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D E C I S I O N
of 26 March 2002

Case Number: T 0950/97 - 3.4.3

Application Number: 91908775.9

Publication Number: 0527827

IPC: H01L 33/00

Language of the proceedings: EN

Title of invention:
Optoelectronic device

Patentee:
BRITISH TELECOMMUNICATIONS public limited company

Opponent:

Headword:

-

Relevant legal provisions:
EPC Art. 84, 54 and 56

Keyword:

"'Product - by - process claim', clarity (yes) (process gives rise to clearly identifiable characteristics in devices produced by it)"

"Novelty (yes)"

"Inventive step (yes)"

"The design of the claimed device makes possible the use of the advantageous and inventive method"

"No direct incitation to modify the teaching of the closest prior art document to arrive at the claimed device"

Decisions cited:

T 0150/82; T 0238/88, T 0823/91, T 0688/91, T 0130/90

Catchword:

-



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Boards of Appeal

Chambres de recours

Case Number: T 0950/97 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 26 March 2002

Appellant: BRITISH TELECOMMUNICATIONS public limited
company
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London EC1A 7AJ (GB)

Representative: Roberts, Simon Christopher
BT Group Legal Services
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Decision under appeal: Decision of the Examining Division of the
European Patent Office posted 18 April 1997
refusing European patent application
No. 91 908 775.9 pursuant to Article 97(1) EPC.

Composition of the Board:

Chairman: M. Chomentowski
Members: G. L. Eliasson
M. B. Guenzel

Summary of Facts and Submissions

I. The European patent application No. 91 908 775.9 (Publication No. 0 527 827), indicating the priority of a filing on 1 May 1990, was refused by a decision of the examining division dated 18 April 1997 on the ground that claim 1 of the main and of the auxiliary request lacked clarity in the sense of Article 84 EPC.

II. Claim 1 of the main request forming the basis of the decision of the examining division had the following wording:

"1. An optoelectronic semiconductor device comprising a first epitaxial layer (2) grown on a semiconductor substrate (1), a second epitaxial layer (3) grown on said first layer (2) and having a higher refractive index than that of the first layer, and a third epitaxial layer in the form of a ridge structure (8) grown on or over said second layer (3), wherein said first epitaxial layer (2) is of a first conductivity type, said third epitaxial layer (8) is of a second conductivity type and a p-n junction is formed in said second epitaxial layer between a region of material of said second conductivity type, which is aligned beneath said ridge structure (8), and adjacent regions of said first conductivity type of said second layer (3), characterised in that the ridge structure (8) is selectively grown."

The further independent claims of the set of 45 of the applicant's main request, ie claims 32, 33 and 39, read as follows:

"32. An optical receiver comprising at least one device as claimed in any one of the preceding claims."

"33. A method of fabricating an optoelectronic device, the method comprising the steps of:

growing a first epitaxial layer (2) of a first conductivity type on a semiconductor substrate (1);
growing a second epitaxial layer (3) of said first conductivity type on said first layer; and
characterised by the steps of:

forming a dielectric layer (5) on or over said second layer;

defining a pattern in said dielectric layer;

using selective epitaxy to grow a third epitaxial layer (8) on semiconductor exposed by the patterned dielectric, said third epitaxial layer including at least one ridge structure; and

diffusing a dopant of a second conductivity type from said third epitaxial layer into said second layer thereby selectively-type-converting regions of said second layer and forming a p-n junction therein without type converting underlying parts of said first epitaxial layer."

"39. A method of fabricating an optoelectronic device, the method comprising the steps of:

(i) growing a planar structure which is all of a first conductivity type and comprises a waveguiding layer (2) and an active layer (3) overlying said waveguiding

layer (2); and characterised by the steps of:

(ii) forming an inorganic dielectric layer (5) on said planar structure;

(iii) patterning said dielectric layer to expose underlying semiconductor;

(iv) using selective epitaxial growth to grow material (8) of a second conductivity type on said exposed semiconductor, the selective epitaxial growth including at least one ridge; and

(v) simultaneously with step (iv) diffusing dopant from said material of a second conductivity type into the planar structure to form a predetermined arrangement of p-n junctions therein, including a lateral p-n junction aligned with said ridge."

III. During the examination proceedings, the following documents were taken into consideration:

D1: US-A-4 163 952;

D5: Electronics Letters, vol. 22, no. 21, 9 October 1986, Stevenage, GB, pages 1117 to 1118; A. Kurobe et al.: "Submillimeter lasing of Zn-diffused mesa buried-hetero $\text{Al}_x\text{Ga}_{1-x}\text{As}/\text{GaAs}$ multi-quantum-well lasers at 77K";

D7: Journal of Crystal Growth, vol. 112, (1991), Amsterdam, NL, pages 111 to 122; O. Kayser et al.: "Control of selective area growth of InP";

- B1: Journal of Crystal Growth, vol. 109, (1991), pages 264 to 271, J.L. Zilko et al. : "Effects of mesa shape on the planarity of InP regrowths performed by atmospheric pressure and low pressure selective metalorganic vapor phase epitaxy";
- B2: Materials Science and Engineering, vol. B21 (1993), pages 130 to 146; E.J. Thrush et al.: "Selective and non-planar epitaxy of InP/GaInAs(P) by MOCVD"; and
- B3: an InP single crystal wafer - data sheet provided by the applicant.

IV. The reasoning in the decision of the examining division with respect to the applicant's main request was essentially as follows:

Claim 1 is a "product-by-process" claim. Such a claim is admissible only if the device as such fulfils the requirement for patentability, ie when it is in particular new and inventive (cf. EPO Guidelines, C-III, 4.7b). Moreover, "product-by-process" claims in which the method produces a distinct and patentable invention are only allowable when the device cannot be described in a different way (cf. the decision T 150/82, OJ EPO 7/1984, 309).

The first portion of claim 1 is known from document D1.

The device of claim 1 is characterized in that the ridge structure (8) is selectively grown. This feature relates to the method of fabrication rather than to the finished device. It has therefore to be examined in the

first place whether the finished optoelectronic device according to claim 1 allows determination of the method with which the ridge structure has been grown.

As to the shape of the ridge's cross section, taking into account the variety of cross sectional shapes of grown ridges shown in eg document D7 (see sections 3.2 and 3.3 and Figures 2 to 7 and 11) or in document B2, it must be concluded that it is not characteristic of the growth method, especially, because neither the semiconductor material, nor the crystal orientation of the substrate, nor the growth conditions are specified in claim 1.

The applicant had also argued that the top surface of a ridge obtained by selective growth cannot have the planarity of the top surface of a ridge etched with the help of a mask, which is as planar as the surface of the substrate. However, document D7 (see page 114, left-hand column and Figure 5a) shows a "nearly flat" top surface obtained by selective growth. Moreover, underetching of the mask can occur; thus, since no specific method features are contained in claim 1, a ridge which is selectively grown cannot be distinguishable in all cases from a ridge obtained by etching, so that this argument is not convincing.

Consequently, a ridge which has been selectively grown cannot be distinguished from a ridge obtained by masking and etching in all possible cases. Since it is not apparent which specific characteristics result from the characterising feature of claim 1, the claim is not clear (Article 84 EPC).

Furthermore, since a variety of ridge shapes can be

obtained by different conditions, the person skilled in the art does not know which conditions should be used. The device is therefore not sufficiently defined in claim 1, so that the clarity requirement of Article 84 EPC is also not met for this reason.

Thus, a former objection that the subject-matter of claim 1 was not structurally distinguished from the device of document D1 so that it lacked novelty, was mentioned. Since the structural differences between a selectively grown ridge and an etched ridge, in particular the alleged different shapes of the cross section of the ridge and of the top surface of the ridge, did not appear to lead to a technical effect, the subject-matter of claim 1 was considered as lacking an inventive step.

Incidentally, it is to be noted that, although not mentioned in the decision, the method of selectively growing the ridge structure as in the independent method claim 37 as filed was considered as non obvious (cf. page 6, paragraph 6b) of the communication of 20 May 1994).

V. The applicant lodged an appeal against this decision on 15 May 1997 paying the appeal fee on the same day. A statement setting out the grounds of the appeal was filed on 28 August 1997.

VI. With the telefax dated 6 March 2002 the appellant (applicant) filed replacement pages and requested that the decision under appeal be set aside and a patent be granted on the basis of the new main or auxiliary request.

The Main request consists of the following patent application documents:

Description:

Pages 1, 2, 4, 6 to 9 and 12 to 23 as filed;
Page 3 filed with applicant's letter of 21 March 1995;
Page 3a (Main request) filed with appellant's telefax dated 6 March 2002;
Pages 5, 5a, 10, 11 and 11a filed on 5 November 1992;

Claims:

Nos. 1 to 6 (first part) (Main request) filed with appellant's telefax dated 6 March 2002;
Nos. 6 (second and last part) to 45 filed with applicant's letter of 21 March 1995;

Drawings:

Sheets 1/4 to 4/4 as filed.

As compared with claim 1 of the main request forming the basis of the decision of the examining division, claim 1 of the appellant's main request comprises an additional feature (emphasized by the Board) and reads as follows:

"1. An optoelectronic semiconductor device comprising a first epitaxial layer (2) grown on a semiconductor substrate (1), a second epitaxial layer (3) grown on said first layer (2) and having a higher refractive index than that of the first layer, and a third epitaxial layer in the form of a ridge structure (8) grown on or over said second layer (3), wherein said first epitaxial layer (2) is of a first conductivity type, said third epitaxial layer (8) is of a second conductivity type and a p-n junction is formed in said

second epitaxial layer between a region of material of said second conductivity type, which is aligned beneath said ridge structure (8) **and which extends from the ridge structure (8) inwardly into the second epitaxial layer (3)**, and adjacent regions of said first conductivity type of said second layer (3), characterised in that the ridge structure (8) is selectively grown."

The appellant requested oral proceedings for the case that his main request would be rejected.

- VII. The appellant submitted essentially the following arguments in support of his main request:

Clarity

Ridges obtained by etching have either re-entrant cross-sectional shapes as see eg document D5 or Figures 1 and 2 of document B1, or have a base wider than the top. Ridges formed by selective epitaxy have not these features so that, while there is no single profile which always characterises either fabrication method, for the skilled person, the shape of the cross-section of a ridge is a good indicator of the fabrication method used.

In addition, the surface flatness of a ridge formed by etching of a non-selectively grown material will equal that of the substrate on which the material is grown, as see e.g. document B3. Conversely, selective epitaxial growth of a ridge always gives rise to a ridge top which is much less flat than that of a standard wafer. The non-flatness can even appear as pronounced ears at either side of the ridge with a

valley between them. So called "flat" selective growth will not give rise to very pronounced ears, but the surface of the ridge will still be several orders of magnitude less than flat than the wafer on which growth took place. As the testimony of Dr. Perrin showed, conventional flatness measurement techniques can readily distinguish between the flatness values typical of wafers (and hence of etched ridges) and those of selectively grown ridges. As Dr. Perrin pointed out, even if one were to etch the top of a selectively grown ridge, one could not achieve the level of flatness found in an etched ridge.

The flat upper surface of the ridge shown in Figure 5a of document D7 may look as having a flat upper surface. However, there are small but distinct ears at the edges of the ridge. Moreover, direct measurement of surface flatness is capable of detecting "non-flatness" (relative to the wafer flatness) where a scanning electron micrograph (SEM) may seem, to the eye, to show a "flat" surface, so that simple eye analysis is not always sufficiently accurate to determine whether a surface is flat or not.

Even if partial loss of the mask when forming a ridge by etching may lead to a non-flat top, the mask would however nevertheless need, if it were to be effective, to protect some of the surface of the ridge during fabrication, so that the relevant part of the ridge would retain a truly flat surface.

Thus, selective epitaxy, like many other industrial processes (such as welding, casting, etc..) gives rise to clearly identifiable characteristics in devices produced by it. Just as with welding or casting, the

precise nature of the characteristics which show that selective epitaxy has been used may vary from device to device, but they are always present for the skilled person to see and to enable him/her to identify the fabrication technique used.

Therefore, the shape of the cross-section of a ridge is a good indicator of the fabrication method used, so that the claim, which is indeed a product-by-process claim, is clear.

Moreover, it is to be noted that the fact that there are a lot of ways of using selective epitaxial growth may result in a claim which a broad scope, but this does not mean that the claim is unclear, as see for instance the decisions T 238/88, OJ EPO 1992, 709, T 823/91 of 23 November 1991 and T 688/91 of 21 April 1993.

Novelty and inventive step

Since as set forth above the use of selective epitaxy does give rise to clearly identifiable characteristics in the finished device which would not be present in a device made according to the teachings of document D1, the subject-matter of claim 1 is indeed new.

The claimed device as a whole cannot be said to have no technical advantage. It is a large benefit of the device of claim 1 that it is easier to make, with fewer steps, and hence higher yield and lower cost than the device known from document D1. It is submitted that the fact that these benefits flow from the method of making the device does not mean that they are unconnected with the design of the device. Rather the design of the

device as defined in claim 1 makes possible the use of the advantageous and inventive method. In any case, there is no indication that the skilled person could be incited to modify the teaching of document D1 to arrive at the device of claim 1.

Therefore, the subject-matter of claim 1 involves an inventive step.

Reasons for the Decision

1. The appeal is admissible.
2. *Main request*
 - 2.1 Admissibility of the amendments

In the optoelectronic semiconductor device of the appellant's main request, a p-n junction is formed in the second epitaxial layer between the region of material of the second conductivity type, which is aligned beneath the ridge structure (8), and adjacent regions of said first conductivity type of said second layer (3); the region of material of the second conductivity type is also specified as extending from the ridge structure (8) inwardly into the second epitaxial layer (3).

The latter feature is based on the whole content of the application as filed (see for instance all the independent method claims, ie, claims 37 and 43).

Therefore, the application satisfies the requirement of

Article 123(2) EPC that a European patent application may not be amended in such a way that its subject-matter extends beyond the content of the application as filed.

2.2 Clarity

Claim 1 is a "product-by-process" claim. As can be seen hereunder in item 2.3, the claim is patentable and other ways of defining the claimed device or delimiting it vis-à-vis the prior art are not directly available (cf. the decision T 130/90 of 28 February 1991, point 3.3 of the reasons).

Therefore, the conditions enounced in the decision T 150/82 (cf. item IV of the Summary of Facts and Submissions, here above) are fulfilled.

Indeed, a variety of ridge shapes can be obtained by different conditions, and no such conditions are contained in claim 1. However, as convincingly argued by the appellant, the fact that there are a lot of ways of using selective epitaxial growth may result in a claim with a broad scope, but this does not *per se* mean that the claim is unclear, see for instance the above-mentioned decisions T 238/88 (cf. point 5.1 of the reasons), T 823/91 (cf. item 3.2 of the reasons) and T 688/91 (cf. item 4.11 of the reasons).

It is also to be noted that claim 1 specifies that the p-n junction is formed in the second epitaxial layer between a region of material of the second conductivity type, which is aligned beneath the ridge structure (8) and which extends from the ridge structure (8) inwardly into the second epitaxial layer (3). This feature of

the optoelectronic device is derivable from the whole content of the application as being a feature essential to the performance of the invention.

Therefore, in the Board's judgement, claim 1 is clear in the sense of Article 84 EPC.

2.3 Novelty and inventive step

2.3.1 Document D1 represents the closest prior art document. The optoelectronic device known from document D1 (see column 1, line 58 to column 2, line 7; column 2, lines 16 to 39), which corresponds to the first portion of claim 1, comprises a projecting rib (7), ie, a ridge structure, which is formed by (non-selective) epitaxial growth, masking and etching.

According to the characterizing portion of claim 1 of the main request, the ridge structure (8) is selectively grown. Indeed, this last feature relates to the method of fabrication rather than to the finished device, and it has to be examined in the first place whether the finished optoelectronic device according to claim 1 comprises specific structural features which allow it to be distinguished from devices wherein the ridge structure is not selectively grown, ie is formed by another, different method.

The following is to be added concerning structural features of ridges obtained by different processes:

A ridge structure being wider at its top than at its bottom is known for ridge structures obtained by etching, see for instance document D5 (cf. Figure 1 and the associated text). However, a large variety of the

cross sectional shape of selectively grown ridges can be obtained depending upon the crystal orientation and the growth conditions, as shown in document D7 (cf. sections 3.2 and 3.3 and Figures 2 to 7 and 11). A ridge structure being wider at its bottom than at other parts thereof can also be obtained as well by etching, see for instance document D5 (cf. Figure 1), as by selective growth, see document B2 (cf. Figure 3b). It is also possible that an etching step for forming a ridge structure can result in etching under the edges of the mask and thus can lead to height variations of the top surface, ie to top surfaces of the ridge structure being only nearly flat, as this is the case for selectively grown ridge structures.

The appellant has argued that simple eye analysis is not always sufficiently accurate to determine whether a surface is flat or not, and that conventional flatness measurement techniques can readily distinguish between the flatness values typical of wafers (and hence of etched ridges) and those of selectively grown ridges. The appellant has argued, more in general, that selective epitaxy, like many other industrial processes (such as welding, casting, etc..) gives rise to clearly identifiable characteristics in devices produced by it and that, just as with welding or casting, the precise nature of the characteristics which show that selective epitaxy has been used may vary from device to device, but they are always present for the skilled person to see and to enable him/her to identify the fabrication technique used.

Indeed, no document showing this in the claimed generality has been provided by the appellant. However, this is generally known to people with a technical

background at least with respect to the cited examples of industrial processes, and it is also credible that a person skilled in the art is not restricted to the simple eye analysis in the comparison of pictures and may be aware of or may use more adapted methods and instruments for determining the method used for fabricating an optoelectronic device. Since moreover at the oral proceedings before the examining division a person presented as an expert, Mr. Perrin, has provided relevant information in this respect and declared that this is the case, and since there is no evidence to the contrary, the appellant's argument is accepted.

Thus, the feature of the characterizing portion of claim 1 that the ridge structure (8) is selectively grown, and not obtained by masking and etching as in document D1, constitutes a distinguishing structural feature.

Incidentally, it is to be noted that the documents D7 and B1 to B3 do not form part of the state of the art as defined in Article 54(2) EPC.

Therefore, the subject-matter of claim 1 is new in the sense of Article 54 EPC.

- 2.3.2 The Board agrees to the finding of the examining division that the method of selectively growing the ridge structure as in the independent method claim 37 as filed is not obvious (cf. item IV of the Summary of Facts and Submissions, here above), and this applies to claims 33 and 39 of the appellant's main request. This implies that, to the skilled person, having regard to the state of the art, it was not obvious to substitute masking and selective growth for epitaxial growth,

masking and etching in the fabrication of an optoelectronic device comprising the further structural features of claim 1.

The appellant has argued that it is a large benefit of the device of claim 1 that it is easier to make, with fewer steps, and hence higher yield and lower cost than the device known from document D1 (cf. item VII of the Summary of Facts and Submissions, here above). Taking into account that substituting the two steps of masking and selective growth for the three steps of epitaxial growth, masking and etching in the fabrication of an optoelectronic device can in particular credibly result in a process with less steps, the Board agrees to the argument that the design of the device as defined in claim 1 makes possible the use of the advantageous and inventive method and that, thus, the claimed device as a whole can be said to have a technical advantage.

For the same reasons as for the process claims 33 and 39, the Board agrees to the appellant's argument that there is no direct incitation to modify the teaching of document D1 to arrive at the device of claim 1.

Therefore, to a person skilled in the art, having regard to the state of the art, the subject-matter of claim 1 is not obvious and thus involves an inventive step in the sense of Article 56 EPC.

2.4 Consequently, claim 1 is patentable in the sense of Article 52(1) EPC.

Therefore, claims 2 to 31, 34 to 38 and 40 to 45, which are claims dependent from claim 1, claim 33 or

claim 39, are also patentable for the same reasons. This is also the case for claim 32, which concerns an optical receiver comprising at least one device as claimed in any of the claims 1 to 31.

3. As a consequence, it is not necessary to consider the set of claims of the appellant's auxiliary request or his auxiliary request for oral proceedings.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.
2. The case is remitted to the first instance with the order to grant a patent on the basis of the following patent application documents:

Description:

Pages 1, 2, 4, 6 to 9 and 12 to 23 as filed;
Page 3 filed with applicant's letter of 21 March 1995;
Page 3a (Main request) filed with appellant's telefax dated 6 March 2002;
Pages 5, 5a, 10, 11 and 11a filed on 5 November 1992;

Claims:

Nos. 1 to 6 (first part) (Main request) filed with appellant's telefax dated 6 March 2002;

Nos 6 (second and last part) to 45 filed with applicant's letter of 21 March 1995;

Drawings:

Sheets 1/4 to 4/4 as filed.

The Registrar

The Chairman

D. Spigarelli

M. Chomentowski