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Datasheet for the decision of 18 September 2018

Case Number: T 2307/13 - 3.4.03

Application Number: 06740668.6

Publication Number: 1889297

IPC: H01L29/778

Language of the proceedings: EN

Title of invention:
GROUP III NITRIDE EPITAXIAL LAYERS ON SILICON CARBIDE SUBSTRATES

Applicant:
Cree, Inc.

Headword:

Relevant legal provisions:
EPC 1973 Art. 84

Keyword:
Claims - clarity (no) (all requests)

Decisions cited:

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It can be changed at any time and without notice.

Catchword:

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Beschwerdekammern

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Case Number: T 2307/13 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 18 September 2018

Appellant: (Applicant)	Cre*e, Inc. 4600 Silicon Drive Durham, NC 27703 (US)
Representative:	FRKelly 27 Clyde Road Dublin D04 F838 (IE)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 18 June 2013 refusing European patent application No. 06740668.6 pursuant to Article 97(2) EPC.**

Composition of the Board:

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

Summary of Facts and Submissions

I. The appeal is against the decision of the Examining Division refusing the European patent application EP 06 740668.6 (published as WO 2006/135477 A1) on the grounds that neither the Main request nor the Auxiliary request before it involved an inventive step within the meaning of Article 56 EPC.

II. After the Board issued summons to oral proceedings accompanied by a preliminary opinion raising objections under Article 84 EPC 1973 (lack of clarity) against all requests then on file, the Appellant filed a new set of requests (Main request and First to Fifth Auxiliary requests) with a letter dated 16 August 2018. With a subsequent letter dated 14 September 2018, the Appellant announced that it would not attend the oral proceedings.

III. At the end of the oral proceedings, which took place in the Appellant's absence, the Appellant's requests - as submitted during the written procedure - were to set the decision under appeal aside and to grant a patent on the basis of the Main request or one of the First to Fifth Auxiliary requests, all filed with the Appellant's letter of 16 August 2018.

IV. Independent claim 1 of the Main request is worded as follows:

A semiconductor structure (30; 40) comprising:
a silicon carbide substrate (31; 41) having a diameter of at least 100 mm;
a Group III nitride heterostructure on said substrate formed of at least two epitaxial layers (33, 34; 43, 44) that are sufficiently different in composition to

generate a two dimensional electron gas (35) at their interface, the Group III nitride heterostructure comprising a gallium nitride layer on said silicon carbide substrate and at least one layer of $Al_xGa_{1-x}N$ *where 0<x<l on the gallium nitride layer opposite the silicon carbide substrate where the* $Al_xGa_{1-x}N$ *is grown in an atmosphere that is predominately nitrogen with minimal hydrogen; and*
said heterostructure having at least one of:
a standard deviation in sheet resistivity across said silicon carbide substrate (31; 41) of less than 3 percent; or a standard deviation in electron mobility across said silicon carbide substrate (31; 41) of less than 3 percent.

Independent claim 14 of the Main request is worded as follows:

A method of epitaxial growth of Group III nitride layers on semiconductor substrates (31; 41) using source gases consistent with metal organic chemical vapor deposition, the method comprising:
growing a heterostructure formed from two Group III nitride epitaxial layers (33, 34; 43, 44) that differ sufficiently in composition from one another to generate a two-dimensional electron gas (35) at their interface, the Group III nitride heterostructure comprising a gallium nitride layer on said silicon carbide substrate and at least one layer of $Al_xGa_{1-x}N$ *where 0<x<l on the gallium nitride layer opposite the silicon carbide substrate, said growing comprising growing the* $Al_xGa_{1-x}N$ *in an atmosphere that is predominately nitrogen with minimal hydrogen and on a substrate that is at least 100 mm in diameter, said heterostructure having at least one of: a standard deviation in sheet resistivity across said silicon*

carbide substrate (31; 41) of less than 3 percent; or a standard deviation in electron mobility across said silicon carbide substrate (31; 41) of less than 3 percent.

V. Independent claims 1 and 14 of the **First Auxiliary** request differ from the corresponding claims of the Main request in that it is defined that the $Al_xGa_{1-x}N$ is grown in an atmosphere that is predominately nitrogen "*with no more than 5% hydrogen*" (instead of minimal hydrogen).

VI. Independent claims 1 and 14 of the **Second Auxiliary** request differ from the corresponding claims of the Main request in that it is defined that the $Al_xGa_{1-x}N$ is grown in an atmosphere that is predominately nitrogen "*with about 5% hydrogen*"(instead of minimal hydrogen).

VII. The **Third, Fourth and Fifth Auxiliary** requests consist only of the method claims of the Main, the First Auxiliary and Second Auxiliary requests respectively. Hence, independent claim 1 in the Third, Fourth and Fifth Auxiliary request has the same wording as the respective independent claim 14 in the Main, First Auxiliary and Second Auxiliary requests.

Reasons for the Decision

1. The appeal is admissible.

2. The invention

2.1 The invention relates to semiconductor structures comprising high electron mobility transistors (HEMTs) made of an heterostructure of epitaxial semiconductor

layers consisting of Group III nitrides on a silicon carbide (SiC) substrate.

According to the description (paragraphs [0001]-[0011]), HEMTs made of heterostructures consisting of epitaxially grown layers made of Group III nitrides on substrates of silicon carbide (SiC) were known in the state of the art. In manufacturing such HEMTs, there had been a limitation on the size of the substrate (wafer) used. Good quality HEMTs were produced using substrates of maximum diameter of 2-3 inches (about 50 - 75 mm). With larger substrates, the forming of the heterostucture was less reliable, since uniform resistivity and electron mobility were not possibe to obtain throughout the whole area of the substrate. This led to unreliable, low(er) quality HEMTs. It was, hence not possible to obtain semiconductor structures with heterostructures made of Group III nitrides on substrates with at least 100 mm diameter that were of high quality and high consistency performance (paragraph [0011]).

On the other hand, the almost standard diameter of substrates for other types of semiconductor structures was 100 mm or more. Hence, it had been necessary to use specialized equipment when HEMTs were to be produced (paragraph [0008]).

The claimed invention consists of such a semiconductor structure comprising a SiC substrate with a diameter of at least 100 mm and a heterostructure of Group III nitrides which has essentially constant resistivity and/or electron mobility across the substrate and a method for manufacturing it.

3. Main request - Clarity (Article 84 EPC 1973)

3.1 Claim 1 defines a semiconductor structure with a heterostructure comprising a layer of gallium nitride (GaN) and a layer of $Al_xGa_{1-x}N$, which has a standard deviation in sheet resistivity and/or electron mobility across the substrate within a specific range (less than 3 percent) but there is no indication of how these values for the standard deviation are to be achieved.

3.2 In the grounds of appeal, the Appellant made reference to paragraphs [0013] and [0079] of the description and explained that such low standard deviations in sheet resistivity and electron mobility were the result of growing the heterostructure by carrying out metal organic chemical vapour (MOCVD) in a predominately nitrogen atmosphere.

3.3 The Board notes that, in the method of epitaxial growth of Group III nitride layers described in paragraph [0013], the layers are grown on semi-insulating semiconductor substrates. In the invention defined in the Main request, the semi-insulating substrate is defined in claim 2, so in the semiconductor structure of claim 1 there is not necessarily such a semi-insulating substrate. The same applies for the method defined in independent claim 14. It is therefore to be concluded that the method and semiconductor structure described in paragraph [0013] does not correspond to the embodiment of the invention claimed in the independent claims 1 and 14 of the Main request.

The sole explanation of the method for obtaining the claimed invention is, hence, in paragraphs [0078] and [0079] of the description.

The relevant passages read as follows:
"A number of background aspects of the growth of Group III nitride layers on silicon carbide substrates are generally well understood in the art and can be practiced by those of ordinary skill in this art without undue experimentation. As a specific discussion, however, the structures shown herein were typically grown using metal organic chemical vapor deposition (MOCVD)." (paragraph [0078]);
and
"*As a particular improvement, however, it has been discovered according to the present invention that the best results appear to be obtained when the AlN and AlGaN layers are grown in an atmosphere containing minimal (about 5 percent) hydrogen* (H_2)*, such as an atmosphere that is predominately nitrogen* (N_2)." (paragraph [0079])

3.4 As already pointed out in the Board's preliminary opinion, there is no indication of any value for the content of nitrogen in the *predominately nitrogen* atmosphere. The terms "predominately" (in *predominantly nitrogen*) and "minimal" (in *minimal hydrogen*) in claims 1 and 14 of the Main request, do not define the claimed scope in a clear manner, since there are no corresponding established values, ranges or thresholds so that it can be defined how much nitrogen and how much hydrogen has to be in the atmosphere for the characterisations "predominately" and "minimal" to apply.

3.5 In its letter dated 16 August 2018, the Appellant argued that the term "predominately" had to be given its "ordinary meaning such that claim 1 requires nitrogen to be the gas in the atmosphere that is the largest in number in the atmosphere" (page 2, fourth

paragraph). Regarding the term "minimal", the Appellant indicated that it meant a value of 5% or less, making reference to the passage of paragraph [0079] cited above.

3.6 Starting from the last point, the Board notes that in the cited passage of paragraph [0079] it is stated "about 5%" and not 5% or less, as the Appellant stated.

Regarding the term "predominately", both the Oxford and Merriam-Webster online dictionaries define it as "for the most part, mainly". The Board understands that this definition does not correspond to the explanation put forward by the Appellant. According to the Appellant's explanation, the term is to be understood as the nitrogen being the gas, which is in the biggest quantity among all the gases in the atmosphere. This would mean, for example, that if there were 5 different gases in the atmosphere, nitrogen could be 21% of the atmosphere, three other gases could be 20% and one 19%. Such a composition would satisfy the definition of a *predominately nitrogen atmosphere.* According to the dictionaries' definition, however, in order for nitrogen to be predominant, it has to be at least 51% of the atmosphere, i. e. the atmosphere has to be for the most part nitrogen.

Already this discrepancy between the Appellant's explanation and the dictionary definition of the term "predominately" indicates the ambiguity in the understanding of the term and speaks against a clear definition of the claimed scope of protection.

3.7 Moreover, as the description states (paragraph [0078]) and independent claim 14 defines, the layers are grown using MOCVD. As it generally known, and it was so by

the priority date of the application, MOCVD is a complex process controlled by many parameters, including the composition of the atmosphere in which it is carried out.

Although the Board agrees with the Appellant that MOCVD as such is part of the skilled person's common general knowledge, it is to be understood that certain conditions must be fulfilled in order to obtain the claimed ranges for the standard deviation of sheet resistivity and/or electron mobility and these conditions would be beyond common general knowledge.

3.8 This is also true regarding claims 3, 4, 5, 7, 10, 11, which depend on claim 1, and which define values for parameters of the claimed semiconductor structure (sheet resistivity, carrier density and corresponding standard deviations) without any indication of how these values are to be obtained.

3.9 The description does not provide any more information, either. In paragraphs [0015], [0041], [0042], [0048], [0053], [0055], [0056] and in the first table on page 12, there are measurements of several semiconductor structures according to the claimed invention, which show different values for the standard deviation in sheet resistivity and in electron mobility across the substrate. There is, however, no indication of how the different values can be obtained, i. e. which values of which parameters of the manufacturing method, and of the percentage of nitrogen in the atmosphere of the MOCVD in particular, influence the consistency (uniformity) of sheet resistivity and electron mobility across the substrate. The information that the description provides is limited to the predominately nitrogen atmosphere with minimal hydrogen. The

indication in parentheses of "about 5%" for the hydrogen is to be understood rather as a possible example and not as a general teaching.

3.10 Since there is no indication in the application as a whole of how the specific values for the standard deviation in claim 1 are to be obtained, the Board is of the opinion that the last feature of claim 1 is formulated as a result to be achieved and, therefore, claim 1 lacks clarity within the meaning of Article 84 EPC 1973. The same applies for independent claim 14, as well.

3.11 In its letter of 16 August 2018, the Appellant made reference to the Guidelines for Examination in the EPO and more specifically to the passage stating that "... [claims which attempt to define the invention by a result to be achieved] may be allowed if the invention either can only be defined in such terms or cannot otherwise be defined more precisely without unduly restricting the scope of the claims and if the result is one which can be directly and positively verified by tests of procedures adequately specified in the description or known to the person skilled in the art and which do not require undue experimentation" (see Part F, Chapter IV, 4.10). The Appellant argued that *while these limitations on the amount of nitrogen and hydrogen in the atmosphere may provide a relatively broad range of acceptable atmospheric compositions for achieving the claimed sheet resistivity or electron mobility, those skilled in the art would nonetheless be able to practice the invention without undue experimentation* (page 2, fourth paragraph of the letter).

3.12 The Board notes that the technical problem the claimed invention is trying to address is how to obtain high electron mobility transistors (HEMTs) with relatively constant sheet resistivity and/or electron mobility on substrates that are at least 100mm in diameter (see also point 2 above). The claimed invention (claim 1) consists of such a semiconductor structure characterised by having essentially a constant value of sheet resistivity or of electron mobility. The invention consists also (claim 14) of a corresponding manufacturing method characterised by the fact that it produces semiconductors having essentially constant value of sheet resistivity or of electron mobility.

The claimed inventions are, hence, merely characterised by the fact that they provide the desired technical effect. In the section of the Guidelines referred to by the Appellant, the sentence preceding the cited passage reads as follows: "As a general rule, claims which attempt to define the invention by a result to be achieved should not be allowed, in particular if they only amount to claiming the underlying problem." (underline by the Board).

The Board is of the opinion that the present claims fall under the latter category.

3.13 As already explained, MOCVD is a rather complex method controlled by many parameters. The Board finds that the application does not provide sufficient information for the skilled person to be able to "directly and positively" verify or even obtain the claimed result by "procedures adequately specified in the description" without undue experimentation. The Appellant's argument that the skilled person would be able to do so based only on common general knowledge does not convince the

Board, either, since if it were the case, there would be no invention to claim.

3.14 The Board concludes, thus, that neither claim 1 nor claim 14 meet the requirement of clarity of Article 84 EPC 1973.

4. Auxiliary requests

4.1 The independent claims of the First to Fifth Auxiliary requests define also a "predominately nitrogen atmosphere". In some of the requests there is a specification regarding the hydrogen content, "no more than 5%" (First and Fourth Auxiliary requests) or "about 5%" (Second and Fifth Auxiliary requests).

4.2 The latter point, however is not considered sufficient to overcome the overall lack of information of how the claimed result is to be achieved, as explained with regard to the Main request.

4.3 The conclusion of the Board is therefore that none of the independent claims of the First to Fifth Auxiliary requests meets the requirement of clarity of Article 84 EPC 1973 because they attempt to define the invention by a result to be achieved.

5. Since none of the requests on file is allowable, 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