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Datasheet for the decision of 13 June 2017

Case Number: T 2150/12 - 3.4.03

Application Number: 04700653.1

Publication Number: 1584110

IPC: H01L29/06

Language of the proceedings: EN

Title of invention:
EDGE RING TERMINATION FOR SILICON CARBIDE DEVICES

Applicant:
Cree, Inc.

Headword:

Relevant legal provisions:
EPC 1973 Art. 56, 84
EPC Art. 52(1), 123(2)
RPBA Art. 13(1)

Keyword:
Late-filed argument - admitted (yes)
Late-filed request - justification for late filing (yes)
Inventive step - (yes)

Decisions cited:
T 0551/09

Catchword:

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Case Number: T 2150/12 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 13 June 2017

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 30 March 2012 refusing European patent application No. 04700653.1 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	G. Eliasson
Members:	S. Ward
	W. Van der Eijk

Summary of Facts and Submissions

I. The appeal is against the decision of the Examining Division refusing European patent application No. 04 700 653 on the ground that the claimed subject-matter did not meet the requirements of Article 123(2) EPC.

II. At the end of the oral proceedings held before the Board the appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of:

- claims 1-11 filed during the oral proceedings at 13.30 hours;
- description, pages 1-16, filed during the oral proceedings at 13.30 hours; and
- drawings, sheets 1/22 - 22/22 as published.

III. The following documents cited by the Examining Division are referred to in this decision:

D1: US 5 994 189 A
D2: EP 1 076 363 A
D3: JP 3 147331 A

IV. Claim 1 reads as follows:

"An edge termination structure for a silicon carbide semiconductor device (20), comprising:
a plurality of p-type spaced apart concentric silicon carbide floating guard rings (34) in a n-type silicon carbide layer (30) that at least partially surround a silicon carbide-based semiconductor junction (32);
an oxide layer (26) on the floating guard rings; and

a p-type silicon carbide surface charge compensation layer (38) between the floating guard rings and adjacent the oxide layer, wherein the surface charge compensation layer has a dopant concentration such that the surface of the surface charge compensation layer adjacent the oxide layer is partially depleted by surface charges of the oxide layer and fully depleted when a reverse bias lower than the blocking voltage of the device is applied to the device;
wherein the p-type surface charge compensation layer (38) extends completely between adjacent ones of the p-type floating guard rings (34);
wherein the p-type surface charge compensation layer (38) has a dose charge of from about $1x10^{12}$ to about $7x10^{12}$ cm^{-2} so as to neutralize a positive charge of the oxide layer of from $1x10^{12}$ to $2x10^{12}$ cm^{-2};
wherein the guard rings (34) have a spacing of from 0.1 µm to 10 µm; and
wherein the floating guard rings (34) extend a first distance into the silicon carbide layer (30) and the surface charge compensation layer (38) extends a second distance into the silicon carbide layer, the second distance being less than the first distance."

Claim 6 reads as follows:

"A method of fabricating an edge termination structure (20) for a silicon carbide semiconductor device, comprising:
forming a plurality of p-type spaced apart silicon carbide concentric floating guard rings (34) in a n-type silicon carbide layer (30) that surround at least a portion of a silicon carbide-based semiconductor junction (32);
forming an oxide layer (26) on the floating guard rings; and

forming a p-type silicon carbide surface charge compensation layer (38) between the floating guard rings and adjacent the oxide layer, wherein the surface charge compensation layer has a dopant concentration such that the surface of the surface charge compensation layer adjacent the oxide layer is partially depleted by surface charges of the oxide layer and fully depleted when a reverse bias lower than the blocking voltage of the device is applied to the device;
wherein the surface charge compensation layer (38) is formed to extend completely between adjacent ones of the floating guard rings (34);
wherein the surface charge compensation layer (38) has a dose charge of from about $1x10^{12}$ to about $7x10^{12}$ cm^{-2} so as to neutralize a positive charge of the oxide layer of from $1x10^{12}$ to $2x10^{12}$ cm^{-2};
wherein the guard rings (34) have a spacing of from 0.1 µm to 10 µm; and
wherein said a plurality of floating guard rings (34) are formed so that they extend a first distance into the silicon carbide layer and wherein said silicon carbide surface charge compensation layer (38) is formed so that it extends a second distance into the silicon carbide layer, the second distance being less than the first distance."

V. The findings of the Examining Division, insofar as they are relevant to the present decision, may be summarised as follows:

Claims 1 and 17 [as then on file] infringed the requirements of Article 123(2) EPC.

Furthermore, for completeness, the subject-matter of claim 1 (and claim 17) did not involve an inventive

step within the meaning of Article 56 EPC. Document D1 was the closest prior art and disclosed an edge termination structure for a semiconductor device. Claims 1 and 17 differed only in specifying that the device was made of silicon carbide, a well-known material with known properties (higher switching speed and higher current density in comparison with silicon). No inventive step could therefore be seen in such a choice.

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

(i) In the letter of 12 May 2017 the appellant introduced an argument not made in the statement of grounds of appeal (or before the department of first instance) that the features of document D1 referred to in the contested decision (in particular, ring shaped p diffusion region 20, and p^- diffusion region 5) were part of the active region of the device and did not form part of an edge termination structure as claimed.

(ii) Consequently, in the oral proceedings, the appellant argued that D1 was an unsuitable starting point, and that document D2 should be taken as the closest prior art.

Reasons for the Decision

1. The appeal is admissible.

2. *Admissibility of the new argument and new request*

2.1 The argument referred to under point VI(i), above, was submitted after the filing of the grounds of appeal. The Board nevertheless took the view at oral proceedings that this argument did not add significantly to the complexity of the case, nor would its introduction seriously compromise the need for procedural economy. Consequently, the Board decided to use its discretion under Article 13(1) RPBA to admit the argument into the proceedings.

2.2 However, since the aim of the new argument was to establish that D1 was not highly relevant, and did not represent a suitable choice of closest prior art, the Board stressed that its admission into the proceedings was likely to lead to a discussion of inventive step based on the documents on file other than D1. The filing of the present main request may be seen as a direct response to those discussions (specifically in relation to D2), and this request is therefore admitted into the proceedings.

3. *Article 123(2) EPC*

Claim 1 is based on original claims 1, 2, 4, 11, 16 and 20, plus features drawn from page 6, lines 15-25, page 10, lines 4-18 and page 11, lines 1-5. Claim 6 is based on original claim 22 plus additions corresponding to those of claim 1 *mutatis mutandis*. Dependent claims 2-5 and 7-11 correspond to claims 12, 15, 18, 19, 30, 33, 36, 39 and 40 as originally filed. The requirements of Article 123(2) EPC are therefore judged to be met.

4. *Article 84 EPC 1973*

4.1 The Examining Division objected that the term "blocking voltage" was vague and unclear. The appellant argued

that the term "blocking voltage" would be well-known to the skilled person as being synonymous with "breakdown voltage".

4.2 Within the context of the technology of the present application, the terminology used in the claims would not, in the opinion of the Board, give rise to confusion in the mind of a skilled reader, and thus the requirements of Article 84 EPC 1973 are met.

5. *Document D1*

5.1 In semiconductor power devices, a reduction in the breakdown voltage can occur as a result of electric field crowding at the edge of the active region. To prevent this, "edge termination structures" are routinely provided in an inactive peripheral region located outside the active region of the device, the active region being typically surrounded by the edge termination structure. As explained in the application, "floating guard rings" located in the peripheral region represent one well-known type of edge termination structure.

5.2 In the contested decision (point 15), document D1 was said to disclose an edge termination structure comprising *inter alia* a plurality of spaced apart concentric floating guard rings, which were identified with the p diffusion region 20.

5.3 The Board accepts that the p diffusion region 20 of D1 comprises individual elements in the form of floating rings ("floating field rings" - column 12, lines 53-58). However, this region is located between the drain electrode 12 and the structure comprising the source electrode 11 and gate electrode 9. It is

therefore within the active region of the device, and not in an inactive or peripheral region. The p diffusion region 20 of D1 does not, therefore, represent an edge termination structure.

5.4 Since document D1 does not disclose an edge termination structure comprising a plurality of floating guard rings (indeed, it does not appear to disclose any edge termination structure at all), the Board agrees with the appellant that it does not represent a suitable choice of closest prior art for the subject-matter claimed in the present application.

6. *Inventive step starting from D2*

6.1 The appellant stated in oral proceedings that D2 was the closest prior art, and the Board also considers this document to be a suitable starting point.

6.2 At least the following two differences between claim 1 and document D2 may be identified (emphasis in bold added by the Board):

(a) the edge termination structure is for a **silicon carbide** device (the floating guard rings, the n-type layer, the p-type surface charge compensation layer and the semiconductor junction are all formed from **silicon carbide**); and

(b) the p-type surface charge compensation layer **extends completely** between adjacent ones of the p-type floating guard rings.

The appellant argued that there are several additional differences between claim 1 and D2 which further contribute to the inventive character of the subject-

matter. In view of the conclusions reached below, it is not necessary for the Board to form a judgement on this aspect of the appellant's case in the present decision.

6.3 Concerning feature (a), it would appear that the use of silicon carbide was seen by the Examining Division as a solution of the problem of providing a higher switching speed and allowing higher current densities (Reasons, point 15), these two advantages of silicon carbide over silicon being also listed in the description (page 1, final paragraph). This is considered to represent a plausible problem.

For completeness, it is mentioned that the problem previously posed by the Examining Division (communication of 18 July 2006, point 2) of "increasing the breakdown voltage of the device" would also have been a plausible problem, in view of the well known advantages of silicon carbide in this regard.

6.4 The problem solved by feature (b) is set out in the description (page 10, lines 26-34) as follows:

"While the structure illustrated in Figure 3 may be effective at compensating for oxide charges, the small spacing between the floating guard rings that are provided in silicon carbide devices may make fabrication of [the devices shown in Figure 3] difficult because of the tight alignment tolerances that may be needed for photolithography. Therefore, in silicon carbide devices, it may be more practical to merge all surface-charge compensating p-layers into one pattern, connecting all guard rings as shown in Figure 4. Thus, as illustrated in Figure 4, a silicon carbide device 20' is provided having a surface charge

compensation layer 38 that is provided between adjacent ones of the floating guard rings 34."

Hence, based on the description of the present application, the problem could be expressed as providing a silicon carbide device in a form which permits simple and straightforward fabrication.

The Board's understanding is that the separation of the guard rings is typically considerably smaller for silicon carbide devices in comparison to similar silicon devices, as stated in the description. Hence, the problem referred to in the description is seen as plausible and not requiring reformulation.

6.5 The two problems solved by features (a) and (b) are not completely independent or unrelated. Starting from D2, which discloses a device made of silicon, the second problem (which is disclosed as resulting from the use of silicon carbide) would only arise if the skilled person had already arrived at the claimed solution of the first problem (to employ silicon carbide instead of silicon). It is therefore justified to carry out the examination of inventive step in two steps, one for the solution to the first problem and one for the solution to the second problem (see T 551/09, Reasons, point 6.3).

Thus, in principle, the Board is required to ask whether the claimed solution to the first problem would be obvious to the skilled person, and if so, whether the claimed solution to the second problem would also be obvious. If the answer to either of these questions is no, then the subject-matter is inventive. If the answer to both of these questions is yes, then the claimed subject-matter could still possibly be

inventive if it represented a true combination rather than merely an aggregation of features (see Case Law of the Boards of Appeal, I.D.9.2.2, 8th edition 2016).

6.6 However, in the present case, it is not necessary for the Board to answer the first question, since, even if it were acknowledged *arguendo* that it would be obvious for the skilled person to select silicon carbide in place of silicon for the device of D2, the Board does not believe that it would be obvious for the skilled person to arrive at feature (b).

6.7 In document D2 the n and p shallow rings 11a and 11b may be seen as corresponding to the claimed surface charge compensation layer. One of these rings may be omitted in the case where the polarity of the charge in the oxide layer is known (paragraph [0017], final sentence). However, there is no hint or suggestion that they may extend completely between adjacent guard rings.

6.8 The p^- diffusion regions in document D1 extend completely between the p diffusion regions 20. However, as noted above, this structure is not an edge termination device, nor does this arrangement have anything to do with problems of manufacturing.

6.9 Document D3 discloses a high breakdown strength semiconductor device. Fig. 2 depicts a first region 2 and a second region 3, both of p^+ type, and a third region 8 of p^- type. The region 2 appears to correspond to an active region of the device (an anode in the case of a diode, and a base in the case of a transistor), and the region 3 corresponds to guard rings, which therefore appear to be located outside the active region. Hence, D3 discloses an edge termination

structure comprising a plurality of floating guard rings of p^+ type, and wherein p^- type layers (third region 8) extend completely between adjacent ones of the floating guard rings.

The purpose of the third region 8 appears to be to achieve a combination of high breakdown voltage and improved switching characteristic. D3 does not disclose that the third region 8 is intended to compensate for the effects of charge in the oxide layer, nor is it implicit that it would be suitable for this purpose - charge in the oxide layer is simply not mentioned. Hence, the Board does not believe that document D3 discloses anything which could properly be referred to as a "surface charge compensation layer".

Moreover, the problem is to provide an arrangement which simplifies the manufacturing of devices formed in silicon carbide. The Board sees no plausible route to the claimed solution (or any solution of this problem) based on D3, a document which does not disclose any particular material, and in which there is no reference to manufacturing.

6.10 The Board therefore judges that the subject-matter of claim 1 involves an inventive step within the meaning of Article 52(1) EPC and Article 56 EPC 1973. The subject-matter of claim 6 involves an inventive step for the same reasons, *mutatis mutandis*. All other claims depend on claims 1 or 6.

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 on the basis of:

   - claims 1-11 filed during the oral proceedings at 13.30 hours;

   - description, pages 1-16, filed during the oral proceedings at 13.30 hours; and

   - drawings, sheets 1/22 - 22/22 as published.

The Registrar: The Chairman:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated