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Datasheet for the decision of 1 March 2018

Case Number: T 1454/13 - 3.4.03

Application Number: 04780967.8

Publication Number: 1661170

IPC: H01L33/40, H01L21/268

Language of the proceedings: EN

Title of invention:
LOCALIZED ANNEALING OF METAL-SILICON CARBIDE OHMIC CONTACTS

Applicant:
Cree, Inc.

Headword:

Relevant legal provisions:
EPC Art. 123(2)
EPC 1973 Art. 56
RPBA Art. 13(1), 13(3)

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

Decisions cited:

Catchword:

Europäisches Patentamt
European Patent Office
Office européen des brevets

Beschwerdekammern

Boards of Appeal

Chambres de recours

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Case Number: T 1454/13 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 1 March 2018

Appellant: (Applicant)	Cree, Inc. 4600 Silicon Drive Durham, NC 27703 (US)
Representative:	Boult Wade Tennant Verulam Gardens 70 Gray's Inn Road London WC1X 8BT (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 21 February 2013 refusing European patent application No. 04780967.8 pursuant to Article 97(2) EPC.**

Composition of the Board:

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

Summary of Facts and Submissions

I. The appeal is against the decision of the Examining Division refusing the European patent application No. 04 780 967.8 (published as WO 2005/020308 A1) on the ground that the Main and First Auxiliary requests before it did not meet the requirements of Article 123(2) EPC and because the Applicant (Appellant) did not approve the proposal of the Examining Division to grant a patent based on the Second Auxiliary request then on file (Article 113(2) EPC).

II. In a communication pursuant Article 15(1) of the Rules of Procedure of the Boards of Appeal (RPBA), which was annexed to the summons to oral proceedings, the Board expressed the preliminary opinion that the requests on file did not meet the requirements of Articles 123(2) EPC and 84 EPC 1973.

III. In reaction to this communication, the Appellant filed with a letter dated 16 January 2018 a Main request as well as 1st, 2nd and 3rd Auxiliary requests to replace those on file at the time.

IV. During the oral proceedings before the Board, the Appellant filed claims of a new 2nd Auxiliary request, titled "Replacement 2nd Auxiliary Request", and demoted the former 2nd and 3rd auxiliary requests to 3rd and 4th auxiliary requests respectively.

V. At the end of the oral proceedings, the Appellant's request was to set the decision under appeal aside and to grant a patent based on either of:

- the **Main request**, filed with letter dated 16 January 2018; or

- the **1st Auxiliary Request** filed with letter dated 16 January 2018; or
- the **2nd Auxiliary Request** consisting of
  - claims 1-26 as filed and amended during the oral proceedings before the Board(titled "Replacement 2nd Auxiliary Request");
  - description pages 1-19 filed during the oral proceedings before the Board;
  - drawing sheets 1/12-12/12 as published; or
- the **3rd Auxiliary Request** filed with letter dated 16 January 2018 (former 2nd Auxiliary request); or
- the **4th Auxiliary Request** filed with letter dated 16 January 2018 (former 3rd Auxiliary request).

VI. The following documents, cited during the first instance proceedings, are relevant for this decision:

D1: Ota Y et al: "Laser Alloying for Ohmic Contacts on SiC at Room Temperature", Materials Science Forum Vols. 264-268 (1998) pp 783-786, Trans Tech Publications, Switzerland;

D2: US 6 274 889 B1;

D3: Eryu Osamu et al: "Formation of an ohmic electrode in SiC using a pulsed laser irradiation method", Nuclear Instruments and Methods in Physics Research B 121 (1997), 419-421;

D4: Nakashima K. et al: "Improved Ohmic Contacts to 6H-SiC by Pulsed Laser Processing", Materials Science Forum Vols. 338-342 (2000) pp 1005-1008, Trans Tech Publications, Switzerland;

D5: Nakashima, K. et al: "Formation of Tungsten Ohmic Contact on n-Type 6H-SiC by Pulsed Laser Processes",

Materials Science Forum Vols. 264-268 (1998) pp 779-782, Trans Tech Publications, Switzerland;

VII. Independent claim 1 of the Main Request is worded as follows:

A method of forming an ohmic contact for a semiconductor device, comprising:
thinning a SiC substrate to provide a reduced thickness SiC substrate;
providing a metal on the reduced thickness SiC substrate; and
laser annealing an interface location of the metal and the reduced thickness SiC substrate by impinging laser light at an energy level above a bandgap of the reduced thickness SiC substrate to form a metal-SiC material thereat that comprises the ohmic contact having a specific contact resistivity of less than 10 e-03 ohm-cm^2 and avoiding annealing at another location on the reduced thickness SiC substrate to avoid forming the metal SiC material thereat.

VIII. Independent claim 1 of the 1st Auxiliary Request is worded as follows:

A method of forming an ohmic contact for a light emitting device (LED), the ohmic contact having a specific contact resistivity of less than 10 e-03 ohm-cm^2, the method comprising:
forming a metal on a Silicon Carbide (SiC) substrate opposite a stack of n/p epitaxial layers;
annealing an interface location of the metal and the SiC substrate to form a metal-SiC material thereat and avoiding annealing at another location on the SiC substrate to avoid forming the metal SiC material thereat, the annealing being carried out with laser

light having photon energies above a bandgap of the SiC substrate; and
forming a bevelled edge to the SiC substrate while dicing the SiC substrate using a saw tip to eliminate an upper portion of the SiC substrate.

IX. Independent claim 1 of the second auxiliary request (titled "Replacement Second Auxiliary Request") is worded as follows:

A method of forming an ohmic contact for a light emitting device (LED), the ohmic contact having a specific contact resistivity of less than 10 e-03 ohm-cm^2, the method comprising:
forming a metal on a Silicon Carbide (SiC) substrate opposite a stack of n/p epitaxial layers; and
annealing an interface location of the metal and the SiC substrate to form a metal-SiC material thereat and avoiding annealing at another location on the SiC substrate to avoid forming the metal SiC material thereat, the annealing being carried out with laser light having photon energies above a bandgap of the SiC substrate.

X. The wordings of the claims of the 3rd and 4th auxiliary requests are not relevant for this decision.

Reasons for the Decision

1. The appeal is admissible.

2. Main request

2.1 Added subject-matter (Article 123(2) EPC)

2.1.1 Claim 1 of the Main Request defines a method of forming an ohmic contact for a semiconductor device comprising the feature *"thinning a SiC substrate to provide a reduced thickness SiC substrate"*. In the decision under appeal, the Examining Division had found that this feature had no basis in the originally filed application.

2.1.2 The Appellant pointed to lines 5 and 6 of page 16 of the original (published) description as basis for this feature. The relevant passage makes reference to Figure 21 and reads as follows:

"The reduced thickness of the substrate 1805 may allow a saw tip to eliminate an upper portion of the substrate 1805 when the wafer is diced."

2.1.3 In the grounds of appeal, the Appellant considered that the finding of the Examining Division was based on an erroneous interpretation of this passage and explained in detail what the correct interpretation should be (grounds of appeal, points 18-22). In addition, the Appellant argued (letter dated 16 January 2018) that, as it could be understood from the presentation of the state of the art in the application (see "BACKGROUND" on pages 2 and 3 of the published application), the claimed invention was aiming to address problems related with forming ohmic contacts on thin silicon carbide (SiC) substrates. In this context, the skilled person would derive from the passage cited above that a step of thinning the substrate was an inherent step of the claimed method.

2.1.4 The Board can agree with the Appellant's explanation of the cited passage as presented in the grounds of appeal. Even in that case, however, there is no basis

for the feature of thinning the substrate in the application as originally filed.

The Board notes that there is no other reference to the thickness of the substrate in relation to the claimed invention in the application, except the above-cited passage. The "BACKGROUND" section, as the Appellant also stated, refers to the state of the art and cannot serve as basis for the amendments in the claims, which define the invention.

The passage on page 16, lines 5-6 cited above merely indicates that, when the substrate has a reduced thickness, a part of it may be removed when it is being diced by a saw, implying that in this way the bevelled structure shown in Figure 21 can be obtained. There is no mention or suggestion of any actual step of actively thinning the substrate or of reducing its thickness. It may well be, for example, that the substrate was manufactured with a reduced thickness from the beginning.

2.1.5 The Board, hence, concludes that this feature has no basis in the originally filed application. Claim 1 of the Main request, therefore, does not fulfill the requirements of Article 123(2) EPC.

3. 1st Auxiliary Request

3.1 Added subject-matter (Article 123(2) EPC)

3.1.1 In claim 1 of the 1st Auxiliary Request, the feature regarding the step of thinning the SiC substrate has been omitted. Moreover, there is no reference to a substrate of reduced thickness at all.

3.1.2 To the Board's remark that the last feature of claim 1 (*forming a bevelled edge to the SiC substrate while dicing the SiC substrate using a saw tip to eliminate an upper portion of the SiC substrate)* was only disclosed in the application in combination with a SiC substrate of reduced thickness (as indicated by the passage cited in paragraph 2.1.2 above), the Appellant argued that this step (forming a bevelled edge while dicing the substrate) was applicable to all SiC substrates, irrespective of their thickness. The expression "when the wafer is diced" in the cited passage from the description indicated that the forming of the bevelled edge on the substrate and the dicing of the wafer did not have to be done simultaneously. The skilled person would understand that it was particularly advantageous to use this method step with a SiC substrate of reduced thickness, since this would allow the two actions (forming the bevelled edge and dicing) to be carried out in one step. However, there was no indication in the application that it was indispensable to have a substrate of reduced thickness in order to dice it and to form a bevelled edge on it.

3.1.3 The Board cannot follow this argument. At first, the claim uses the term "while" (*forming a bevelled edge...while dicing the wafer*), which indicates that the two actions are carried out simultaneously, i. e. in one step. As explained previously, the passage cited in paragraph 2.1.2 above (page 16, lines 5 and 6 of the published application) is the only mention of this feature in the application as originally filed. According to this passage, the forming of a bevelled edge (eliminate an upper portion of the substrate by the tip of a saw) when the wafer (substrate) is diced is only possible because the substrate has a reduced thickness. This corresponds also to the Appellant's

detailed explanations in the grounds of appeal that it is the fact that the substrate has a reduced thickness that allows the forming of the bevelled edge of the substrate while the substrate is diced, i. e. in one step (grounds of appeal, page 9, point 39).

3.1.4 The Board concludes, therefore, that the inclusion of the feature *forming a bevelled edge to the SiC substrate while dicing the SiC substrate using a saw tip to eliminate an upper portion of the SiC substrate* into the claim without any reference to a substrate of reduced thickness amounts to an unallowable intermediate generalisation. Claim 1 of the 1st Auxiliary Request, therefore, does not meet the requirements of Article 123(2) EPC.

4. 2nd auxiliary request

During the oral proceedings, after the Board expressed its negative opinion regarding the 1st Auxiliary Request, the Appellant submitted a set of claims titled "Replacement 2nd Auxiliary Request" and requested for it to be admitted as its 2nd auxiliary request in the proceedings.

4.1 Admissission

Claim 1 of the 2nd auxiliary request corresponds to claim 1 of the 1st auxiliary request except that the last feature (*forming a bevelled edge to the SiC substrate while dicing the SiC substrate using a saw tip to eliminate an upper portion of the SiC substrate)* has been removed. The dependent claims 2-26 correspond to the the respective dependent claims of the 1st auxiliary request with the exception of claim 17, which

has been deleted, and the corresponding corrections to the numbering and the dependencies of the claims.

4.1.1 The Board, taking into account that:

- the specific objection under Article 123(2) EPC against the 1st Auxiliary request was raised for the first time during the oral proceedings;
- the deletion of the last feature from claim 1 represented a legitimate attempt to overcome this objection;
- the objection appeared *prima facie* to be overcome;
- there were no other features added or removed from the claims;
- the Board was in a position to deal with the request without adjourning the oral proceedings in view of the prior art documents available and the content of the file,

decided to exercise its discretion pursuant Articles 13(1) and (3) RPBA and to admit this request into the proceedings.

4.2 Amendments (Article 123(2) EPC)

With the deletion of the last feature of claim 1 (*forming a bevelled edge to the SiC substrate while dicing the SiC substrate using a saw tip to eliminate an upper portion of the SiC substrate)* the objection under Article 123(2) EPC raised against claim 1 of the 1st Auxiliary request has become moot.

The Board is satisfied that the remaining combination of features is supported by the description and claims as filed, and, hence, that the 2nd auxiliary request meets the requirements of Article 123(2) EPC.

4.3 Patentability

4.3.1 None of the prior art documents discloses forming a metal on a silicon carbide (SiC) substrate opposite a stack of n/p epitaxial layers. Documents D1, D3-D5 do not disclose a SiC substrate with epitaxial layers formed on one side at all. Only D2 discloses such a SiC substrate, but the metal is formed on the same side of the substrate with the stack of the epitaxial layers and not the opposite one, see Figures 7-9 and column 10, line 55 - column 11, line 16.

The subject matter of claim 1 of the 2nd auxiliary request is, therefore, new (Article 54(1) EPC).

4.3.2 Document D1 is considered to represent the closest prior art as it also describes a method for forming ohmic contacts on SiC substrates and has the most features in common with the claimed method.

D1 describes a method for forming ohmic contacts on a SiC substrate using laser annealing at room temperature. In more detail (using the terminology of the claim), D1 discloses a method of forming an ohmic contact (see title of D1, for example), the ohmic contact having a specific contact resistivity of less than 10 e-03 ohm-cm^2 (see Abstract on first page of D1), the method comprising forming a metal on a silicon carbide (SiC) substrate (second page (784), first paragraph), and annealing an interface location of the metal and the SiC substrate to form a metal-SiC material thereat and avoiding annealing at another location on the SiC substrate to avoid forming the metal SiC material thereat (see Figure 1 and last paragraph on first page).

4.3.3 D1 does not disclose:

(i) that the method relates to forming ohmic contact for a light emitting device (LED);

(ii) that the metal is formed on a SiC substrate opposite a stack of n/p epitaxial layers; and

(iii) that the laser light used for annealing has photon energies above a bandgap of the SiC substrate.

Regarding (i), D1 focuses on the formation of ohmic contacts on SiC substrates without regard of their possible uses in other devices. There is mention of a Schottky diode (point 4, last page (786)) and general mention of "SiC devices" (point 5, last page (786)), but no mention or suggestion of a LED.

Regarding (ii), there is no mention of any epitaxial layers on the SiC substrate, either. As previously explained, D1 relates to the forming of ohmic contacts on SiC substrate without any details of a possible device that they could be used in and, hence, there are no details about other possible layers on the substrate.

Regarding (iii), D1 discloses that the wavelength of the laser light is longer than the bandgap of SiC (which indicates that the photon energy of the laser light is lower than the bandgap of SiC), so that the metal layers on the SiC substrate are selectively heated and alloyed (last lines on the first page).

4.3.4 The technical effect of the distinguishing features is a better protection of the epitaxial layers from the laser light during the annealing of the metal. By using a laser with photon energy above the bandgap of SiC,

the substrate will absorb any laser energy that might penetrate the metal during the annealing. In this way, the laser will not reach the epitaxial layers on the opposite site of the substrate, eliminating any risk of damaging them. At the same time, it allows for the possibility to have thinner ohmic contacts, since the SiC substrate will absorb any laser energy that would penetrate the metal.

4.3.5 In D1 there is no mention of epitaxial layers on the SiC substrate and the problem of their protection from the laser is, hence, of no concern. Even if it would be considered that the method of forming an ohmic contact described in D1 would be used in the manufacturing a semiconductor or even a LED device, D1 teaches away from the idea of using a laser with photon energy above the bandgap of SiC. On the contrary, in D1 the laser used for the annealing of the metal has energy below the bandgap so that it is made sure that the SiC substrate will not be heated during the annealing (see last lines on the first page).

4.3.6 Document D2 is the only prior art document which mentions epitaxial layers on the substrate, however, they are formed on the same side as the metal contacts (see Figures 7-9 and column 10, line 55 - column 11, line 16). In addition, in the only embodiment where the energy of the laser used for the annealing is mentioned, it is below the bandgap of the SiC substrate in order to make sure that only the metal is annealed and no damage is done to the substrate (see column 4, lines 34-42).

4.3.7 Documents D3, D4 and D5 all describe methods for forming ohmic contacts on SiC substrates using pulsed laser deposition (PLD). In this process, the metal for

the ohmic contact is deposited on the SiC substrates and annealed using laser light.

In D3, metal (Ni) is deposited on a 6H-SiC substrate using PLD (last lines of left column on first page). There is a mask used so that metal is deposited and annealed only on selected locations (first paragraph on left column on second page). The laser light used for the deposition has a wavelength of 248 nm (first page, right column first paragraph), which corresponds to a photon energy of about 5 eV, which is above the bandgap of 6H-SiC, which is known to be between 2.86 and 3.02 eV. There is no mention of any epitaxial layers on the SiC substrate or of any consideration regarding the relation between the photon energy level of the laser light and the bandgap of the SiC substrate. In addition, the specific resistivity of the formed contact is higher than the values defined in the claim (second page, right column, middle of second paragraph).

D4 describes the use of a PLD method for depositing metal contacts (W/Ti and Al/Ti) on 6H-SiC substrates (first page third paragraph). The PLD is carried out using a KrF excimer laser (first page third paragraph), which is known to have a wavelength of 248 nm and, hence, a photon energy above the bandgap of SiC, as explained previously. There is no mention of any epitaxial layers on the SiC substrate nor of annealing the deposited metal only selected locations of the substrate. There is no consideration regarding the relation between the photon energy level of the laser light and the bandgap of the SiC substrate, either.

D5 describes also the use of a PLD method for depositing metal (W) on 6H-SiC substrates (last

paragraph on first page). A KrF excimer laser is used, which has a photon energy above the bandgap of SiC as explained previously. Like D3 and D4, D5 mentions no epitaxial layers on the SiC substrate. There is no indication of annealing the deposited metal only on selected locations of the SiC substrate nor any consideration regarding the relation between the photon energy level of the laser light and the bandgap of the SiC substrate. Finally, the specific resistivity of the obtained contact is outside the claimed range (see last lines in last page (782)).

Summarizing, documents D3, D4 and D5, although they all disclose the use of laser light with a photon energy above the bandgap of the SiC substrate, they do not disclose any epitaxial layers on the substrate and, hence, the problem of protecting such layers during the annealing of the metal contact is never considered at all.

4.3.8 The skilled person starting from D1 and wishing to obtain the identified technical effect (see paragraph 4.3.4 above) would not consider any of the prior art documents D2-D5 since the corresponding technical problem is never considered in any of them. In addition, the teaching of D1 speaks against a combination with the teaching of any of D3, D4 or D5, since in D1 it is explicitly stated that the photon energy of the laser light used for the annealing is lower than the bandgap of the SiC substrate in order to avoid any damage on the substrate. The skilled person would, thus, not consider using the KrF laser of documents D3, D4 or D5 which has a photon energy above the bandgap of SiC, since this would risk damaging the substrate.

4.3.9 The conclusion is that the subject-matter of claim 1 of the 2nd auxiliary request involves an inventive step within the meaning of Article 56 EPC 1973.

4.4 Claims 2- 26 depend, directly or indirectly on claim 1 and are, therefore, inventive, as well. The description has been adapted to the claims and D1 is cited therein.

5. The Board is, hence, satisfied that the application meets the requirements of the EPC and the EPC 1973.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance with the order to grant a patent with the following documents:

   Description pages 1-19 filed during the oral proceedings before the Board;

   Claims 1-26 as filed and amended during the oral proceedings before the Board, titled "Replacement 2nd Auxiliary Request";

   Drawings: sheets 1/12-12/12 as published.

The Registrar: The Chairman:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated