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Datasheet for the decision of 13 July 2023

Case Number: T 2465/19 - 3.4.03

Application Number: 09812501.6

Publication Number: 2353183

IPC: H01L29/24, H01L21/331, H01L29/737

Language of the proceedings: EN

Title of invention:
SEMICONDUCTOR DEVICES WITH CURRENT SHIFTING REGIONS AND RELATED METHODS

Applicant:
Wolfspeed, Inc.

Headword:

Relevant legal provisions:
EPC Art. 56
RPBA 2020 Art. 13(2)

Keyword:
Inventive step - (yes) - non-obvious alternative
Amendment after summons - filed on express invitation from the Board - not detrimental to procedural economy - taken into account (yes)

Decisions cited:
G 0002/21, T 1294/16

Catchword:
Admittance under Article 13(2) RPBA of claims and an adapted description filed as a response to the express invitation of the Board in its communication under Article 15(1) RPBA to file such amended application documents (Reasons 3).

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Case Number: T 2465/19 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 13 July 2023

Appellant: (Applicant)	Wolfspeed, Inc. 4600 Silicon Drive Durham, NC 27703 (US)
Representative:	Boult Wade Tennant LLP Salisbury Square House 8 Salisbury Square London EC4Y 8AP (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 12 March 2019 refusing European patent application No. 09812501.6 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	T. Häusser
Members:	M. Stenger
	T. Bokor

Summary of Facts and Submissions

I. The appeal concerns the decision of the Examining Division to refuse European application no. 09 812 501. In the contested decision, the Examining Division set out that none of the main request and auxiliary requests 1 and 2 then on file was allowable under Articles 52(1) and 56 EPC. The contested decision further contains some remarks concerning objections under Articles 84 and 123(2) EPC.

II. The appellant requests that the contested decision be set aside and that a patent be granted according to a main request filed with letter dated 5 June 2023. The main request consists of the following application documents:

Description, Pages

2, 7-8, 10, 12, 13, 15, 17-18, 25-26 as published,

1, 11, 14, 16, 20, 23 as filed with letter dated 7 February 2012,

3, 3a, 4, 6 as filed with letter dated 9 October 2013,

5, 9, 19, 21, 22, 24 as filed with letter dated 5 June 2023,

Claims, Numbers

1-13 as filed with letter dated 5 June 2023,

Drawings, Sheets

1-6 as published.

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

A semiconductor device comprising:
a semiconductor buffer layer (209) having a first conductivity type;
a semiconductor mesa (203) having the first conductivity type on the buffer layer;
a current shifting region (211) within the semiconductor buffer layer having a second conductivity type adjacent a corner between the semiconductor mesa and the semiconductor buffer layer, wherein the first and second conductivity types are different conductivity types;
a semiconductor control layer (215) having the second conductivity type on the semiconductor buffer layer so that the semiconductor buffer layer is between the semiconductor control layer and the semiconductor mesa and so that semiconductor buffer layer is between the current shifting region and the semiconductor control layer;
and
a control contact region (207) having the second conductivity type, wherein the control contact region extends through the semiconductor buffer layer to provide electrical coupling with the semiconductor control layer, wherein the control contact region is spaced apart from the current shifting region so that the current shifting region is electrically isolated from the control contact region.

IV. Claim 10 of the main request has the following wording:

A method of forming a semiconductor device, the method comprising:

providing a semiconductor buffer layer (209) having a first conductivity type;
providing a semiconductor mesa (203) having the first conductivity type on the buffer layer;
providing a current shifting region (211) within the semiconductor buffer layer having a second conductivity type adjacent a corner between the semiconductor mesa and the semiconductor buffer layer, wherein the first and second conductivity types are different conductivity types;
providing a semiconductor control layer (215) having the second conductivity type on the semiconductor buffer layer so that the semiconductor buffer layer is between the semiconductor control layer and the semiconductor mesa and so that semiconductor buffer layer is between the current shifting region and the semiconductor control layer;
and
providing a control contact region (207) having the second conductivity type, wherein the control contact region extends through the semiconductor buffer layer to provide electrical coupling with the semiconductor control layer, wherein the control contact region is spaced apart from the current shifting region so that the current shifting region is electrically isolated from the control contact region.

V. It is referred to the following document:

D1: WO 2006/135031 A2

VI. The appellant argued essentially that neither the claimed invention nor its benefits were obvious to the skilled person.

Reasons for the Decision

1. The appeal is admissible.

2. The invention

The invention (see in particular paragraphs [10] and [11]) relates to semiconductor devices with a mesa provided on the surface of a buffer layer, both having the same conductivity type. To mitigate the problems of electric field crowding at the mesa corner and current gain degradation by surface recombination of carriers, a current shifting region with a conductivity type different than the conductivity type of the mesa and the buffer layer is provided adjacent the mesa corner between the mesa and the buffer layer.

3. Admittance of the request underlying the present decision, Article 13(2) RPBA

3.1 The claims and the adapted description had been filed as a response to the express invitation of the Board in its communication under Article 15(1) RPBA to file such amended application documents. The Board also indicated in its communication what amendments were expected. The Board is also satisfied that the amendments address the Board's objections, and already prima facie appear suitable to overcome the outstanding objections.

3.2 The Board holds that such a situation cannot be considered to constitute truly "exceptional circumstances" as required by Article 13(2) RPBA, at least according to its plain wording. After all, such conduct of the proceedings can even be considered as

perfectly normal in an appeal against a decision of an examining division (ex-parte appeal proceedings).

3.3 Nevertheless, the Board is convinced that the procedural situation in the present case is certainly covered by the legislative intent underlying the structure of Articles 12 and 13 RPBA, and the request is not inadmissible for the absence of exceptional circumstances.

3.4 The appellant stated that the Board raised new objections. Indeed, this is a situation that was foreseen to constitute an exceptional circumstance for the purposes of Article 13(2) RPBA (see the explanatory notes to the RPBA 2020, Supplementary Publication 1 to OJ EPO 2020, p. 178, the explanations to Article 13(2) RPBA, English version, are on page 221). However, some of the objections mentioned by the Board were not new. The invitation to adapt the description may have been new, but certainly could not have been surprising.

3.5 On that basis, the Board could have come to the conclusion that the amendments were not admissible under Article 13(2) RPBA. On the other hand, there is a further procedural aspect that strongly supports the admittance of the request. Articles 12 and 13 of the RPBA make no formal distinction between inter-partes and ex-parte cases, the provisions are equally applicable. However, these provisions mainly serve to prevent the raising of such issues that cannot be expected to be treated by other parties or the Board within the foreseeable extent of the appeal proceedings, and in particular in view of the expected decision at the end of the oral proceedings (Article 15(6) RPBA). In the present case the Board is satisfied that the amendments in fact do not raise new issues for

the Board. They are therefore not detrimental to procedural economy, and there is also no other party whose interest could be jeopardized by such late amendments (see also decision T 1294/16 cited in the Case Law of the Boards of Appeal, 10th edition, July 2022, reasons 18.2 and 18.3). The Board also sees no reason to depart from the settled practice to adapt the description only after the establishment of an allowable claim set.

3.6 The Board observes that even in the situation where the Board raises new objections, the appellant is expected to provide an explanation for the late filing of any amendments. In view of the totality of the circumstances of the present case, in particular in view of the fact that the amendments were filed following the express invitation from the Board, requiring such an explanation from the appellant is clearly counter-intuitive. The Board is well aware for which purpose the amendments were filed and why they were filed at that stage. Thus no detailed arguments and reasons are required from the appellant in the present case.

3.7 For these reasons, the Board admits the main request under Article 13(2) RPBA.

4. Articles 84 and 123(2) EPC

The objections of the Examining Division with respect to Article 84 EPC (unclear use of the definite article) and Article 123(2) EPC (intermediate generalisation) have been overcome by the amendments of the application documents filed with the letter dated 5 June 2023.

5. Inventive step, Article 56 EPC

5.1 Closest prior art

The Examining Division chose D1 as representing the closest state of the art. This was never contested by the appellant and the Board sees no reason to disagree.

5.2 Difference, technical effect

5.2.1 The Examining Division set out that the subject-matter of claim 1 of the main request differed from D1 by the following feature:

i) *wherein the control contact region is spaced apart from the current shifting region so that the current shifting region is electrically isolated from the control contact region.*

The appellant did not contest this finding and the Board, in particular in view of Figure 7 of D1 and the corresponding parts of the description, sees no reason to disagree.

The Examining Division, referring to page 14, lines 4 to 9 and 17 to 19 and page 19, lines 3 to 10 of D1, found that the recombination-inhibiting layer 57 of the device of that document (see also page 23, lines 2 to 10 and Figure 7) had the same function and effect as the corresponding current shifting region of the application, namely, to reduce the surface recombination by keeping carriers away from the surface. D1 and the application therefore solved the same (subjective) technical problem and feature i) had no (additional) advantage or surprising/beneficial effect. Feature i) was therefore not important.

The Examining Division further set out that the original description was not only totally silent about any such advantage or beneficial/surprising effect, but that the statement in paragraph [88] of the application ("While a gap is shown between current shifting region 211xx and electrode 205, portions of buffer layer 209xx and base contact region 207 may occupy this gap without changing the results of the simulation") indicated in fact that a direct contact between the current shifting region and the base contact region would not have much influence, supporting the Examining Division's view that feature i) was not important and rather represented an arbitrary modification.

On the contrary, the influence of defects and recombination was, according to D1, neutralised along a larger part of the surfaces and side walls of the device, thereby improving the current gain even more than the current shifting region 57 according to feature i), which was formed only directly adjacent the mesa corner. In addition, the manufacturing of the claimed configuration was more complicated and costly as compared to that of D1. The claimed configuration was therefore disadvantageous with respect to the one taught in D1.

An arbitrary modification of a known device having only disadvantages as compared to that known device could not justify an inventive step.

5.2.2 The appellant accepted that D1 and the application (in paragraph [10]) had the common goal to reduce surface recombination. This did not prove, however, that the novel feature of the invention provided no advantage (grounds for appeal, page 6, last paragraph to page 7, second paragraph). The appellant further submitted that

the disclosure of advantages in the description was not a requirement for inventive step, as long as such advantages were derivable from the application (grounds for appeal, page 2, last paragraph).

The recombination inhibiting layer of D1 might lead to a current pathway with higher resistance than the preferred pathway, whereby a higher proportion of current would take the preferred pathway. However, the recombination inhibiting layer was part of a forward biased p-n junction, whereby some carriers would be injected into it, creating an alternative current pathway. This alternative current pathway would negatively impact the gain of the BJT (grounds for appeal, page 3, second and third paragraphs).

In contrast thereto, according to the invention, the p-n junction surrounding the current shifting region was isolated from the contact control region. It was therefore not forward biased and the depletion region surrounding the current shifting region acted as a current barrier, reducing alternative current pathways around the mesa and thereby improving current gain (grounds for appeal, page 3, last paragraph to page 4, second paragraph). Thus, the number of carriers recombining due to surface defects was lower than in D1, leading to an improvement in long-term device performance by avoiding damage to the device (grounds for appeal, page 7, third and fourth paragraphs).

That a p-n junction between the buffer layer and the current shifting region reduced/prohibited the flow of electrical current through the current shifting region was disclosed in the application in paragraph [55] and derivable from paragraphs [70] and [88] (grounds for appeal, page 6, penultimate paragraph).

The passage in paragraph [88] of the application cited by the Examining Division comprised the conjunction "and" and not the conjunction "and/or" and could thus not be interpreted as meaning that the gap shown in figure 6B could be occupied by either the buffer layer or the base contact region. Such an interpretation would furthermore contradict paragraph [70]. Instead, the cited passage should be read as meaning that the gap could be filled by both the buffer layer and the base contact region, thereby excluding a filling only by the base contact region and thus an electrical contact between the current shifting region and the base contact region (grounds for appeal, page 5, last paragraph to page 6, antepenultimate paragraph).

5.2.3 The Board notes that D1 aims at improving the current amplification factor (page 6, lines 11 to 14) by inhibiting recombination of holes and electrons at surface states (page 4, lines 13 to 23). This is achieved by separating the surface having a large number of surface states from the portion that primarily conducts the current (page 6, lines 6 to 11).

The application aims at avoiding current gain degradation (paragraph [10]) due to carrier recombination and/or surface recombination, especially in emitter mesa corners, by reducing surface recombination at emitter mesa corners (paragraph [50]). This is achieved by shifting current (crowding) away from mesa corners toward the (SiC) bulk (paragraphs [50] and [55]).

Both the application and D1 thus aim at reducing surface recombination by avoiding the presence of carriers near surfaces of the device, as acknowledged

by the appellant, and the recombination-inhibiting layer 57 of D1 has the same general function and effect as the corresponding current shifting region of the application, namely, to keep current / carriers away from such surfaces, as noted by the Examining Division (contested decision, point 1.3).

5.3 Objective technical problem, obviousness

5.3.1 This general function and effect is, however, achieved by different means as evident from the wording from claim 1 as follows. Starting from D1, the objective technical problem may then be formulated as how to achieve the effect of keeping the current away from the surface of the semiconductor in an alternative manner.

The Board accepts that the application does not explicitly mention any particular additional advantage or surprising beneficial effect obtained by the control contact region being "spaced apart from the current shifting region so that the current shifting region is electrically isolated from the control contact region", as pointed out by the Examining Division (point II.1.3 of the contested decision: "the original description being totally silent about such a beneficial effect").

However, the wording of claim 1 with respect to the current shifting region and the surrounding regions requires that the current shifting region is spaced apart from the control contact region by a p-n junction, as set out by the Examining Division with respect to auxiliary request 1 underlying the contested decision (point II.4).
The wording of claim 1 even requires that the current shifting region is surrounded by a p-n junction, as pointed out by the appellant (grounds of appeal,

paragraph bridging pages 3 and 4) and in line with the remark of the Examining Division that the wording of claim 1 implies "actually a total number of two p-n junctions" (point II.4 of the contested decision).

The presence of this surrounding p-n junction implies that there is an additional p-n junction in the undesirable current path between the emitter region and the base contact region close to the semiconductor surface. This p-n junction is not forward biased and provides a depletion region blocking this current path, as submitted by the appellant (grounds of appeal, page 8, fourth paragraph). Thus, contrary to what the Examining Division set out, feature i) cannot be said to have only disadvantages with respect to D1. Further, since the advantages of the (additional) p-n junction are mentioned in paragraph [55] as pointed out by the appellant, this feature cannot be seen as arbitrary, contrary to the Examining Division's opinion. The Board notes that the technical effect of an invention over the closest prior art need not be explicitly stated in the application, as long as it is derivable from the original application, in particular since the closest prior art may not have been known to the applicant when drafting it (see also decision G 2/21, Headnote II.).

5.4 The passage in paragraph [88] (referring to Figure 6B) of the published application cited by the Examining Division mentioning that "portions of buffer layer 209xx and base contact region 207 may occupy this gap without changing the results of the simulation" might *per se* be read as meaning that filling the upper part of the gap by portions of the base contact region only and the lower part of the gap by portions of the buffer layer only does not change the results of the simulation. The Board notes that such a gap filling

arrangement would be in line with the use of the conjunction "and" instead of "and/or" in the passage cited by the Examining Division, as postulated by the appellant. A gap filled in that manner would essentially correspond to the arrangement disclosed in D1, as set out by the Examining Division (page 7 of the contested decision, penultimate paragraph: "covering in fact also a direct contact between the current shifting region and the base contact region ... in analogy to D1").

However, the Board notes that such an arrangement is not shown in any of the embodiments of the application. On the contrary, in each of Figures 2A, 2B, 2C, 3A, 3B, 4A, 4B, 5A and 5B, a portion of the buffer layer 209 is arranged at the surface of the semiconductor device between the emitter 203 and the base contact region 207 (reference numerals 209, 203 and 207 corresponding to Figure 2A). Therefore, the Board holds that the cited passage has to be read, in the context of the application as a whole, as *excluding* that the gap mentioned is filled in the upper part near the semiconductor surface exclusively by portions of the base contact region. Thus paragraph [88] cannot be interpreted as meaning that the results of the simulation would be the same for the arrangements according to the application on the one hand and D1 (having a direct contact between the base contact region and the recombination inhibiting region) on the other hand. Rather, it has to interpreted as meaning that the results of the simulation would be the same for an arrangement as shown in Figures 2A, 2B, 2C, 3A, 3B, 4A, 4B, 5A and 5B and an arrangement where there is, at the semiconductor device surface, a gap between the current shifting layer and the base contact region (as shown in Figure 6B, where the p-n junction defined

in claim 1 is replaced by a gap, which definitely would block electrical current from passing). Thus, the passage of paragraph [88] cited by the Examining Division does not support its view that feature i) is not important (contested decision, page 7, antepenultimate and penultimate paragraphs).

5.5 It follows from the above that the distinguishing feature i) does not represent an arbitrary modification of the device of D1 having only foreseeable disadvantages in the sense of section I.D.9.21.1 of the Case Law of the Boards of Appeal of the European Patent Office (10th edition 2022), on which no acknowledgement of an inventive step can be based as set out by the Examining Division.

Instead, distinguishing feature i) rather represents an alternative solution to a known problem as referred to in section I.D.4.5 of the Case Law of the Boards of Appeal (10th edition 2022), having particular properties with respect to the solution known from D1.

For instance, the structure of D1 might be easier to manufacture than the structure according to the application because the mask used for mesa etching can be used for implanting the recombination inhibiting region, as set out in the contested decision (page 5, third paragraph). Further, the region in which the current is reduced is larger in D1 than in the application, because it extends completely between the emitter region and the base contact region, as also set out by the Examining Division.

On the other hand, in the application, a smaller area of the surface of the semiconductor device has to be doped by ion implantation and the function of keeping

current away from the surface is provided by the depletion region of an additional p-n junction adjacent the mesa corner instead of a low dopant concentration over the whole surface (irrespective of whether or not the latter would lead to an alternative current path as submitted by the appellant or not).

5.6 In the absence of any corresponding suggestions (e.g. from the other available documents of the state of the art), the Board finds that it would not have been obvious for the skilled person, starting from D1, to change the geometry of the recombination inhibiting region when attempting to find an alternative solution for the problem of keeping the current away from the surface of the semiconductor. Instead, the Board believes that the skilled person, starting from D1, would rather have tried to modify the dopant concentration or to provide an additional recombination-inhibiting film (similar to film 58 shown in Figure 7 of D1) to solve the problem at hand.

The Board thus concludes that the subject-matter of claim 1 of the main request involves an inventive step within the meaning of Article 56 EPC with respect to D1 as closest state of the art and combined with the common general knowledge of the skilled person.

The same conclusion applies to independent method claim 10 of the main request (which corresponds to claim 1) and therefore also to the dependent claims.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the Examining Division with the order to grant a European patent in the following version:

Description, Pages

2, 7-8, 10, 12, 13, 15, 17-18, 25-26 as published

1, 11, 14, 16, 20, 23 as filed with letter dated 7 February 2012

3, 3a, 4, 6 as filed with letter dated 9 October 2013

5, 9, 19, 21, 22, 24 as filed with letter dated 5 June 2023

Claims, Numbers

1-13 as filed with letter dated 5 June 2023

Drawings, Sheets

1-6 as published

The Registrar: The Chairman:

S. Sánchez Chiquero T. Häusser

Decision electronically authenticated