

Publication in the Official Journal Yes / No

File Number: T 409/90 - 3.4.1  
Application No.: 85 101 755.8  
Publication No.: 0 156 156  
Title of invention: Avalanche photodiodes

Classification: H01L 31/10

D E C I S I O N  
of 29 January 1991

Proprietor of the patent: FUJITSU LIMITED

Headword:

EPC Article 87(1); Article 56

Keyword: Right to priority (NO) - Different inventions  
Inventive step (NO) - Arbitrary dimensioning on the basis of known effects.

Headnote

I. The invention which is the subject of the priority document has to be determined from a consideration of the priority document as a whole, as read by a skilled person (cf. point 2.3.(a) of the reasons for the decision).

II. When considering what is disclosed by a claim of a priority document it is relevant that the purpose of the claim is to define the protection which is sought. The fact that a claim in a priority document is broad enough to cover specific subject-matter claimed for the first time in a European patent application cannot by itself be sufficient evidence that such subject-matter has already been disclosed in the priority document to as to establish identity of invention for the purpose of claiming priority under Article 87 EPC (cf. point 2.3(a) of the reasons for the decision).

Publication in the Official Journal ~~Year~~ / No

File Number: T 409/90 - 3.4.1  
Application No.: 85 101 755.8  
Publication No.: 0 156 156  
Title of invention: Avalanche photodiodes

Classification: H01L 31/10

D E C I S I O N  
of 29 January 1991

Proprietor of the patent: FUJITSU LIMITED

Headword:

EPC Article 87(1); Article 56

Keyword: Right to priority (NO) - Different inventions  
Inventive step (NO) - Arbitrary dimensioning on the basis of known  
effects

Headnote



((2))

Case Number : T 409/90 - 3.4.1

**D E C I S I O N**  
of the Technical Board of Appeal 3.4.1  
of 29 January 1991

**Appellant :**  
FUJITSU LIMITED  
1015, Kamikodanaka  
Nakahara-ku  
Kawasaki-shi  
Kanagawa 211  
JAPAN

**Representative :**  
Sunderland, James Harry  
HASLITINE LAKE & CO  
Hazlitt House  
28 Southampton Buildings  
Chancery Lane  
London WC2A 1AT  
United Kingdom

**Decision under appeal :**  
Decision of Examining Division of the European  
Patent Office dated 4 December 1989 refusing  
European patent application No. 85 101 755.8  
pursuant to Article 97(1) EPC.

**Composition of the Board :**

**Chairman :** Paterson G.D.  
**Members :** Reich H.J.  
van Henden Y.

## Summary of Facts and Submissions

- I. European patent application No. 85 101 755.8 (publication number 0 156 156) is a divisional application from parent application No. 81 305 658.7 (publication number 0 053 513) and was refused by a decision of the Examining Division in respect of published Claim 1 reading as follows:

"1. An avalanche photodiode comprising:-

a light absorbing layer (3), of a semiconductor containing at least one impurity of one conductivity type,

an active layer (5) of a semiconductor providing lattice matching between itself and the light absorbing layer (3) and having a larger band gap than that of the semiconductor of the light absorbing layer (3), the active layer (5) being formed on the light absorbing layer (3) and primarily containing at least one impurity of the said one conductivity type, and

a surface layer (16) of a semiconductor providing lattice matching between itself and the active layer (5) and having a larger band gap than that of the semiconductor of the light absorbing layer (3), the surface layer (16) being formed on the active layer (5) and primarily containing at least one impurity of the said one conductivity type, in a concentration less than that of the active layer (5), but the surface layer (16) and an upper portion of the active layer (5) having therein a region which contains at least one impurity of a conductivity type opposite to the said one conductivity type to provide a light sensitive

region separated from other regions of the surface layer and the active layer by a well shaped p-n junction (18) of which the bottom is located in the active layer (5)."

Published Claims 2-7 are dependent on Claim 1.

- II. The reason given for the refusal was that the structure of the avalanche photodiode according to Claim 1 would not comprise the highly doped intermediate layer (4) between active (or multiplying) layer (5) and light absorbing layer (3) belonging to the fundamental teaching of the priority document of the present divisional application:

D3: JP-A-169 889/80.

For this reason, Claim 1 would only be entitled to the priority of the filing date of the European parent application on 1 December 1981 and, therefore, would have to be examined with regard to the disclosure in document:

D1: "Electronics Letters", 29 October 1981, Vol. 17,  
No. 22, pages 826 and 827,

as state of the art according to Article 54(2) EPC. The distinction between the subject-matter of Claim 1 and that of document D1 - a further diffusion of the pn-junction from the interface of the n<sup>-</sup>InP- and n InP layers of D1 into the active (n InP) layer as claimed - would be obvious in particular in view of the fact that this distinction does not result in unexpected effects or properties.

- III. The Appellant lodged an appeal against this decision.
- IV. In a communication accompanying a summons to oral proceedings, the Board drew the Appellant's attention to

the following additional document cited in the European Search Report:

D2: "Electronics Letters", 19 July 1979, Vol. 15, No. 15, pages 453-455.

The Board notified the Appellant of a number of facts supporting the Board's provisional view that in the subject-matter of Claim 1 no use is made of the invention claimed in priority document D3. In the event that document D1 would have to be regarded as state in the art according to Article 54(2) EPC, it might be considered as obvious for a skilled person to apply the advantageous teaching of document D2 in the photodiode disclosed in document D1. Arriving thus at the subject-matter of Claim 1 would not imply an inventive step in the sense of Article 56 EPC.

- V. Oral proceedings were held before the Board at the end of which the Appellant requested that the decision under appeal be set aside and that the patent be granted on the basis of the main request in accordance with the description, claims and drawings as published or the first, second and third auxiliary requests as filed at the oral hearing.

Claim 1 of the first auxiliary request corresponds to that of the main request (see paragraph I above) with the following amendments: The words "at least one" are cancelled wherever they appear before the word "impurity", and the last part of Claim 1 starting with the words "to provide a light sensitive region" is replaced by the following text:

"... separated from other regions of the surface layer and the active layer by a p-n junction (18) of which the bottom, corresponding to a light sensitive region of the

photodiode, is located in the active layer (5) and the sides rise abruptly or substantially vertically through the surface layer (16)." Claims 2 to 7 of the first auxiliary request are dependent on Claim 1.

Claim 1 of the second auxiliary request has the following wording:

"1. An avalanche photodiode comprising:

a light absorbing layer (3), of a semiconductor containing at least one impurity of one conductivity type,

a first layer (4, 5), of a semiconductor providing lattice matching between itself and the light absorbing layer (3) and having a larger band gap than that of the semiconductor of the light absorbing layer (3), being formed on the light absorbing layer and containing at least one impurity of the said one conductivity type,

a second layer (5, 16) of a semiconductor providing lattice matching between itself and the first layer (4, 5) having a larger band gap than that of the semiconductor of the light absorbing layer, being formed on the first layer (4, 5) and primarily containing at least one impurity of the said one conductivity type in a concentration less than that of the first layer (4, 5), and

a region, containing at least one impurity of a conductivity type opposite to the said one conductivity type, formed above and separated from the light absorbing layer (3) and separated from other regions of the photodiode by a p-n junction having a relatively deep part, relatively close to the light absorbing

layer (3), corresponding to a light sensitive region of the photodiode, and shallower parts, further away from the light absorbing layer and located in the second layer, providing a guard ring junction."

Claim 1 of the third auxiliary request corresponds to that of the second auxiliary request, wherein the words "at least one" are cancelled wherever they appear before the word "impurity".

Claims 2 to 11 of the second and third auxiliary requests are dependent on the respective Claim 1.

VI. In support of his requests, the Appellant argued essentially as follows

(1) with regard to his right of claiming priority from document D3:

- (a) In order to verify that document D3 and the present divisional application deal with "the same invention" in the sense of Article 87(1) EPC no comparison of scope, embodiments or terminology would be decisive, but an identification of the common essential features.
- (b) As exemplified in sketch 1, handed over during oral proceedings, priority document D3 and the present application have the same prior art as starting point, and both aim at reducing the dark current of an avalanche photodiode.
- (c) This aim is achieved in both cases by providing an intermediate region between pn-junction and absorption layer, which region causes the intensity of the electrical field to decrease before it



arrives at the interface of the absorption layer and thus reduces the field intensity within the absorption layer and thereby the dark current originating from it. This "shielding effect" would be present in priority document D3 as well as in the present divisional application.

- (d) As sketch 2 handed over during oral proceedings shows, the "multiplying" layer (5) of priority document D3 can be described as the "surface" layer (16) of the present application and the "intermediate" layer (4) corresponds to the "active" layer (5) of the present application. Thus, in both cases, the following layer structure is present: first a lower doped layer, then a higher doped layer and thereafter a light absorbing layer.

The absolute value of the n-dopant concentration in the "intermediate" layer (4) of the priority document D3 is about four to six times higher than in the "active" layer (5) of the present divisional application, and that in the "multiplying" layer (5) of the priority document about eight times higher than in the "surface" layer (16) of the present divisional application. Hence, the dopant concentration is everywhere higher in the priority document D3 than in the present divisional application. This difference would not affect the invention, i.e. the shielding of the light absorbing layer for reducing dark current.

- (e) The higher doped part directly overlying the light absorbing layer need neither be a distinct layer nor terminate at some distance above the pn-junction. If the intermediate layer (4) of the

priority document D3 would be sufficiently thick, the pn-junction could also be located within this layer.

- (f) As derivable from the wording of document D3, page 2, lines 9-12, the claim of this priority document does not specify the location of the pn-junction. Also from the description of the priority document, page 7, lines 19-23, it is open whether the pn-junction is provided in the higher or lower doped layer above the light absorbing layer. The present divisional application selects one of the two existing possibilities, i.e. the pn-junction within the higher doped layer. Hence, the present divisional application is concerned with a specific, alternative embodiment of the invention as disclosed in the priority document. A limitation in the present divisional application of the invention according to the priority document D3 would not deprive the Appellant of his right to claim the priority of the filing date of document D3. The remaining part of the higher doped region between pn-junction and light absorbing layer would produce, without any doubt, a shielding effect. Hence, the essential feature of the invention disclosed in the priority document D3 would still exist in the present divisional application and thus the basic prerequisite for claiming priority would be fulfilled.

(2) With regard to inventive step:

- (a) A skilled person would never think of applying any teaching of document D2 in the diode disclosed in document D1 due to difference in structure and doping concentration. In document D2, the teaching

of Figure 2 and of the optimum  $0.6 \mu\text{m}$  distance between pn-junction and the upper border of the light absorbing layer applies to a  $4 \mu\text{m}$  thick n InP-layer with a doping concentration about  $4 \times 10^{16} \text{ cm}^{-3}$ , whereas document D1 discloses a  $2 \mu\text{m}$  thick n<sup>-</sup>InP-layer with a dopant concentration of  $3-5 \cdot 10^{15} \text{ cm}^{-3}$  above a  $1 \mu\text{m}$  thick n InP-layer with a dopant concentration of  $1 \cdot 10^{16} \text{ cm}^{-3}$ .

- (b) Starting from document D1, nothing would lead a skilled person to bring the pn-junction from its disclosed position in the interface between lower and higher doped layers down into the higher doped layer, the n<sup>-</sup>/n boundary being a natural limit for diffusion. In order to approach the pn-junction to the boundary of the light absorbing layer, a skilled person could as well reduce the thickness of the highly doped region and maintain the interface-position of the pn-junction.
- (c) Starting from document D2, there is no reason in providing the n<sup>-</sup>InP-layer of document D1 on top of the n InP-layer of document D2.
- (d) Due to the fact that the application has been made ten years ago, an interpretation of Figure 2 of document D2 would go beyond a skilled person's abilities. Hence, a combination of documents D1 and D2 would not be legitimate but based on hindsight on the basis of an unallowable ex-post-facto logic.

VII. At the conclusion of the oral proceedings, the decision was announced that the appeal was dismissed, since the claim to priority was rejected and the claimed invention lacked an inventive step.

## Reasons for the Decision

1. The Appeal is admissible.

2. Right to Priority - Main and First Auxiliary Requests

2.1 The subject-matter of Claims 1 of the Appellant's main and first auxiliary requests is explicitly directed to a pn-junction "of which the bottom is located in the active layer (5)" beneath a surface layer (16). These features were disclosed for the first time as part of the "third embodiment" in the parent European patent application: see Figures 10 and 11 (identical to Figures 1 and 2 of the present divisional application) and the corresponding description. The Japanese priority document D3 comprises only a first and second embodiment; see D3, Figures 5 and 8 and the corresponding description. Comparing Figure 2 of the present divisional application with Figure 8 of priority document D3 shows that in Figure 2 of the present application there is no layer with a reference sign "4", i.e. no "intermediate" layer (having a dopant concentration higher than  $2 \cdot 10^{16} \text{ cm}^{-3}$ ). The pn-junction stays in layer (5) (having a dopant concentration of at least  $5 \cdot 10^{15} \text{ cm}^{-3}$ ) with its terminology changed from "multiplying" into "active" layer. In the parent application, page 5, line 13, the terminology "a multiplication or active layer" is used for the term "active layer (5)" of the present divisional application. From this it follows that the multiplying layer (5) according to priority document D3 corresponds to the active layer (5) of the present divisional application. A new layer (16) (having a dopant concentration of  $1 \cdot 10^{15} \text{ cm}^{-3}$ ) on top of layer (5) is added and nominated a "surface" layer.

2.2 A problem underlying all embodiments of the invention is the reduction of dark currents.

2.3 In examining whether, despite the above described structural and dopant concentration differences, the essential technical features of the invention claimed in the present divisional application constitute the same invention as is disclosed in priority document D3, the following facts and matters have to be taken into account:

(a) Document D3 commences with a "Claim" defining an avalanche diode type semiconductor photo detector, comprising

- (a) a substrate;
- (b) a "photo absorbing" layer,
- (c) a thin film ("intermediate layer"),
- (d) a "multiplying layer";

and ending with a paragraph (e) (page 2, lines 9 to 12) stating "the region (photo sensing part) containing the impurity of the conductivity type different from that of said impurity at a high concentration on the part of said multiplying layer."

The claim is general, and paragraph (e) in particular is silent as to the position of the pn-junction. As set out in paragraph VI(1)(f) above, the Appellant has relied upon this paragraph (e) of the claim as a broad disclosure of the subject-matter claimed in the present divisional application, as well as covering what is specifically described in the description of priority document D3.

In the Board's view, when considering what is disclosed in a claim of a priority document such as the "Claim"

discussed above, it is necessary to bear in mind the purpose of the claim, namely to define the protection which is sought. The fact that a claim in a priority document is broad enough to cover (or "comprehends the possible provision of") specific subject-matter which is filed for the first time in a later application, cannot by itself be sufficient evidence that such a subsequently filed subject-matter has already been disclosed in the priority document, or that subsequent claims based on that later filed subject-matter still define the same invention as that which is the subject of the priority document.

The fact that a claim in a priority document is broad enough to cover a particular specific technical feature does not necessarily mean that it discloses that particular feature, for the purpose of claiming its priority under Article 87 EPC.

For the purpose of deciding upon a right to priority, the invention which is the subject of the priority document has to be determined from a consideration of the disclosure of the priority document, as a whole, as read by a skilled person.

- (b) As further interpretation of paragraph (e) at page 2, lines 9 to 12 of document D3, the "Detailed Description of the Invention" beginning immediately after the claim, consistently states that the pn-junction is formed in the multiplying layer - see page 3, line 7, for example, as well as the description of the first and second embodiments shown in Figures 5 and 8 of document D3.

Hence, the location of the pn-junction is clearly specified to be within the uppermost layer.

Furthermore, within a passage describing generally the subject-matter of the "present invention", beginning at page 6, line 19, the text on page 7, lines 11 to 19, states that the multiplying layer has a dopant concentration "which is a fraction or less" of that of the intermediate layer. From the disclosure in document D3, page 20, line 21 to page 21, line 4, a skilled person derives that by providing a high impurity concentration between multiplying layer 5 and light absorbing layer 3, the field intensity at the light absorbing layer becomes very weak.

The text at page 7, lines 19 to 23 refers to the formation of the photo sensing part "on a part of this multiplying layer by diffusing the impurity having the conductivity type different from that of said impurity in a high concentration and comparative depth".

- (c) Hence, in the Board's view, a skilled person will interpret the above disclosure in document D3 as follows: The essential technical feature for reducing dark current is the provision of a higher doped region mainly reducing the field intensity below a lower doped region, mainly multiplying, wherein the pn-junction is located. Therefore, in the Board's opinion, the skilled reader will ascribe the shielding effect to the provision of a higher dopant concentration in between the pn-junction and light absorbing layer. In the present divisional application, however, higher dopant concentration is missing in this region. For the above reasons, the Board finds that the invention of priority document D3 is different from that which is claimed in the present divisional application.

(d) In his argumentation according to paragraphs VI-(1)-(e) and (f), the Appellant has generalised the above technical facts to such an extent that they no longer characterise the invention disclosed in priority document D3 but apply to the avalanche photodiode described in document D2, i.e. the state of the art with regard to priority document D3. In this diode, the dark current is reduced via shielding by a part of the multiplying layer itself, see document D2, page 454, Figure 1 and the corresponding description.

- 2.4 A further indication that different inventions are disclosed in priority document D3 and in the present divisional application is the fact that the description of the present application expressly states that the higher doped intermediate layer in between the multiplying (i.e. active) layer and the light absorbing layer of the priority document D3 is not provided, in order to simplify the layer configuration and thus the production of the diode (see the description of the present divisional application, page 10, lines 10-20, and page 7, lines 14-31). In the present divisional application, the obtainable low dark current is ascribed to the "extremely marginal impurity concentration in the surface layer (16)"; see page 11, lines 7-11.
- 2.5 For the above reasons, in the Board's judgement, with reference to the Appellant's main and first auxiliary requests, the invention claimed in the present divisional application is a different invention from that disclosed in the priority document D3, so that according to Article 87(1) EPC the Appellant is not entitled to claim the priority of the filing date of document D3 in the present divisional application.



### 3. Right to Priority - Second and Third Auxiliary Request

The wording of Claims 1 of the Appellant's second and third auxiliary requests comprises also the characteristics of the third embodiment of Figures 10 and 11 of the European patent application, i.e. the diodes according to Figures 1 and 2 of the present divisional application. Hence, these claims contain an alternative which, for the reason set out in paragraph 2 above, represents a different invention from that disclosed in document D3. Therefore, the finding of paragraph 2.5 above applies also to Claims 1 of the second and third auxiliary requests.

### 4. Inventive Step - Main, First, Second and Third Auxiliary Request

4.1 For the reasons set out in paragraphs 2 and 3 above, the filing date of the European parent application No. 81 305 658.7 on 1 December 1981 has to be regarded as the filing date of the present European divisional application. Therefore, document D1 has to be additionally taken into account as state of the art according to Article 54(2) EPC.

4.2 The avalanche photodiode disclosed in document D1 has the same layer configuration as claimed in Claims 1 of all four requests of the Appellant; see document D1, Figure 1 and the corresponding description. However, in the diode of document D1, the bottom of the pn-junction is located right in the interface between the active layer (n InP) and the surface layer (n<sup>-</sup>InP).

Hence, from this prior art, the subject-matter of Claims 1 of the main and first auxiliary requests distinguishes in that:

- (a) the bottom of the pn-junction "is located in the active layer",

and that of Claims 1 of the second and third auxiliary requests in that:

(a') the deep part of the pn-junction is located "relatively close to the light absorbing layer".

- 4.3 The avalanche photodiode disclosed in document D2 distinguishes from the subject-matter of Claims 1 of all four requests mainly in that a lower doped surface layer is missing.
- 4.4 Due to the identical layer configuration, in the Board's view, document D1 has to be regarded as the nearest prior art in view of formulating the objective problem underlying the present invention.

It is the general practice of the Boards of Appeal that for the purpose of examining inventive step the problem has to be determined objectively by comparing what is disclosed to be achieved by the subject-matter of a claim under consideration with that achieved by the nearest prior art. Hence, starting from document D1, the objective problem has to be seen in reducing the number of parameters to be regulated in the method for producing the diode, so that the location of the pn-junction is more freely determinable; see the description, page 8, lines 24-31 and page 10, lines 14 and 15. Aiming at a simplification of a method, in the Board's view, is obvious for a skilled person. Thus, no contribution to inventive step is to be found in the recognition of the objective problem underlying the claimed subject-matter.

- 4.5 In order to arrive at the subject-matter claimed in the present invention from the diode disclosed in document D1 a skilled person has to shift the location of the pn-junction

from its known position in the interface between active and surface layer nearer to the light absorbing layer, so that

(a) the bottom of the pn-junction is located in the active layer (Claims 1 of the main and first auxiliary request); or

(a') the deep part of the pn-junction is located "relatively close to the light absorbing layer" (Claims 1 of the second and third auxiliary request).

4.6 Document D2 teaches a skilled person, via Figure 2 in combination with page 454, left column, last paragraph and right column, paragraph 1, that a shifting of the pn-junction nearer to the interface between the active and light absorbing layer influences breakdown voltage, the maximum avalanche gain and the dark current. In the Board's view, on the basis of the generally known avalanche multiplication mechanism, a skilled person has no logical reason to assume that a lowering of the dopant concentration within the active layer and an additional provision of a lower doped surface layer on top of the active layer changes the basic character of the curves in Figure 2 of document D2. The Appellant has given no physical explanation for his opposite opinion mentioned in paragraph VI-(2)-(a) above.

Hence, contrary to the Appellant's view in paragraph VI-(2)-(b), a skilled person would make use of the teaching of document D2 in the diode of document D1 and shift the pn-junction into the higher doped layer, in the event that he wishes to decrease the breakdown voltage of the diode disclosed in document D1. The simultaneous increase of the dark current represents a disadvantage which can be properly assessed beforehand and which, therefore, is not decisive in the judgement on inventive step. A skilled

person - in the Board's view - must be free to select the location of the pn-junction according to his wishes and to optimise thereby parameters, such as breakdown voltage, avalanche gain and dark current, in view of practical needs. Nothing inventive can be seen in the fact that the position of the pn-junction is changed instead of the thickness of the higher doped layer, only these two possibilities existing for approaching the pn-junction towards the light absorbing layer in the parameter optimisation.

- 4.7 No unexpected, surprising effects have been disclosed or put forward by the Appellant to appear when moving a pn-junction from its position in the interface between lower and higher doped layer as disclosed in document D1 into the higher doped layer. Hence, the choice of the position of the pn-junction within the (higher doped) "active layer" - as claimed in Claims 1 of the main and auxiliary requests - or "relatively close to the light absorbing layer" - as claimed in Claims 1 of the second and third auxiliary requests - has the character of an arbitrary dimensioning on the basis of known effects, which is regarded to be obvious for a skilled person.
- 4.8 For the reasons set out in points 4.4 to 4.7 above, the subject-matter of Claims 1 of the main, first, second and third auxiliary requests is not considered to involve an inventive step within the meaning of Article 56 EPC.
5. As set out above, Claims 1 of the main, first, second and third auxiliary requests are not allowable with regard to Articles 52(1) and 56 EPC. Claims 2-7 of the main and first auxiliary requests and Claims 2-11 of the second and third auxiliary requests are not allowable either, since they are dependent on respective unallowable Claim 1.

**Order**

**For these reasons, it is decided that:**

**The Appeal is dismissed.**

**The Registrar:**

**M. Beer**

**The Chairman:**

**G.D. Paterson**