**Internal distribution code:**

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

## Datasheet for the decision of 17 December 2019

**Case Number:** T 1940/15 - 3.4.03

**Application Number:** 06734062.0

**Publication Number:** 1859484

**IPC:** H01L29/778, H01L29/20, H01L29/207, H01L29/423

**Language of the proceedings:** EN

**Title of invention:**
GROUP III NITRIDE FIELD EFFECT TRANSISTORS (FETS) CAPABLE OF WITHSTANDING HIGH TEMPERATURE REVERSE BIAS TEST CONDITIONS

**Applicant:**
Cree, Inc.

**Headword:**

**Relevant legal provisions:**
EPC 1973 Art. 56

**Keyword:**
Inventive step - (no)

**Decisions cited:**



This datasheet is not part of the Decision.
It can be changed at any time and without notice.

**Catchword:**



This datasheet is not part of the Decision.
It can be changed at any time and without notice.

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

**Case Number: T 1940/15 - 3.4.03**

# D E C I S I O N
## of Technical Board of Appeal 3.4.03
## of 17 December 2019

**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 30 April 2015 refusing European patent application No. 06734062.0 pursuant to Article 97(2) EPC.**

**Composition of the Board:**

**Chairman** T. Häusser
**Members:** M. Stenger
W. Van der Eijk

## Summary of Facts and Submissions

I. The appeal of the applicant concerns the decision of the Examining Division to refuse European application no. 06734062.

II. At the end of the oral proceedings before the Board, the appellant requested that the contested decision be set aside and that a patent be granted on the basis of a main request filed with the grounds of appeal on 10 September 2015 or on the basis of auxiliary requests 1 or 2, filed with letter dated 15 November 2019.

III. Reference is made to the following documents:

D2: HANSEN P ET AL: "AlGaN/GaN metal-oxide-semiconductor heterostructure field-effect transistors using barium strontium titanate", JOURNAL OF VACUUM SCIENCE AND TECHNOLOGY B: MICROELECTRONICS AND NANOMETER STRUCTURES PROCESSING, MEASUREMENT AND PHENOMENA, AMERICAN INSTITUTE OF PHYSICS, NEW YORK, NY, US, vol. 22, no. 5, 13 October 2004, pages 2479-2485, XP012074652, ISSN: 1071-1023

D3: US 2004/124435 A1

D4: HEIKMAN S ET AL: "Growth of Fe doped semi-insulating GaN by metalorganic chemical vapor deposition", APPL. PHYS. LETT. 81, 439 (2002)

D2 and D3 were discussed in the contested decision. D4 is cited in the description of the application on page 11 and was mentioned in relation to the claimed Fe doping concentration in point 5.2 of the Board's communication preparing the oral proceedings.

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

(a) *A Group III Nitride based field effect transistor, FET,*
(b) *characterised by a power degradation of less than 3.0 dB when operated at high temperature, reverse biased, HTRB, conditions including a drain-to-source voltage,* $V_{DS}$ *, of about 56 volts, a gate to source voltage,* $V_{gs}$ *, of from -8 to -14 volts and a temperature of 140 °C. for at least 10 hours, the FET comprising:*
(c) *an AlN layer (14) on a GaN channel layer (12);*
(d) *an AlGaN (16) layer on the AlN layer;*
(e) *a T-gate contact (32) on the AlGaN layer;*
(f) *an insulating layer on a surface of the FET comprising a passivation layer including silicon nitride, SiN;*
(g) *and wherein all but 1.0 µm of a surface of the GaN channel layer is doped with Fe.*

V. The wording of claim 1 of auxiliary request 1 differs from the wording of claim 1 of the main request in that it is directed at a *HEMT* instead of a *FET* (resulting in features (a'), (b') and (f')) as well as by additional features (h) and (i) after feature (f) as follows (labeling added by the Board):

(h) *source (20) and drain (22) contacts on the AlGaN layer; and*

(i) *wherein the GaN channel layer has a thickness of from about 2.0 µm to about 8.0 µm,*

and in that feature (g) is replaced by modified feature (g') as follows:

(g') *and wherein all but about 1.0 µm of a surface of the GaN channel layer is doped with Fe to a concentration of from about 2 x* $10^{16}$ $cm^{-3}$ *to about 2 x* $10^{18}$ $cm^{-3}$ *.*

VI. The wording of claim 1 of auxiliary request 2 differs from the wording of claim 1 of auxiliary request 1 in that feature (f') is deleted and in that features (b') and (i) are replaced by modified features (b'') and (i') as follows (labeling added by the Board):

(b'') *characterised by a power degradation of less than 3.0 dB when operated at high temperature, reverse biased, HTRB, conditions including a drain-to-source voltage,* $V_{DS}$ *, of about 56 volts, a gate to source voltage,* $V_{gs}$ *, of from -8 to -14 volts and a temperature of 140 °C. for at from 10 hours to 62 hours, the HEMT comprising:*

(i') *wherein the GaN channel layer has a thickness of about 6.0 µm*

VII. The arguments of the appellant may be summarised as follows:

The devices described in D2 were not related to optimising the FETs with respect to power degradation

under HRTB conditions at all whereby D2 did not disclose feature (b).
Further, the properties of FETs including the low power degradation values under HTRB conditions depended on a complicated interplay of the different structural parameters (e.g. the compositions and thicknesses of the layers) of these devices.
In particular, a thickness of the undoped part of the GaN channel layer of 1 µm improved their power degradation characteristics.
In addition, starting from D2, the skilled person would not consider to reduce the undoped part of the GaN channel layer to 1 µm, because this would correspond to a strong modification of the ratio of the thicknesses of the doped and the undoped parts of the GaN channel layer.

## Reasons for the Decision

1. The appeal is admissible.

2. The application

The application is directed at wide band gap group III Nitride based field effect transistors (FETs), more particularly high electron mobility transistors (HEMTs, see the description of the application, page 1, line 12 to page 2, line 22).
The aim of the application is to create transistors of that type which can withstand high temperature, reverse bias (HTRB) conditions (see the description of the application, page 9, lines 8 to 15), in particular FETs/HEMTs which have power degradations of less than

3.0 dB after having been subjected to a particular HTRB test involving a much shorter than usual period of time (see the description of the application, page 3, lines 3 to 7; page 9, lines 19 to 32 and page 10, lines 9 to 17).

The structure of the FETs/HEMTs is generally described with respect to figure 1A of the application and comprises a plurality of layers which include a GaN channel layer 12 (which, according to the description, may be Fe doped), an AlN layer 14, an AlGaN layer 16, a T-gate contact 32 and an insulation layer, which may be made of SiN. The application further discloses six series of test runs relating to six different groups of devices.

3. State of the art

3.1 D2

D2 discloses a HEMT (or HFET) comprising a GaN channel layer, the lower part of which is Fe doped, an AlN interfacial layer, and an AlGaN cap layer (Figure 1(a)). This document further discloses using a SiN layer to protect the AlGaN surface and a T-gate contact (Figure 1(c)).

3.2 D3

D3 discloses a HEMT comprising a GaN buffer/channel layer 12, an AlN interfacial layer 14b, an AlGaN cap layer 14a and a T-gate contact 24 (figure 1 and paragraphs [48] to [51]).

3.3 D4

D4 is cited in D2 (reference number 28) and discloses Fe doping to render GaN layers semi-insulating by compensating the background doping intrinsic to GaN. The purpose thereof is to render such layers usable for lateral conduction AlGaN/GaN HEMTs (see abstract and page 439, left-hand column, first two sentences). Fe doping concentrations of between 7.1 x $10^{17}$ $cm^{-3}$ and 9.9 x $10^{18}$ $cm^{-3}$ are disclosed (Figure 1 and page 440, left-hand column, last paragraph).

4. Main request, D2

4.1 Features (a), (c), (d), (e), (f) and (g)

D2 (see generally the paragraph bridging pages 2479 and 2480 in combination with figures 1(a) and 1(c)) discloses, in the wording of claim 1 of the main request,

(a) A Group III Nitride based field effect transistor, FET, (AlGaN/GaN HFET structure)
the FET comprising:
(c) an AlN layer (AlN interfacial layer) on a GaN channel layer (GaN base layer);
(d) an AlGaN layer (AlGaN cap layer) on the AlN layer;
(e) a T-gate contact on the AlGaN layer (AlGaN cap layer);
(f) an insulating layer on a surface of the FET comprising a passivation layer including silicon nitride, SiN;

(g, part) and wherein all but 2.0 µm of a surface of the GaN channel layer is doped with Fe (the GaN base layer is 2.6 µm thick and the first 0.6 µm are Fe doped).

The Board is aware that features (a), (c), (d) and the feature relating to Fe doping are disclosed in Figure 1(a) of D2 (see also page 2480, left-hand column, first paragraph), while features (e) and (f) are only disclosed in Figure 1(c) of D2. However, D2 *generally* discloses to use an SiN passivation layer on top of the AlGaN cap layer (page 2480, right-hand column, last paragraph and Figure 1(c)) and states with respect to the devices shown in Figure 1(c) that they *were processed in a similar manner as that described above* (sentence bridging pages 2480 and 2481). The skilled person would thus derive directly and unambiguously from D2 as a whole that the device shown in the schematic sketch of Figure 1(c) implicitly comprises all the layers shown in and discussed with respect to Figure 1(a), although Figure 1(c) does not show explicitly all these layers.
The Board notes that this was already discussed in the Board's communication preparing the oral proceedings (page 6, second paragraph).

D2 thus discloses features (a), (c), (d), (e) and (f) in combination. It further discloses part of feature (g), with the exception of the thickness value of the undoped part of the GaN layer (D2: 2.0 µm, feature (g) of claim 1: 1.0 µm).

This was not disputed by the appellant.

4.2 Feature (b)

The appellant argued that the devices described in D2 did not disclose feature (b).

Feature (b) corresponds to the aim of the application in its broadest sense (see the description of the application, page 3, lines 3 to 7) as noted above and relates to a property that all FETs described as embodiments of the invention possess, in particular the FETs described with respect to figures 1A to 3 (see the description of the application, page 10, lines 9 to 19).

The properties of a semiconductor device are determined by its structural features. The Board is thus convinced that any FET which has the same structural features as the FETs described with respect to figures 1A to 3 implicitly has the same properties including the property defined by feature (b).

4.2.1 Structural features of the FETs described with respect to figure 1A

In the present case, these structural features relate essentially to the layer structure of the FET consisting of a GaN channel layer, an AlN layer, an AlGaN layer and a passivation layer. In particular with respect to figure 1A, these layers are defined as follows.

The **GaN** channel layer can be Fe doped (see page 11, lines 27 to 33). If this is the case, it may be partially doped with a very thin layer of about 0.01 µm of the top which is very low doped or undoped (page 11, line 33 to page 12, line 2). The GaN channel layer may be grown to a thickness from about 0.01 to about 20 µm (page 12, lines 3 to 6).
The **AlN** layer may have a thickness of from about 0.2 to about 2.0 nm (page 12, line 14).
The **AlGaN** layer may have a thickness of from about 10 to about 40 nm and an Al composition from about 15 to about 30 percent (page 12, lines 16 to 17).

Finally, a passivation layer *may* be deposited on the structure, which may be **SiN** (page 13, lines 5 to 7).

4.2.2 Structural features of the HEMT described in D2

The HEMT disclosed in D2 also possesses a layer structure consisting of a GaN channel layer, an AlN layer, an AlGaN layer and a passivation layer as argued above with respect to features (c), (d) and (f).

In particular (see page 2480, left-hand column, first paragraph), the **GaN** channel layer is grown to a thickness of 2.6 µm. It is partially Fe doped leaving a top layer of 2 µm thickness which is undoped.
The **AlN** layer has a thickness of 0.5 nm.
The **AlGaN** layer has a thickness of 30 nm and the composition $Al_{0.3}Ga_{0.7}N$ and thus an Al composition of about 30 percent.
A passivation layer of **SiN** is deposited on the structure as argued above with respect to feature (f).

4.2.3 Conclusion with respect to feature (b)

It follows from the above that the layer structure disclosed in D2 corresponds essentially to the layer structure as discussed in the application with respect to figure 1A.
Consequently, it must be concluded that the HEMT disclosed in D2, if it was subjected to the test conditions as defined in feature (b), would also show a power degradation of less than 3 dB.

Thereby, D2 implicitly discloses feature (b) as well, even if neither an HTRB test nor a power degradation value is mentioned in that document.

5. Difference

It follows from the above that the subject-matter of claim 1 of the main request differs from the HEMT disclosed in D2 in that the undoped part of the GaN channel layer defined in feature (g) has a thickness of

1 µm (instead of 2 µm as in D2).

6. Technical effect

6.1 General part of the description

A thickness of 1 µm of the undoped part of the GaN channel layer is mentioned in the application only in the general part of the description on pages 3 to 5 as an optional feature (e.g. page 4, lines 9 to 11: "*The FET may include a GaN channel layer having a thickness of about 6.0 µm and all but 1.0 µm of a surface of the GaN channel layer may be doped with Fe to a concentration of from about 2 x* $10^{16}$ $cm^{-3}$ *to about 2 x* $10^{18}$ $cm^{-3}$").

Some particular power degradation values of not greater than about 0.40 dB, 0.45 dB and 1.3 db are mentioned in this part of the description with respect to the Fe doped embodiments (page 3, line 19 and page 4, lines 7 and 29). However, these values differ from each other and consequently, no effect of the particular thickness of 1 µm of the undoped layer of the GaN channel, alone or in combination with other layer parameters, on the power degradation can be derived from these parts of the application, contrary to the argument of the appellant.

6.2 Series of test runs

Concerning the six series of test runs, the first, third and fifth series relate to embodiments where Fe doping is not mentioned at all.
Only the second, fourth and sixth series of test runs relate to embodiments where (part of) the GaN channel is Fe doped (page 14, lines 22 to 32; page 15, lines 9 to 20 and page 16, lines 3 to 14, respectively). With respect to none of these three series of test runs involving Fe doping, however, a thickness value of the undoped part of the GaN channel of 1.0 µm is mentioned.

Instead, the description relating to the second series of test runs refers with respect to Fe doping to the discussion of Figure 1A, according to which the undoped part of the GaN channel layer corresponds to the *channel region, or about 0.01 µm of the top of the GaN buffer* (page 11, line 33 to page 12, line 2). This value is two orders of magnitude smaller than the value defined by the differentiating feature.
With respect to the fourth series of test runs, the application mentions that the "*wafer with the most doping closest to the channel produced a power degradation of from about 1.0 dB to about 2.0 dB*" (page 15, lines 13 to 14), which is worse than the results of any of the test runs carried out with devices without any Fe doping of the GaN channel layer (i.e. the first, third and fifth series of test runs as mentioned above).
Relating to the sixth series of test runs, the application only mentions that the devices tested had varying amounts of Fe doping but does not mention any undoped part of the GaN channel at all.

Further, the power degradation values obtained for FETs without Fe doping range from 0.07 dB (lowest power degradation value obtained in the first series of test runs, see page 14, line 12) to 1.0 dB (highest power degradation values obtained in the third and fifth series of test runs, see page 14, line 34 and page 15, line 22).
The power degradation values obtained for FETs with Fe doping, on the other hand, range from 0.0 dB (lowest power degradation value obtained in the sixth series of test runs, see page 16, line 4) to 1.3 dB (highest power degradation value obtained in the second series of test runs, see page 14, line 23) and even 2.0 dB (under certain conditions in the fourth test run, see page 15, line 14).
That is, the power degradation values obtained for FETs with Fe doping are similar to the power degradation values obtained for FETs without Fe doping.

It is thus already difficult (if not impossible) to derive any effect obtained by Fe doping in general on the power degradation values from the series of test runs.
An effect on the power degradation in an FET with Fe doping obtained by an undoped part of the GaN channel layer with the particular thickness of 1 µm can certainly not be derived from the six series of test runs.

6.3 Interplay of structural features

The Board can in principle accept the consideration of the appellant that the properties of FETs such as the ones disclosed in the application and the prior art depend on a complicated interplay of the different structural features of these devices.

However, the application does not disclose such an interplay of the different layers of the described FETs. Instead, most of the features of the individual layers (e.g. their composition and thickness) mentioned in the general part of the application are qualified as being optional and some of the parameters of the devices investigated in the various series of test runs are defined by ranges involving factors of up to two orders of magnitude (e.g. the Fe concentration in the fourth series of test runs).
In particular, it cannot be derived from the application as a whole that a thickness of the undoped part of the GaN layer of 1 µm improves the power degradation by means of such an interplay with the other structural features of the FETs, contrary to the argument of the appellant.

6.4 Conclusion concerning the technical effect

It follows from the above that no particular technical effect improving the power degradation achieved by the differentiating feature alone can be derived from the application as a whole. Instead, the power degradation values obtained in the series of test runs where no Fe doping was present at all are similar to the values obtained in the series of test runs with Fe doping.
It must therefore be concluded that no particular improvement of the power degradation is achieved by the particular thickness of 1 µm of the undoped part of the GaN channel layer.

7. Objective technical problem to be solved

It follows from the above that the technical effect alleged by the appellant is in fact not achieved by the differentiating feature.
The Board cannot conceive any other particular, plausible technical effect of the differentiating feature in the framework of FETs or HEMTs, either.

Therefore, the Board holds that the only possible formulation of the objective technical problem is:
- how to provide an *alternative* Group III Nitride based FET.

8. Inventive step

The Board accepts that an alternative way for achieving a known technical effect could, in some cases, be considered to involve an inventive step. However, achieving a known, trivial technical effect by means of modifications of the closest prior art which would be obvious to the skilled person cannot be considered inventive.

The thickness of each of the various layers making up a semiconductor structure is a parameter that is in a general manner always subject to routine experimentation by the skilled person in order to generally improve the properties of the semiconductor structure and to adapt it to a particular intended use.

Therefore, the skilled person would always consider modifying the thickness of the undoped part of the GaN channel layer in D2. A thickness of 1 µm instead of 2 µm has thus to be seen as a choice the skilled person would make, according to the circumstances, without the exercise of inventive skills.

The argument of the appellant that the skilled person starting from D2 would not consider increasing the thickness of the doped part of the GaN layer because this would strongly change the thickness ratio between the doped and the undoped parts of the GaN layer cannot be accepted by the Board.

The Board does not consider the thickness ratio between the doped and the undoped parts of the GaN channel layer to be a technically relevant parameter. Instead, the Board holds that these two parts of the channel layer define different properties of the FET.
In particular, the thickness of the Fe doped and thus semi-insulating part of the layer influences the leakage current from the GaN channel region to the substrate.
By contrast, the thickness of the undoped part of the layer defines, in combination with its width, the cross-section of the current carrying part of the channel region and therefore contributes to determining the current-switching capacities of the FET.
Thus, the Board believes that the skilled person would adapt the thicknesses of each of the undoped and doped parts of the GaN layer in an independent manner according to the circumstances, without the exercise of an inventive step.

It follows from the above that the subject-matter of claim 1 of the main request lacks an inventive step within the meaning of Article 56 EPC 1973 in view of D2 combined with the common general knowledge of the skilled person.

9. Auxiliary request 1

The source and the drain contacts shown in figures 1(a) and 1(c) of D2 are arranged on the AlGaN layer as defined by feature (h) of claim 1 of auxiliary request 1.
Further, D2 discloses a GaN layer thickness of 2.6 µm which is well within the range defined by additional feature (i) of claim 1 of auxiliary request 1.

Consequently, D2 also discloses features (h) and (i).

D2 does not, however, give any particular value to be used for the Fe doping concentration. The skilled person would thus have to fill that gap when putting into practice the teaching of D2.
With respect to Fe doping, D2 refers to document D4 (see D2, page 2480, left-hand column, reference 28). Starting from D2, the skilled person would thus turn to D4 when looking for suitable Fe doping concentrations.

D4 suggests various such concentrations. The lowest concentration mentioned is $7.1 \times 10^{17}$ $cm^{-3}$ (see figure 1 and page 440, left-hand column, second paragraph) which falls within the range defined by feature (g') of claim 1 of auxiliary request 1. The skilled person would thus be prompted by D4 to use an Fe doping concentration according to feature (g') when putting into practice the teaching of D2.

For these reasons, the subject-matter of claim 1 of auxiliary request 1 is not inventive in view of D2 combined with the teaching of D4 and the common general knowledge of the skilled person within the meaning of Article 56 EPC 1973.

10. Auxiliary request 2

Feature (b'') puts an upper limit (62 hours) to the time the HEMT is subjected to HTRB conditions. The lower limit (10 hours), however, is the same as the one defined by feature (b). Thereby, feature (b'') defines effectively less severe HTRB test conditions than feature (b), whereby any FET having the property defined by feature (b) will inevitably also possess the property defined by feature (b'').
Hence, since D2 implicitly discloses feature (b) as discussed above, D2 equally implicitly discloses feature (b'').

Feature (i') more narrowly defines the thickness of the GaN layer as a whole (including the Fe doped and the undoped part) to be 6 µm and thus adds an additional differentiating feature as compared to D2 (where the GaN layer has a thickness of 2.6 µm).

The value of 6 µm is mentioned in the embodiments described in the application on page 4, line 6 to page 5, line 4 as optional ("*The FET may include a GaN channel layer having a thickness of about 6 µm ...*"). This value is further mentioned in relation to the fourth to sixth series of test runs on page 15, line 9 to page 16, line 14. However, the application as a whole does not allow to derive any particular technical effect achieved by the particular value of 6 µm. Instead, it appears that this particular thickness of the GaN channel is fully within the range commonly used for this particular layer (10 nm to 20 µm according to the present application; in D3, values between 300 nm and 20 µm are indicated for that layer, see paragraph [48]).

Further, as mentioned above, the thickness of the different layers in semiconductor devices must be considered as a parameter that is always subject to routine trial and error experiments with the aim of improving or adapting the devices. The particular value of 6 µm must therefore be seen as a choice the skilled person would make according to the circumstances, without the exercise of inventive skills.

It follows from the above that the subject-matter of claim 1 of auxiliary request 2 lacks an inventive step within the meaning of Article 56 EPC 1973 in view of D2 combined with the teaching of D4 and the common general knowledge of the skilled person.

11. Since none of the requests fulfill the requirements of the EPC, the appeal must fail.

## Order

## For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

S. Sánchez Chiquero T. Häusser

Decision electronically authenticated