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Datasheet for the decision of 28 November 2013

Case Number: T 0883/09 - 3.4.03

Application Number: 02769049.4

Publication Number: 1440460

IPC: H01L21/04

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Title of invention:
FORMATION OF SIC BACKSIDE OHMIC CONTACTS FOR SEMICONDUCTOR DEVICES

Applicant:
CREE, INC.

Headword:

Relevant legal provisions:
EPC 1973 Art. 54(1), 56
EPC Art. 123(2)

Keyword:
Amendments - added subject-matter (no)
Novelty (no) - main request
Inventive step (no) - first and second auxiliary request

Decisions cited:

Catchword:

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Case Number: T 0883/09 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 28 November 2013

Appellant: (Applicant)	CREE, INC. 4600 Silicon Drive Durham, NC 27703 (US)
Representative:	Brophy, David Timothy FRKelly 27 Clyde Road Ballsbridge Dublin 4 (IE)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 9 December 2008 refusing European patent application No. 02769049.4 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman:	G. Eliasson
Members:	R. Bekkering
	P. Mühlens

Summary of Facts and Submissions

I. This is an appeal against the refusal of application 02 769 049 for added subject-matter, Article 123(2) EPC.

II. Oral proceedings were arranged as requested by the appellant. The summons to these oral proceedings was provided with an annex in which a provisional opinion of the board on the matter was given.

Reference was made to the following document cited in the application:

D9: S.M. Sze, "*Physics of Semiconductor Devices*", Second Edition, 1981.

In the annex, it was noted that the subject-matter of claim 1 of the main request and the first and second auxiliary requests appeared to lack an inventive step, Article 56 EPC 1973, *inter alia* with respect to document D1 and common general knowledge (as shown by document D9).

III. In a letter dated 24 October 2013, in response to these summons, the appellant filed a new main request and new first and second auxiliary requests.

In a further letter dated 14 November 2013, the appellant announced that a representative for the applicant would not be attending the oral proceedings.

Oral proceedings were held on 28 November 2013 in the absence of the appellant.

IV. The appellant requested in the letter dated 24 October 2013 that the decision under appeal be set aside and that a patent be granted on the basis of the following:

Main request:

Claims 1 to 4 filed with the letter of 24 October 2013,

First auxiliary request:

Claim 1 filed with the letter of 24 October 2013,

Second auxiliary request:

Claim 1 filed with the letter of 24 October 2013.

V. Claim 1 of the main request reads as follows:

"*A method for forming an ohmic contact to silicon carbide for a semiconductor device, the method comprising:*
implanting phosphorus atoms at room temperature into a first surface of an n-type silicon carbide substrate, thereby forming a zone in the silicon carbide substrate having a maximum phosphorus concentration at the first surface, wherein the phosphorus concentration decreases from the first surface toward the opposite surface of the substrate;
thereafter annealing the implanted silicon carbide substrate at or above a first temperature;
thereafter growing at least one epitaxial layer on a surface of the silicon carbide substrate opposite the implanted surface, the at least one epitaxial layer comprising a material incapable of withstanding temperatures at or above the first temperature; and

thereafter depositing a layer of metal on the implanted surface of the silicon carbide to form an ohmic contact between the phosphorus-implanted silicon carbide and the deposited metal."

VI. Claim 1 of the first auxiliary request reads as follows:

"*A method for forming an ohmic contact to silicon carbide for a semiconductor device, the method comprising:*
implanting phosphorus atoms at room temperature into a first surface of an n-type silicon carbide substrate at a plurality of implant energy levels of 25 keV up to 100 keV each with doses of 10^{15} cm^{-2} *or more, thereby forming a zone in the silicon carbide substrate having a maximum phosphorus concentration at the first surface, wherein the phosphorus concentration decreases from the first surface toward the opposite surface of the substrate;*
thereafter annealing the implanted silicon carbide substrate at or above a first temperature; and
thereafter growing at least one epitaxial layer on a surface of the silicon carbide substrate opposite the implanted surface, the at least one epitaxial layer comprising a material incapable of withstanding temperatures at or above the first temperature;
thereafter depositing a layer of metal selected from titanium, aluminium, nickel, silver and platinum on the implanted surface of the silicon carbide to form an ohmic contact between the phosphorus-implanted silicon carbide and the deposited metal."

VII. Claim 1 of the second auxiliary request reads as follows:

"*A method for forming an ohmic contact to silicon carbide for a semiconductor device, the method comprising:*
implanting phosphorus atoms at room temperature into a first surface of an n-type silicon carbide substrate at a plurality of implant energy levels of 25 keV up to 100 keV each with doses of 10^{15} cm^{-2} *or more, thereby forming a zone in the silicon carbide substrate having a maximum phosphorus concentration at the first surface, wherein the phosphorus concentration decreases from the first surface toward the opposite surface of the substrate;*
thereafter annealing the implanted silicon carbide substrate at a temperature of 1300°C or more; and
thereafter growing at least one epitaxial layer on a surface of the silicon carbide substrate opposite the implanted surface, the at least one epitaxial layer comprising a material incapable of withstanding temperatures at or above 1300°C; and
thereafter depositing a layer of metal selected from titanium, aluminium, nickel, silver and platinum on the implanted surface of the silicon carbide to form an ohmic contact between the phosphorus-implanted silicon carbide and the deposited metal."

VIII. The appellant submitted in substance the following arguments:

All amendments were properly based on the application documents as originally filed, so that no subject-matter was added.

Moreover, the cited art failed to describe the features of claim 1, as the cited art completely failed to address when one or more delicate epitaxial layers had to be grown in relation to the creation of an ohmic

contact in order to minimize damage to the layers and generate a reliable ohmic contact. The cited art required at least one annealing process after the growth of epitaxial layers in the semiconductor device, which would permanently damage epitaxial layers that were incapable of withstanding such temperatures. Accordingly, the skilled person following the teaching of Dl would never modify the process of Dl so as to include a step of growing at least one epitaxial layer comprising a material incapable of withstanding annealing temperatures prior to depositing the layer of metal to form an ohmic contact. Moreover, there was nothing to suggest that replacement of the multiple nitrogen implants of D1 with phosphorous implants would eliminate a need for a final contact anneal. The skilled person would, furthermore, know that different parameters (e.g. annealing temperatures, dopant concentrations etc.) were required for different dopants, so that he would never automatically assume that a temperature or any other parameter suitable for annealing nitrogen implants (or a temperature close to this temperature) should also be used for annealing phosphorous implants.

Hence, the subject-matter of claim 1 of the main and the first and second auxiliary requests involved an inventive step.

Reasons for the Decision

1. The appeal is admissible.

2. *Procedural issues*

The amended new claims according to the appellant's main, first auxiliary and second auxiliary request were filed after oral proceedings before the board were arranged.

In view of the fact that the amendments were filed in advance of the oral proceedings, constitute an attempt to overcome the objections raised and are provided with reasons in support thereof, and as the board is able to deal with the requests in substance, without adjournment of the oral proceedings, the new requests are admitted into the proceedings (Article 13(1) and (3) RPBA).

However, an appellant filing amendments, but renouncing to come to oral proceedings before the board to which it was duly summoned, must be taken to waive its right to present comments on any ground for an adverse decision which may arise (Article 113(1) EPC 1973, Article 15(3) RPBA).

3. *Main request*

3.1 *Amendments*

Claim 1 as amended is based on claims 1, 2, 3 and 7 as originally filed, and concerning the feature that the at least one epitaxial layer comprises a material incapable of withstanding temperatures at or above the first temperature, on the description, paragraph [0042] as originally filed.

Accordingly, the amendments to claim 1 of the main request comply with Article 123(2) EPC.

3.2 *Novelty*

3.2.1 Document D1 discloses a method of forming ohmic contacts to devices that include a plurality of semiconductor materials.

In particular, D1 discloses, using the terminology of claim 1, a method for forming an ohmic contact to silicon carbide for a semiconductor device, the method comprising:
implanting phosphorus atoms at room temperature into a first surface of an n-type silicon carbide substrate (cf page 8, line 25 to page 9, line 10),
thereby forming a zone in the silicon carbide substrate having a maximum phosphorus concentration at the first surface, wherein the phosphorus concentration decreases from the first surface toward the opposite surface of the substrate (cf page 9, line 26 to page 10, line 6);
thereafter annealing the implanted silicon carbide substrate at or above a first temperature (cf page 10, line 13 to page 11, line 8);
thereafter growing at least one epitaxial layer on a surface of the silicon carbide substrate opposite the implanted surface, the at least one epitaxial layer comprising a material incapable of withstanding temperatures at or above the first temperature (cf page 11, lines 9 to 11 and 13 to 16); and
thereafter depositing a layer of metal on the implanted surface of the silicon carbide to form an ohmic contact between the phosphorus-implanted silicon carbide and the deposited metal (cf page 11, line 17 to page 12, line 2).

3.2.2 The appellant essentially argued that document D1 failed to address when one or more delicate epitaxial

layers should be grown in relation to the creation of an ohmic contact in order to minimize damage to the layers and generate a reliable ohmic contact. In fact, D1 required at least one annealing process after the growth of epitaxial layers in the semiconductor device, which would permanently damage epitaxial layers that were incapable of withstanding such temperatures. The skilled person following the teaching of Dl would, thus, never modify the process of Dl so as to include a step of growing at least one epitaxial layer comprising a material incapable of withstanding annealing temperatures prior to depositing the layer of metal to form an ohmic contact.

3.2.3 The board, however, disagrees. Document D1 in fact explicitly indicates that "*the desired epitaxial layer or subsequently fabricated device may be made of or comprised of a material (e. g., gallium nitride or a silicon oxide) incapable of withstanding the high temperature anneal of the implanted substrate. In this instance, the epitaxial layer may be formed after the dopant implantation*" and "*After the semiconductor substrate is implanted and a well annealed zone of increased dopant concentration is established, and any epitaxial layers placed on the substrate, the metal selected to form the ohmic contact is applied to the surface of the substrate at the zone of increased carrier concentration*" (cf page 11, lines 13 to 20).

Moreover, insofar as the appellant argued that the method of document Dl required a contact anneal after applying the metal to the surface of the substrate at the zone of increased carrier concentration in order to obtain an satisfactory ohmic contact between the metal and the silicon carbide substrate, it is noted, as was pointed out in the annex to the summons to the oral

proceedings, that claim 1 does not exclude a final contact anneal.

In D1 a contact anneal is foreseen in which "*temperatures and time periods are sufficiently low to avoid damaging any epitaxial layers that are on the substrate*" (cf page 11, lines 30 to 31). Moreover, in fact also the possibility of no final anneal is mentioned (cf page 13, lines 6 to 8)).

3.2.4 Accordingly, the subject-matter of claim 1 of the main request is not new over document D1, Article 54(1) EPC 1973.

The appellant's main request is, therefore, not allowable.

4. *First auxiliary request*

4.1 *Amendments*

Claim 1 according to the appellant's first auxiliary request differs from claim 1 of the main request in that the following further features are defined:

- the implanting is at a plurality of implant energy levels of 25 keV up to 100 keV each with doses of 10^{15} cm^{-2} or more, and
- the metal is selected from titanium, aluminium, nickel, silver and platinum.

The basis for the above first further feature is in the last full sentence of page 9 of the description as originally filed.

In the board's judgement, a further restriction to specific energy levels as suggested in the decision under appeal is not necessary for the amendment to be admissible, the specific energy levels given clearly being only exemplary.

The basis for the above second further feature is in originally filed claim 6.

Accordingly, the amendments to claim 1 of the first auxiliary request comply with Article 123(2) EPC.

4.2 *Novelty*

Regarding the above first further feature, in D1 in a specific embodiment of the invention, an n-type SiC substrate is first implanted at an energy of 50 keV with a $3x10^{14}$ cm^{-2} dose of atomic nitrogen followed by a second implantation at 25 keV at $5x10^{14}$ cm^{-2} (cf page 12, lines 3 to 6).

No details on implant energies or doses are provided in document D1 for a phosphorous implantation.

The above second further feature is known from document D1, according to which preferred metals include nickel, palladium, platinum, titanium and aluminum (cf page 11, lines 23 to 24).

Accordingly, the subject-matter of claim 1 of the first auxiliary request is new over document D1, Article 54(1) EPC 1973.

The subject-matter of claim 1 of the first auxiliary request is also new over the remaining available, more remote prior art.

4.3 *Inventive step*

4.3.1 Regarding the above first further feature, as would be clear to a person skilled in the art, more than the maximum dose of an implant, the cumulative dose of the plurality of implants and the respective energies is important as it defines the carrier concentration and profile of the SiC contact region. In this respect it is noted that according to the application this region is about 100 nm in depth and has a surface carrier concentration of $1x10^{20}$ to 10^{21} cm^{-3} (page 10, lines 4 to 8) compared to D1 in which this region is about 100 nm in depth and has a surface carrier concentration of $1x10^{19}$ to 10^{20} cm^{-3} (page 10, lines 2 to 6).

The objective problem to be solved relative to document D1, thus, is to provide suitable doping conditions.

As it is generally known that the contact resistivity of a metal-semiconductor-contact decreases for higher doping concentrations of the semiconductor (see document D9, pages 304 and 305, equation (99) and figure 43), it would be obvious to a person skilled in the art to use higher doping concentrations and thus higher implant doses. The implant energies used in D1 are eg 25 and 50 keV, falling in the claimed range 25 keV up to 100 keV. Moreover, as document D1 already indicates that phosphorous is a suitable alternative n-type dopant to nitrogen, it would be obvious to the skilled person to implant phosphorous instead.

4.3.2 The appellant essentially argued that there was nothing to suggest that replacement of the multiple nitrogen implants of D1 with phosphorous implants would eliminate a need for a final contact anneal.

It is, however, noted that according to D1 "*The preferred n-type dopants for use in forming the zone of increased carrier concentration 16 are nitrogen, arsenic and phosphorous*" (page 7, lines 18 to 21). As such, there is nothing in D1 to suggest that there would be any fundamental difference between using nitrogen and phosphorous, so that the skilled person would in fact expect the same advantages in ohmic contact formation.

4.3.3 Accordingly, the subject-matter of claim 1 of the first auxiliary request, having regard to the state of the art, is obvious to a person skilled in the art and, therefore, lacks an inventive step, Article 56 EPC 1973.

The appellant's first auxiliary request is, thus, also not allowable.

5. *Second auxiliary request*

5.1 *Amendments*

Claim 1 according to the appellant's second auxiliary request differs from claim 1 of the first auxiliary request in that the following further features are defined:

- annealing the implanted silicon carbide substrate is specified to be at a temperature of 1300 $^{\circ}$C or more, and
- the at least one epitaxial layer is specified to comprise a material incapable of withstanding temperatures at or above 1300 $^{\circ}$C.

The basis for these further amendments is in claim 5 as originally filed, as well as paragraphs [0041] and [0042] of the description as originally filed.

Also here, in the board's judgement, a further restriction to specific anneal times as suggested in the decision under appeal is not necessary for the amendment to be admissible, the specific anneal times indicated clearly only being given by way of example. The view that the anneal time would be indispensable for the function of the invention is not shared by the board. Different numbers of implants, implant energies within the claimed range and doses as well as anneal temperatures within the claimed range and times would yield the desired implanted zone allowing to form an ohmic contact as striven for in the application.

Accordingly, the amendments to claim 1 of the second auxiliary request comply with Article 123(2) EPC.

5.2 *Inventive step*

5.2.1 According to D1 "*Testing shows that annealing the room temperature implanted SiC substrate at temperatures between approximately 1000 °C and 1300 °C for about two hours or less will yield satisfactory results*" (page 11, lines 5 to 7) and "*the desired epitaxial layer or subsequently fabricated device may be made of or comprised of a material (e.g., gallium nitride or a silicon oxide) incapable of withstanding the high temperature anneal of the implanted substrate*" (page 11, lines 13 to 15). Both features above are, thus, suggested in document D1.

For the rest of the subject-matter of the claim, the same applies as for claim 1 of the first auxiliary request discussed above.

5.2.2 The appellant argued that the skilled person would know that different parameters (e.g. annealing temperatures, dopant concentrations etc.) were required for different dopants, so that he would never automatically assume that a temperature or any other parameter suitable for annealing nitrogen implants (or a temperature close to this temperature) should also be used for annealing phosphorous implants.

This argument is, however, not found convincing. Although the skilled person would be aware that parameters might have to be adjusted, there is nothing in D1 suggesting that a fundamentally different set of parameters would be required for phosphorous, indicated in D1 to be an alternative n-type dopant to nitrogen. Accordingly, there would be no reason for the skilled person not to simply take at first the same parameters, in particular the same anneal temperature, for phosphorous.

5.2.3 Accordingly, the subject-matter of claim 1 of the second auxiliary request, having regard to the state of the art, is also obvious to a person skilled in the art and, thus, lacks an inventive step, Article 56 EPC 1973.

The appellant's second auxiliary request is, therefore, not allowable either.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated