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Case Number: T 0571/13 - 3.4.03

Application Number: 01916604.0

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Language of the proceedings: EN

Title of invention:
FABRICATION OF SEMICONDUCTOR MATERIALS AND DEVICES WITH CONTROLLED ELECTRICAL CONDUCTIVITY

Applicant:
Cree, Inc.

Headword:

Relevant legal provisions:
EPC 1973 Art. 56

Keyword:
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Decisions cited:

Catchword:

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Case Number: T 0571/13 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 9 November 2017

Appellant: (Applicant)
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Representative:
FRKelly
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Decision under appeal:
Decision of the Examining Division of the European Patent Office posted on 12 October 2012 refusing European patent application No. 01916604.0 pursuant to Article 97(2) EPC.

Composition of the Board:

Chairman G. Eliasson
Members: M. Stenger
T. Bokor

Summary of Facts and Submissions

I. The appeal concerns the decision of the Examining Division to refuse European patent application no. 01916604 for non-compliance with Articles 123(2) and 56 EPC.

II. Reference is made to the following document:
D2: US 5930656 A

III. With the summons to oral proceedings, the Board expressed its preliminary opinion that the subject-matter of the independent claims of all requests did not involve an inventive step in particular in view of the fourth and fifth embodiment of prior art document D2.

IV. With letter dated 9 October 2017, the appellant filed a new main request as well as new first and second auxiliary requests, replacing the previous requests.

V. Oral proceedings were held on 9 November 2017 in the absence of the appellant, as announced previously. At the end of the oral proceedings, the chairman announced the decision of the Board.

VI. Claim 1 of the main request of the present application reads (labelling added by the Board):

A method for reducing the passivation of acceptor and donor species in semiconductor material during and after its growth, comprising:

(a) growing said semiconductor material (30, 50) in a reactor (10) at a growth temperature,

(b) said semiconductor material grown on a single crystal sapphire substrate;

(c1) evacuating excess growth source gases (16, 26)

(c2) by opening a purge valve (25) to allow a pump (24) to evacuate said reactor of excess growth source gases; and

(d1) after the evacuation of said reactor (10) of excess growth source gases (16, 26), depositing a passivation barrier layer (32)

(d2) formed from a compound which is chemically inert to said semiconductor material

(d3) on said semiconductor material (30, 50) while it is in said reactor (10),

(e1) wherein during the depositing step, a non-hydrogen carrier gas is injected into the reactor

(e2) to prevent hydrogen from diffusing into said semiconductor material during deposition of the passivation barrier layer,

(f) and said barrier layer is capable of preventing hydrogen from diffusing into said semiconductor material by chemically binding hydrogen trapped in said semiconductor material (30, 50).

VII. Claim 1 of the first auxiliary request differs from claim 1 of the main request in that features (c1), (c2) and (f) now read (additions in bold, deletion in strike-through):

(c1') ***stopping the growth of said semiconductor material by*** *evacuating excess growth source gases (16, 26)* ***and***

(c2') ***keeping a carrier gas flowing in said reactor and/or purging the reactor with a gas wherein evacuation of growth source gases is aided*** *by opening a purge valve (25) to allow a pump (24) to ~~evacuate~~* ***assist in evacuating*** *said reactor of ~~excess~~ growth source gases; and*

(f') and said barrier layer is capable of preventing hydrogen from diffusing into said semiconductor material by chemically binding hydrogen trapped in said semiconductor material (30, 50) ***or prevents hydrogen from reaching said semiconductor from an ambient gas phase.***

VIII. Claim 1 of the second auxiliary request differs from claim 1 of the first auxiliary request in that features (c1') and (c2') now read (additions in bold):

(c1'') stopping the growth of said semiconductor material by evacuating excess growth source gases (16, 26) ***not necessary for the stabilization of said semiconductor material*** *and*

(c2'') keeping a ***non-hydrogen*** *carrier gas flowing in said reactor and/or purging the reactor with a gas, wherein evacuation of* ***excess*** *growth source gases is aided by opening a purge valve (25) to allow a pump (24) to assist in evacuating said reactor of* ***excess*** *growth source gases* ***wherein said purge valve and said pump are connected to said reactor through a gas purge line (23)****; and*

IX. The appellant's arguments, insofar as they are relevant to the present decision, may be summarized as follows:

D2 did not disclose that the excess growth source gases (reactive gases and doping gases) were evacuated prior to the formation of the barrier layer (SiO_2 or SiON passivation film 33).
Further, D2 did not disclose when the exhaust port and/or the vacuum pump were operated to evacuate the reaction chamber.
D2 also did not disclose a barrier layer capable of preventing hydrogen from diffusing into said semiconductor material by chemically binding hydrogen trapped in said semiconductor material.
In addition, the skilled person could not derive any suggestion concerning these differentiating features from D2.

Reasons for the Decision

1. Document D2
D2 discloses forming semiconductor compound layers on a substrate in a reaction chamber by means of metal organic chemical vapor deposition (MOCVD). After the growth of the semiconductor layers, the substrate is kept in the reaction chamber and a passivation film is formed on top of the grown layers (see abstract).
The manufacturing apparatus used in the fourth and the fifth embodiments is shown in figure 4 and comprises an exhaust port (to the right) connected to a vacuum pump (column 3, lines 37 to 39).
For depositing layers, a gas flow consisting of carrier gas(es) and reactive gases is maintained in the reaction chamber. The composition of the gas flow is essential for the composition of the deposited layers.

2. Main request, claim 1

2.1 In the fourth embodiment, D2 discloses a method for reducing the passivation of acceptor and donor species in semiconductor material (column 3, lines 1 to 4, *prevents oxidization and contamination on the surface*) during and after its growth, comprising:

(a) growing said semiconductor material (layers 23 to 31) in a reactor 10 (*reaction chamber*, column 6, lines 23 to 29) at a growth temperature (column 6, lines 33-34; to grow the same layers as in the other embodiments, the same temperatures are required),

(c1) evacuating excess growth source gases (*reaction gases .. are stopped .... only the carrier gas of* N_2 *is supplied*, column 6, lines 35 to 38; this implies that the previously supplied reaction gases are evacuated from the reaction chamber), and

(d1), (d3) after the evacuation of said reactor of excess growth gases, depositing a passivation barrier layer 33 (SiO_2 *film*) on said semiconductor material while it is in said reactor (column 6, lines 37 to 43);

(e1) wherein during the depositing step, a non-hydrogen carrier gas (N_2) is injected into the reactor (column 6, line 37-38).

For the fifth embodiment, D2 explicitly discloses these features as well (column 7, lines 1 to 43).

2.2 In figure 4 of D2 as well as in the corresponding part of the description, the presence of a valve between the exhaust port and the vacuum pump is not explicitly indicated.

The Board is, however, not aware of any MOCVD apparatus without a valve between the exhaust port and the vacuum pump for controlling the gas flow; such a valve is essential to maintain the appropriate gas flow in an MOCVD apparatus required during deposition.

In this respect, the Board further notes that both the pumps 53 and 54 shown in figure 5 of D2 in relation to a different embodiment are linked to the reaction chamber via valves.

It must be concluded that the presence of a (purge) valve between the exhaust port and the vacuum pump is an implicit feature of the apparatus shown in figure 4 of D2.

Then, it is a matter of course that this (purge) valve must be opened whenever the composition of the gas stream is to be changed, in order to evacuate the gases corresponding to the previous composition.

Thus, D2 also discloses that excess growth source gases are evacuated

(c2) by opening a purge valve to allow a pump to evacuate said reactor of excess growth source gases.

2.3 The compounds of the barrier layers disclosed in the fourth and fifth embodiments of D2 (SiO_2 and SiON, respectively) are defined in the application as being compounds that are suitable for the purpose of forming the barrier layer according to claim 1 (see, e.g., page

10, lines 17 to 19 and claim 3, *SiN_x, SiO_x, and alloys thereof*).
Further, the deposition method disclosed in D2 corresponds to the preferred one of the application (MOCVD) and the passivation films are deposited on the same semiconductor material (GaN) as in the application. The barrier layers of the fourth and fifth embodiments of D2 are deposited in the reactor using a non-hydrogen carrier gas as defined in claim 1. The thickness of the layer according to the application (page 12, line 29 to page 13, line 7, *A 2 - 500 nm thick barrier layer*) corresponds to the thickness disclosed in D2 for the fourth and fifth embodiments (column 6 lines 46 to 47 and column 7, lines 28 to 29).

Since the passivation films 33 of the fourth and fifth embodiment of D2 consist of compounds suitable for the passivation barrier layer defined in claim 1 and are deposited in the same manner as the passivation barrier layer of claim 1, it must be concluded that these passivation films have the same chemical and physical properties as the passivation barrier layer defined in claim 1.

This finding of the Board corresponds to the reasoning of the Examining Division in section 3.4 of the contested decision.

Thus, D2 also discloses the features relating to physical and chemical properties of the passivation barrier layer that

(d2) the passivation layer is formed from a compound which is chemically inert to said semiconductor material, (e2) hydrogen is prevented from diffusing into said semiconductor material during deposition of the passivation barrier layer, and

(f) said barrier layer is capable of preventing hydrogen from diffusing into said semiconductor material by chemically binding hydrogen trapped in said semiconductor material.

2.4 Difference

The subject-matter of claim 1 of the main request thus differs from D2 in that

(b) said semiconductor material is grown on a single crystal sapphire substrate.

2.5 Inventive step

The application mentions that the single crystal sapphire substrate can be replaced by other crystal substrates like AlGaN or GaAs (see page 7, lines 25 to 27). No specific advantage or particular technical effect obtained by the use of a single crystal sapphire substrate as opposed to other substrates can be derived from the application.

Single crystal sapphire is one of the standard materials used for the growth of semiconductor thin layers (see, e.g., embodiments 1 to 3 of D2), due to its physical and chemical compatibility with semiconductor material as well as cost considerations. Thus, the choice of single crystal sapphire as a substrate must be regarded as a straightforward design option.

Thereby, the skilled person, starting from the fourth or fifth embodiment of D2 and using his common general knowledge, would replace the substrates used in these embodiments with a single crystal sapphire substrate, e.g., to reduce costs, and thus arrive at the subject-matter of claim 1 of the main request without the exercise of an inventive step (Article 56 EPC 1973).

3. Discussion of the arguments of the appellant:

3.1 The appellant argued that D2 did not disclose the evacuation of reactive and doping gases used to form the semiconductor material 23 - 31 prior to the formation of the passivation film 33.

The Board does not find this argument convincing. In both the fourth and the fifth embodiment, the supply of (some of) these gases is stopped while at least N_2 is still supplied to the reaction chamber (column 6, lines 35 to 38 and column 7, lines 16 to 19).
The gases that are necessary for the growth of the passivation film 33 are then supplied only *after* the temperature has dropped to a certain level, which takes some time. This implies that *before* these gases are supplied and the passivation film 33 starts growing, the reactor is evacuated of excess growth source gases to some extent. The Board notes that the extent up to which the excess growth source gases should be evacuated is nowhere defined in the application.

The Board thus concurs with the reasoning provided by the Examining Division on this issue (see page 6 of the contested decision).

3.2 The appellant further argued that there was no teaching in D2 as to *when* the exhaust port and vacuum pump of D2 were operated to evacuate the reaction chamber.

The Board is not convinced by this argument. According to D2, the composition of the gas flow is changed between the deposition of layers 23 to 31 and the formation of the passivation film 33. This can only be done by operating the exhaust port, the vacuum pump and the inevitable valve in between.

Hence, the process disclosed in D2, when put into practice, implies that all these elements are operated *between* the deposition of the layers 23 - 31 and the formation of passivation layer 33.

3.3 The appellant additionally argued that D2 did not disclose or suggest that the passivation films of D2 could chemically bind hydrogen or could prevent hydrogen from reaching the semiconductor surface from the ambient gas phase.

This argument does not convince the Board either. As reasoned above, the passivation films 33 of D2 have compositions corresponding to possible compositions of the passivation barrier layer according to the application and are produced in the same manner. Hence, it must be concluded that they also have the same chemical and physical properties.

4. First auxiliary request

Amended feature (c1') additionally only mentions a consequence of evacuating excess growth source gases and thus does not limit claim 1 more than feature (c1).

Keeping a carrier gas flowing in said reactor and/or purging the reactor with a gas according to feature (c2') is disclosed in D2 for both the fourth and the fifth embodiments (column 6, lines 37 to 39, *only the carrier gas of* N_2 *is supplied to the reaction chamber*; column 7, lines 18 to 19, *only the carrier gas of N2 and the reactive gas of* NH_3 *are supplied*).

The additional property mentioned in feature (f') that hydrogen is prevented from reaching the semiconductor from an ambient gas phase must also be a property of the passivation films disclosed in D2 for the same reason as for the other chemical and physical properties as reasoned above.

Hence, the subject-matter of claim 1 of the first auxiliary request does not involve an inventive step for the same reasons as for claim 1 of the main request.

5. Second auxiliary request

The amendment in feature (c1'') that only the excess growth source gases that are *not necessary for the stabilization of the semiconductor material* are evacuated as well as the two amendments in feature (c2'') that the carrier gas that is kept flowing is a *non-hydrogen* carrier gas and that *the purge valve and the the pump are connected to the reactor through a gas purge line* are all disclosed in the fifth embodiment of D2.

In this embodiment, a flow of NH_3 (which stabilizes the GaN semiconductor material, see page 11, lines 28 to 30 of the application) is supplied together with the non-hydrogen carrier gas of N2 after the semiconductor layers are completely grown (see column 7, lines 16 to 19). Further, the exhaust port shown in figure 4 to the right corresponds to the gas purge line 23 of claim 1 of the second auxiliary request (see also section 2.2 above).

Thus, the subject-matter of claim 1 of the second auxiliary request does not involve an inventive step for the same reasons given for claim 1 of the main request with respect to the fifth embodiment of D2.

6. None of the requests of the appellant fulfills the requirements of Article 52(1) EPC and Article 56 EPC 1973. Thus, 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