

ii) an aluminium free gallium nitride barrier layer (3),
iii) an aluminium free indium gallium nitride (col. 4, lines 15 to 21, figure 1; even InN appears to fall within the definition of InGaN given on page 11, line 12 or on page 7, line 2 of the application) channel layer (4) on the barrier layer (3);
iv) an aluminium free GaN cap layer (upper part of 6) on the channel layer (4); and
v) a doped GaN layer (lower part of 6) disposed between the cap layer (upper part of 6) and the channel layer (4).

According to the examining division the subject-matter of claim 1 differs from the device shown in figure 1 of D2 in that:

(a) the GaN barrier layer comprises a semi-insulating or insulating region proximate the substrate and an undoped region proximate the channel layer;

(b) the doped GaN layer comprises a Tin (Sn), Oxygen (O) and/or Germanium (Ge) doped GaN layer.

5.2.2 The appellant identified the same differences and argued in addition that D2 did not disclose that the doped GaN layer is disposed between the cap layer and the channel layer, either.

5.2.3 The Board agrees with the examining division that, since claim 1 does not exclude that the "cap layer" is of doped GaN, i.e. of the same material as the claimed "doped GaN layer", layer 6 of D2 may be subdivided into two (sub-)layers. According to the description of the present application, the GaN cap layer may be doped (see e.g. page 10 lines 1 to 4 or lines 11 to 14, page

11 lines 29 to 31), in which case also in the present application the "cap layer" and the "doped GaN layer" are made of the same material.

As the Board shares the examining division's view that GaN layer 6 of D2 can be divided into a (doped) GaN cap layer and a doped GaN layer in the sense of claim 1, the only differences between claim 1 and figure 1 of D2 are features (a) and (b). In D2, neither the internal structure of the GaN barrier layer 3 nor the dopant species in the doped GaN layer 6 are disclosed, although silicon dopants in GaN are mentioned in col. 6, lines 38 to 45 for example 4.

5.3 Objective technical problems

5.3.1 Regarding features (a) and (b), the appellant argued that they solved the objective technical problem of providing an "improved HEMT", see the statement of grounds of appeal, page 6, first paragraph for feature (a) and page 4, penultimate paragraph to page 5, second paragraph for feature (b) (in the context of the discussion the main request with D1 or D2 as the closest prior art).

Regarding feature (a), the appellant stated that D2 used an AlN barrier layer 2 and argued that using a semi-insulating GaN barrier layer reduced migration of Al and was advantageous for the 2DEG formation, see statement of the grounds of appeal, page 6, third paragraph.

Regarding feature (b), the appellant stated that tin, oxygen and germanium were less spatially mobile than silicon and that "the inventors of the present invention have discovered that a layer doped with tin,

oxygen and/or germanium would need less strain to keep the elements where they are supposed to be."

5.3.2 The Board notes that the application as filed is silent about any synergistic effect between (a) and (b) in the sense that their functions are interrelated and lead to an additional effect that goes beyond the sum of the effects of each feature taken in isolation.

While it might be possible that both (a) and (b) provide an "improved HEMT", their functions are clearly not interrelated and they do not contribute in improving a HEMT by achieving together a single technical effect. The Board therefore finds it appropriate to formulate - as did the examining division - a respective partial technical problem related to the technical effects provided by each feature (a) and (b).

The appellant's argumentation regarding feature (a) has not convinced the Board, because it is not plausible the AlN layer used in D2 had any detrimental effect on the 2DEG formation at the interface between InGaN channel layer 4 and the upper portion of GaN barrier layer 3 in view of the large thickness (2 µm, D2, col. 3, line 33) of the GaN barrier layer 3, see also the present application page 11, lines 3 to 9, which states that a thickness of larger than 1000 Angstroms (0.1 µm) is already sufficient to prevent Al migration. The Board notes that the application as originally filed does not particularly describe any surprising advantage of the claimed barrier layer compared to the undoped one known from D2, see e.g. page 10, line 34 to page 11, line 3.

For the Board, the objective technical problem related to (a) is therefore to electrically insulate the HEMT from other elements. Although this effect is not explicitly mentioned in the application as originally filed, the Board accepts than a semi-insulating or insulating GaN barrier layer provides a priori a better electrical insulation than the undoped (i.e. n-type) GaN layer 3 used in D2, figure 1. In this respect, the Board agrees with the examining division.

Regarding feature (b), the Board is of the opinion that the argument regarding the reduced spatial mobility had been brought forward by the appellant for the first time in its letter dated 8 March 2012 and merely repeated in the reply to the summons to attend oral proceedings before the examining division and the statement of grounds of appeal. The appellant did not attend the oral proceedings before the examining division to provide further explanations or even comparative tests.

The Board notes that the application as originally filed is silent about the alleged advantage of Sn, O and Ge dopants in GaN compared to Si. It does not mention any advantages or surprising effects related to the dopants according to feature (b), see e.g. page 12 line 22 or page 13 line 16. Rather, Si, Sn, O and Ge are mentioned as straightforward alternatives. The Board notes that in each of the more specific examples using a doped GaN layer shown in figures 4C to 4N silicon is used as dopant. No indication is given that tin, oxygen, germanium dopants would provide improved results. The Board opines that the alleged advantage is based only on speculation so that the formulation of the objective technical problem related to feature (b) is less ambitious. As D2 does not explicitly disclose

that silicon dopants are used for the doped GaN layer 6 in D2, the Board opines that the objective technical problem related to (b) is the selection of a suitable dopant species for doped GaN layer (lower part of 6).

5.4 Obviousness of distinguishing feature (a)

5.4.1 The examining division held that feature (a) was obvious in view of document D7.

5.4.2 The appellant stated that the use of an AlN layer 2 in D2 taught the skilled person away from including a semi-insulating or insulating GaN barrier layer.

5.4.3 The Board takes the view that claim 1 does not exclude an additional AlN layer between the substrate and the GaN barrier layer of D2. The Board agrees that the skilled person wishing to solve the objective technical problem would consider document D7, which states in paragraph [0011] that it "is an object [...] to provide a nitride layer suitable for group III-V nitride compound semiconductor devices, the nitride layer being superior in insulating performance with high resistivity, permitting good electrical isolation of elements, without the active layer decreasing in conductivity." D7 provides this improved insulating performance by introducing impurities in the buffer region (or barrier layer) well below the 2DEG, see figure 1, region 3c, [0054], the 2DEG being at the interface 14 or see figure 12, region 3a. When applying this teaching to the device of D2, the skilled person would render insulating the lower part of GaN barrier layer 3 close to the substrate 1 by introducing suitable dopants and keep the upper part of barrier layer 3 undoped. The Board agrees with the examining

division that this is a standard design option in the field of GaN HEMTs.

5.5 Obviousness of distinguishing feature (b)

Regarding feature (b), the Board agrees with the examining division that each of the claimed dopants (Sn, O, Ge) is known as n-type dopant for Group III-N semiconductors and straightforward alternative for Si in the technical field of Group III-nitride FETs, see e. g. D5 (paragraph 33) for Sn or D6 (paragraph 44) for O and Ge. The skilled person wishing to solve the objective technical problem would use Sn, O, Ge as suitable dopants for the GaN doped layer 6 in D2.

5.6 For the above reasons, the Board concurs with the examining division that the subject-matter of claim 1 of the first auxiliary request does not involve an inventive step in the sense of Article 56 EPC 1973.

Second auxiliary request

6. For the second auxiliary request, feature (b) has been removed and layers vi) to viii) have been added to claim 1.

The Board concurs with the examining division that claim 1 of the second auxiliary request is based on original claims 1, 8, 17, 21, 23 and 27 and page 11, lines 1 to 3. The Board understands that the stack formed by layers i) to viii) is formed on the substrate, i. e. that that the aluminium free gallium nitride barrier layer is formed on the substrate.

7. Inventive step - Article 56 EPC 1973

7.1 Closest prior art and distinguishing features

7.1.1 The examining division held in section 10.1 of the contested decision that D2 disclosed (in the wording of claim 1 according to the second auxiliary request) a high electron mobility transistor (figure 1), comprising:
i) a substrate (1);
ii) an aluminium free gallium nitride barrier layer (3),
iii) an aluminium free indium gallium nitride channel layer (4) on the barrier layer (3);
iv) an aluminium free GaN cap layer (upper part of 6) on the channel layer (3); and
v) a doped GaN layer (lower part of 6) disposed between the cap layer (upper part of 6) and the channel layer (4);
vi) a first undoped GaN layer (5) between the doped GaN layer (lower part of 6) and the channel layer (4).

According to the examining division the subject-matter of claim 1 differed from the device shown in figure 1 of D2 in that:

(a) the GaN barrier layer comprises a semi-insulating or insulating region proximate the substrate and an undoped region proximate the channel layer;

(c) a second doped GaN layer is provided between the GaN barrier layer and the channel layer, a second undoped GaN layer being provided between said second doped GaN layer and said channel layer.

7.1.2 The appellant argued that - in addition - D2 did not disclose that a first doped GaN layer is disposed between the cap layer and the channel layer and that a first undoped GaN layer is between the first doped layer and the channel layer.

7.1.3 The Board agrees with the examining division that the distinguishing features are features (a) and (c) as defined above. For the reasons given for the first auxiliary request, D2 discloses the first doped GaN layer (lower part of (6)). A first undoped GaN layer (5) is shown in figure 1 of D2.

7.2 Objective technical problems

7.2.1 Regarding features (a) and (c), the appellant argued that both solved the objective technical problem of providing an "improved HEMT", see the statement of grounds of appeal, page 7, third to fifth paragraphs. Regarding feature (c), the appellant cited page 13, lines 13 to 29 and argued that the configuration of layers between the channel layer and the barrier layer "improves carrier mobility in the channel and reduces impurity scattering in the channel".

7.2.2 Similar to auxiliary request 1, the Board could not identify any indication of a synergistic effect between features (a) and (c) so that it is appropriate to formulate partial technical problems for each of them.

The objective technical problem related to (a) is to electrically insulate the HEMT from other elements, see section 5.3.2 above.

Regarding feature (c), the Board notes that the passage indicated by the appellant, i.e. page 13, lines 13 to

29, refers to figure 3C and 3D, which do not show embodiments of claim 1 according to the second auxiliary request. Furthermore, an improved mobility in the InGaN channel is not disclosed. Page 13, lines 20 to 22 mention mobility and minimized impurity scattering as a result from layers 250 and 260, which are already present in document D2 and which do not correspond to feature (c). The appellant's argument therefore does not appear pertinent. The Board agrees with the examining division that the objective technical problem related to (c) is to compensate the parasitic hole channel at the heterojunction between the channel and the lower barrier layer.

7.3 Obviousness of distinguishing feature (a): see section 5.4 above

7.4 Obviousness of distinguishing feature (c)

The examining division held that feature (c) is rendered obvious by document D1.

The Board shares the examining division's view given in section 10.5 of the contested decision. The skilled person wishing to solve the objective technical problem would consult document D1, because page 4, line 26 to 30 and page 5, line 33 to 34 mention the objective technical problem for the device of figure 1(a) of D1, which is similar to the device known from figure 1 of D2. D1 teaches to dope the upper portion of GaN barrier layer (1) with n-type dopants (see D1, figure 1C, 4). D1 also teaches to insert a thin undoped GaN spacer (21, figure 8) to separate the channel from the dopant ions (page 7, lines 11 to 15). When applying the teaching of D1 in the HEMT of D2, the skilled person

would provide the second doped and the second undoped GaN layer according to feature (c).

7.5 For the above reasons, the Board concurs with the examining division that the subject-matter of claim 1 of the second auxiliary request does not involve an inventive step in the sense of Article 56 EPC 1973.

8. Although the Board focuses in this decision on claim 1 of the main request and the auxiliary requests, it also maintains its objections raised in its communication against the remaining claims.

9. 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:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated