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Datasheet for the decision of 10 January 2013

Case Number: T 1381/09 - 3.4.03

Application Number: 99949566.6

Publication Number: 1112593

IPC: H01L 29/51, H01L 21/28, H01L 29/24

Language of the proceedings: EN

Title of invention:
Layered dielectric on silicon carbide semiconductor structures

Applicant:
CREE, INC.

Headword:
-

Relevant legal provisions:
EPC Art. 123(2)
RPBA Art. 13(1), 15(3)

Relevant legal provisions (EPC 1973):
EPC Art. 56, 113(1)

Keyword:
"Added subject-matter (yes) - main and first and second auxiliary requests"
"Inventive step (no) - third auxiliary request"

Decisions cited:
-

Catchword:
-

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Case Number: T 1381/09 - 3.4.03

D E C I S I O N
of the Technical Board of Appeal 3.4.03
of 10 January 2013

Appellant: (Applicant)
CREE, INC.
4600 Silicon Drive
Durham, NC 27703 (US)

Representative:
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Decision under appeal:
Decision of the Examining Division of the European Patent Office posted 13 February 2009 refusing European patent application No. 99949566.6 pursuant to Article 97(2) EPC.

Composition of the Board:

Chairman: G. Eliasson
Members: R. Q. Bekkering
T. Karamanli

Summary of Facts and Submissions

I. This is an appeal against the refusal of application 99 949 566 for lack of an inventive step, Article 56 EPC, over *inter alia* documents

D1: US 5 510 630 A

D5: Nishimura A. et al: "Long Term Reliability of $SiO_2/SiN/SiO_2$ Thin Layer Insulator Formed in 9 µm Deep Trench on High Boron Concentrated Silicon", International Reliability Physics Symposium 1989, Conference proceedings, IEEE, New York, USA, 11 April 1989, pages 158-162.

II. Summons to oral proceedings before the board requested by the appellant applicant were issued with an annex containing objections against the main request and the first to third auxiliary request then on file.

In reply, the appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of the main request or of one of the first to third auxiliary requests, all filed with letter dated 6 December 2012.

Moreover, the board was informed with letter dated 8 January 2013 that neither the representative nor the applicant would be attending the oral proceedings.

Oral proceedings before the board took place on 10 January 2013 in the absence of the appellant.

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

"*A silicon carbide semiconductor device comprising a silicon carbide portion (16) and a dielectric structure of oxide-nitride-oxide on said silicon carbide portion,*
wherein the dielectric structure comprises a first layer (17) of silicon dioxide on said silicon carbide portion, a layer (20) of silicon nitride on said first layer of silicon dioxide and a second layer (21) of silicon dioxide on said silicon nitride layer, the silicon nitride having a dielectric constant higher than the dielectric constant of silicon dioxide, characterised in that the layers (17, 21) of silicon dioxide each have a thickness representing between about 7.7% and 20% of the thickness of the dielectric structure, and the layer (20) of silicon nitride makes up the remainder of the thickness of said dielectric structure."

IV. Claim 1 of the first auxiliary request corresponds to claim 1 of the main request, but with the following characterising portion:

"*characterised in that the layers (17, 21) of silicon dioxide have a combined thickness representing between about 23% and 40% of the thickness of the dielectric structure,*
and the layer (20) of silicon nitride makes up the remainder of the thickness of said dielectric structure, wherein the device is a power device and wherein the dielectric structure forms passivation portions of the power device."

V. Claim 1 of the second auxiliary request corresponds to claim 1 of the first auxiliary request, but with the end of the claim reading:

"*wherein the device is a power device designed to operate in fields of 1 or more megavolts per centimeter and operable above 200°C, and*
wherein the dielectric structure forms passivation portions of the power device."

VI. Claim 1 of the third auxiliary request corresponds to claim 1 of the main request, but with the following characterising portion:

"*characterised in that the first and second layers (17, 21) of silicon dioxide each have a thickness representing about 20% of the thickness of the dielectric structure, and the layer (20) of silicon nitride has a thickness representing about 60% of the thickness of the dielectric structure.*"

VII. The appellant submitted in substance the following arguments in writing:

The original description pages 6 and 11 provided a basis for the percentage ranges relating to the relative thicknesses of the silicon dioxide and silicon nitride layers of the dielectric structure, as claimed in accordance with the main and the first to third auxiliary requests. Accordingly, the amendments were in conformity with Article 123(2) EPC.

Furthermore, none of the references disclosed or suggested the claimed features. At the time of the

invention, persons skilled in the art would not have known whether the oxide-nitride-oxide dielectric structures, known for addressing the issue of breakdown of the dielectric of silicon semiconductor devices, would even work for silicon carbide semiconductor devices. In addition, the claimed dielectric structure provided unexpected results far exceeded expectations. Accordingly, the subject-matter of claim 1 of all requests was new and involved an inventive step over the cited prior art.

Reasons for the Decision

1. The appeal is admissible.

2. *Procedural issues*

The appellant's main and first to third auxiliary requests for the grant of a patent on the basis of amended claims were filed after oral proceedings before the board were arranged.

Any such request entails *inter alia* an assessment by the board as to the conformity of the request with procedural requirements, the request being filed after the statement setting out the grounds of appeal have been submitted and thus its admission and consideration being subject to the board's discretion (Article 13(1) RPBA), as well as, if the request is admitted into the proceedings, an assessment as to the conformity of the claimed subject-matter with the requirements of the EPC, notably clarity, added subject-matter, novelty and inventive step, as a result of which grounds for a

decision adversely affecting the appellant may arise. An appellant submitting such a request should, therefore, expect such grounds to be advanced.

An appellant 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 such grounds (Article 113(1) EPC 1973).

It is, moreover, noted that a different conclusion, ie that the appellant should be given the opportunity to comment, specifically on his request being held inadmissible or not allowable, would make a continuation of the proceedings in writing necessary and, thus, oblige the board to delay its decision in the proceedings by reason only of the absence of the party at the oral proceedings, contrary to Article 15(3) RPBA.

In view of the fact that the requests 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 satisfied that it is able to deal with the requests in substance without adjourning the oral proceedings, exercising its discretionary powers under Article 13(1) RPBA, it admitted the requests into the proceedings.

3. *Main request*

3.1 *Amendments*

Amended claim 1 of the main request contains the feature "*that the layers (17, 21) of silicon dioxide*

each have a thickness representing between about 7.7% and 20% of the thickness of the dielectric structure, and the layer (20) of silicon nitride makes up the remainder of the thickness of said dielectric structure."

According to the appellant, basis for this claim could be found at page 6, lines 19-25 and page 11, lines 8-20 of the application as filed. In particular, at page 6, lines 23-25, each layer was disclosed as having a thickness of 20% of the dielectric structure. This delineated an upper end of a sub-range within the overall range of 0.5% to 33% disclosed at page 6, line 21-23 and claimed in claim 6 of the application as filed. In the example on page 11 on which the passage of page 6 was based, the first dioxide layer had a thickness of 100 Å (10 nm), the nitride layer had a thickness of 500 Å (50 nm) and the second dioxide layer had a thickness of ranging between 50 Å-100 Å (5-10 nm). The second layer was therefore disclosed as having a thickness of as little as 50 Å/650 Å, about 7.7% of the dielectric structure and so this delineated the lower end of a sub-range within the overall range of 0.5% to 33% disclosed at page 6 line 21-23 of the application as filed.

However, as is apparent from the passages above referred to by the appellant, only the second dioxide layer has been disclosed as having a thickness of as little as 50 Å. The first dioxide layer has a thickness of 100 Å, which, following the calculation scheme of the appellant would represent at least 14% (100 Å/700 Å) of the thickness of the dielectric structure. Accordingly, the claimed feature that the layers of

silicon dioxide **each** have a thickness representing between about 7.7% and 20% of the thickness of the dielectric structure, has no basis in the application as originally filed.

Moreover, it is noted that the percentages calculated from the specific thickness of the respective layers of the embodiment on page 11, lines 8 to 20, according the calculation scheme of the appellant extend the relative thicknesses of the layers of the embodiment to layers of any thickness with these relative thicknesses and, thus, constitute an undue broadening with respect to the original disclosure.

Accordingly, the amendments introduce subject-matter, which extends beyond the content of the application as filed, contrary to the requirement of Article 123(2) EPC.

3.2 Therefore, the appellant's main request is not allowable.

4. *First auxiliary request*

4.1 *Amendments*

Amended claim 1 of the first auxiliary request contains the feature "*that the layers (17, 21) of silicon dioxide have a combined thickness representing between about 23% and 40% of the thickness of the dielectric structure, and the layer (20) of silicon nitride makes up the remainder of the thickness of said dielectric structure, wherein the device is a power device and*

wherein the dielectric structure forms passivation portions of the power device".

The appellant argued that again the basis for the upper end of the range, 40%, could be found at page 6, lines 23-25 of the application as filed. From the example on page 11, where the first dioxide layer had a thickness of about 100 Å and the second dioxide layer had a thickness of about 50 Å, it could be seen that this involved a total oxide thickness of 150 Å/650 Å, about 23% of the thickness of the dielectric structure.

However, whereas the embodiment only discloses that the first dioxide layer has a thickness of about 100 Å and the second dioxide layer a thickness of about 50 Å, claim 1 as amended provides for the first and second dioxide layers to have a combined thickness of about 23% of the thickness of the dielectric structure, thereby now encompassing any other thickness of the first and second dioxide layers, provided the sum of the thicknesses meets the claimed criterion. This is an undue broadening with respect to the original disclosure.

Moreover, the embodiment of page 11 referred to above and on which according to the appellant the amendments of claim 1 are based, relates to the dielectric structure of a MIS capacitor. According to claim 1 as amended, however, this dielectric structure now forms passivation portions of a power device. There is no indication in the application as originally filed that this specific dielectric structure would also be suitable to this end.

Accordingly, the amendments introduce subject-matter, which extends beyond the content of the application as filed, contrary to the requirement of Article 123(2) EPC.

4.2 Therefore, the appellant's first auxiliary request is not allowable either.

5. *Second auxiliary request*

5.1 *Amendments*

Claim 1 of the second auxiliary request includes the same amendments of claim 1 of the first auxiliary request.

For the reasons above, these amendments introduce subject-matter, which extends beyond the content of the application as filed, contrary to the requirement of Article 123(2) EPC.

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

6. *Third auxiliary request*

6.1 *Amendments*

Amended claim 1 of the third auxiliary request contains the feature "*that the first and second layers (17, 21) of silicon dioxide each have a thickness representing about 20% of the thickness of the dielectric structure, and the layer (20) of silicon nitride has a thickness*

representing about 60% of the thickness of the dielectric structure."

Basis for this feature is provided on page 6, lines 21 to 25 of the application as originally filed.

The board is, thus, satisfied that the amendments are in conformity with Article 123(2) EPC.

6.2 *Inventive step*

6.2.1 *Document D1*

Document D1 discloses a silicon carbide semiconductor device comprising:
a silicon carbide portion (20, 24, 26) and a dielectric structure (36, 44) of oxide-nitride-oxide (ONO) on said silicon carbide portion (cf column 7, lines 57 to 64), wherein the dielectric structure comprises a first layer (36 and first oxide layer of ONO layer 44) of silicon dioxide on said silicon carbide portion, a layer of silicon nitride (nitride layer of ONO layer 44) on said first layer of silicon dioxide and a second layer of silicon dioxide (second oxide layer of ONO layer 44) on said silicon nitride layer, the silicon nitride having a dielectric constant higher than the dielectric constant of silicon dioxide (implicit material properties) (cf figures 3E to 3H and corresponding description).

Accordingly, a device according to the pre-characterising portion of claim 1 is known from document D1.

Since document D1 is silent on the thickness of the silicon oxide and nitride layers, the subject-matter of claim 1 differs from the device of Dl in that, as specified in the characterising portion of claim 1, the first and second layers of silicon dioxide each have a thickness representing about 20% of the thickness of the dielectric structure, and the layer of silicon nitride has a thickness representing about 60% of the thickness of the dielectric structure.

6.2.2 The objective problem to be solved relative to document D1, providing the closest prior art, is, thus, to select appropriate thicknesses for the silicon oxide and nitride layers forming the dielectric structure.

It is noted in this respect that the ONO dielectric structure with its advantages is well known to a person skilled in the art working in the field of semiconductor technology and it can be safely assumed that he will be familiar with the effects associated with the respective thicknesses of the layers.

Accordingly, the person skilled in the art would select appropriate thicknesses in view of the desired characteristics of the dielectric, as a matter of routine practice, in particular thereby on the one hand taking advantage of the higher dielectric constant of silicon nitride and on the other hand providing sufficiently thick top and bottom oxide layers eg to control the leakage current through the dielectric and the break-down electric field, thereby arriving at thicknesses as claimed.

Reference is, for instance, made to document D5, in which ONO dielectric structures for various thicknesses for use in a silicon DRAM device are compared. Material g in Table 1 of this document, for example, has a bottom oxide thickness of 68 Å, a nitride thickness of 190 Å (values in brackets are actual nitride thickness) and a top oxide thickness of 60 Å. Accordingly, the bottom and top oxide layers each have a thickness representing about 20% (68 Å/318 Å = 21% and 60 Å/318 Å = 19%) of the thickness of the dielectric structure, and the layer of silicon nitride has a thickness representing about 60% of the thickness of the dielectric structure. As can be seen from the above, the claimed relative thicknesses are conventional.

6.2.3 The appellant argued that at the time of the invention, persons skilled in the art would not have known whether the oxide-nitride-oxide dielectric structures of silicon semiconductor devices would even work for silicon carbide semiconductor devices. Just because oxide-nitride-oxide structures were used to address the issue of breakdown of the dielectric at high voltages for silicon semiconductor devices did not necessarily mean that the same structures would address the same problem for silicon carbide semiconductor devices due to the inherent differences between silicon and silicon carbide. In addition, the claimed dielectric structure provided unexpected results. Even if persons skilled in the art would have conceived of applying the prior art oxide-nitride-oxide dielectric structures (ONO) for silicon semiconductor devices to a silicon carbide semiconductor device, the results achieved by the recited dielectric structure far exceeded expectations. As described on page 16 of the application, the claimed

dielectric structure resulted in a 100x or better improvement in high temperature lifetime and, as described on page 18, it had no leakage out to 6 kV (as compared to 2.6 kV and 3.6 kV for SiN and oxide) and broke at a "*world-record level of 5.9 kV*".

It is, however, noted that, contrary to what is argued by the appellant, from document D1 the person skilled in the art already knew that the oxide-nitride-oxide dielectric structures worked for silicon carbide semiconductor devices. It is also noted, that in D1 the ONO dielectric layer is used both as a capacitor dielectric and as passivation to electrically isolate the cell (see column 7, lines 57 to 64 and figures 3F to 3H). Moreover, since it is generally known that eg one of the advantages of the ONO structure is that the higher dielectric constant of silicon nitride compared to silicon oxide allows for thicker layers, reducing the incidence of weak spots and increasing the break-down electric field (see eg document D5, "*Introduction*"), the skilled person would in fact expect the ONO structure to perform better than eg a mere silicon dioxide layer.

6.2.4 Accordingly, the subject-matter of claim 1 according to the third 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 in the sense of Article 56 EPC 1973.

6.3 Accordingly, the appellant's third auxiliary request is not allowable either.

Order

For these reasons it is decided that:

The appeal is dismissed.

Registrar: Chair:

S. Sánchez Chiquero G. Eliasson