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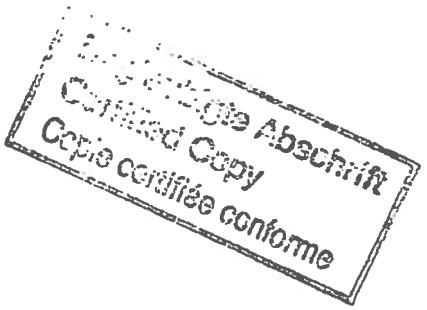

D E C I S I O N
of 5 April 2000

Case Number: T 1125/98 - 3.4.3

Application Number: 92303909.3

Publication Number: 0511864

IPC: H01L 21/20

Language of the proceedings: EN

Title of invention:
Epitaxially grown compound semiconductor crystals with buffer layers

Applicant:
SUMITOMO CHEMICAL COMPANY LIMITED

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step: yes (after amendment)"

Decisions cited:
-

Catchword:
-

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Beschwerdekammern | Boards of Appeal | Chambres de recours

Case Number: T 1125/98 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 5 April 2000

Appellant: SUMITOMO CHEMICAL COMPANY LIMITED
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Osaka-shi
Osaka 541-0041 (JP)

Representative: Dixon, Donald Cossar
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 30 July 1998 refusing European patent application No. 92 303 909.3 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. K. Shukla
Members: M. Chomentowski
A. C. G. Lindqvist

Summary of Facts and Submissions

I. European patent application No. 92 303 909.3 (Publication No. 0 511 864) was refused by a decision of the examining division dated 30 July 1998 on the ground of lack of inventive step having regard to prior art documents

D4: Patent Abstracts of Japan, vol. 9, No. 251 (E-348) (1974), 8 October 1985 & JP-A-60 101 976,

and

D3: US-A-4 688 062.

Claim 1 of the main request forming the basis of the decision under appeal reads as follows:

"1. An epitaxial compound semiconductor crystal comprising a substrate (21), a buffer layer formed directly or indirectly on said substrate, and an active layer (17) formed on said buffer layer, said buffer layer comprising

(A) an AlGaAs or AlGaInP layer (19) doped with oxygen and/or a transition metal having a resistance of 1 x 105 Ω.cm or more, and formed thereon,

(B) a layer (18) consisting of GaAs, InGaP or AlGaAs with a net residual impurity of 1 x 10^{16} per cm^3 or less."

Claims 2 to 14 are dependent on claim 1.

Claim 15 concerns a field-effect transistor or semiconductor integrated circuit which is fabricated from a compound semiconductor crystal as claimed in any

preceding claim, and claim 16 concerns a method of making a compound semiconductor crystal as claimed in any of the claims for the compound semiconductor crystal, which comprises vapour phase epitaxial growth of successive layers on a cleaned substrate from appropriate vaporized sources and sources of dopants.

Claim 1 of the auxiliary request forming the basis of the decision under appeal is distinguished from claim 1 of the main request in that it specifies that the substrate is a GaAs substrate.

In the decision under appeal, the examining division took the following view:

Main request

An epitaxial compound semiconductor crystal is known from document D4 comprising a substrate (1), a buffer layer (2) formed directly or indirectly on said substrate, and an active layer (3) formed on said buffer layer, said buffer layer comprising an AlGaAs or AlGaInP layer doped with oxygen and/or a transition metal having a resistivity of 1×10^5 Ω.cm or more.

However, contrary to the claimed crystal, there is on the buffer layer (2) of the known crystal no further layer consisting of GaAs, InGaP or AlGaAs with a net residual impurity of 1×10^{16} per cm^3 or less.

A problem which arises in structures of the type known from document D4 is that negative charge builds up which is caused by ionisation of deep-level acceptors in the AlGaAs:O layer.

A solution to this problem is an extra buffer layer having a small dopant density, for example in the range of 1×10^{14} to 3×10^{15} per cm^3, which is arranged

between the high-resistivity buffer layer and the active layer. Such an extra layer providing a small amount of conduction is known from document D3, see column 3, lines 28 to 32 and column 3, line 66 to column 4, line 10. From the above, it is immediately evident that the skilled person would naturally apply an extra layer as taught by document D3 in a structure according to document D4 in order to overcome those disadvantages caused by the charge build-up in the high-resistivity layer.

Therefore, the subject-matter of claim 1 does not involve an inventive step.

Auxiliary request

Claim 1 of the auxiliary request does not involve an inventive step for the same reasons as for claim 1 of the main request, and additionally for the reason that the use of a GaAs substrate as claimed is known from document D4.

II. The applicant lodged an appeal against this decision on 29 September 1998 paying the appeal fee the same day. The statement of the grounds of appeal was filed on 26 November 1998 along with a new set of 13 claims. Oral proceedings were requested auxiliarily.

III. In response to a communication from the Board informing the applicant of the Board's provisional view that the claims appeared to lack clarity, the appellant (applicant) filed with his letter dated 16 December 1999 a new page 27 containing claims 1 to 6 and claim 7 (first part) and new pages 4, 4a, 6, 10 to 13 and 15 of the description.

The appellant requests that the decision under appeal be set aside and that a patent be granted on the basis of the following patent application documents:

Description:
Pages 1 to 3, 5, 7 to 9, 14 and 16 to 26 as filed;
Pages 4, 4a, 6, 10 to 13 and 15 filed with letter dated 16 December 1999;

Claims:
Nos. 1 to 7 (first part) filed with letter dated 16 December 1999;
Nos. 7 (second and last part) to 13 as filed with appellant's letter dated 26 November 1998;

Drawings:
Sheets 1/7 to 7/7.

Claim 1 of the appellant's request reads as follows:

"1. An epitaxial grown compound semiconductor crystal on a substrate (21), comprising a buffer layer formed directly or indirectly on said substrate, and an active layer (17) formed on said buffer layer, said buffer layer comprising

(A) a high resistivity AlGaAs or AlGaInP layer (19) doped with oxygen of 1×10^{17} to 1×10^{21} atoms/cm^3 , having a resistivity of 1×10^5 Ω.cm or more, and formed thereon,

(B) a high purity layer (18) consisting of GaAs, InGaP or AlGaAs with a net residual impurity of 1×10^{16} per cm^3 or less."

IV. The appellant has submitted the following arguments in support of his request:

Document D4 only shows the use of an oxygen-doped single buffer layer (2) of high resistivity. The purpose of this construction is emphasised in the abstract as follows:

"Consequently, high resistivity as 10^{10} Ω (sic) is obtained even in film thicknesses such as 1 µm. Accordingly, a substrate having low resistivity can be used as the substrate 1, and the deterioration of an element generated by Cr in the semi-insulating GaAs substrate can be prevented."

Document D3 is also concerned with problems arising from Cr-doping of the substrate. A Cr doped buffer layer is discussed, which can lead to an ionization problem and which fails to provide an adequate solution for the out-diffusion problem. Document **D3** accordingly teaches the addition of a shielding layer (16) "substantially deplete of chromium" in order to isolate the active layer (17) from out-diffusion of Cr from the substrate (12) and the buffer layer (14), thereby eliminating the decrease in electron mobility and loss in r.f. power associated with such out-diffusion.

Both documents D4 and D3 focus upon the difficulties arisings from Cr-doping of the substrate. Document D3 is limited to Cr-doping alone leading to the problem of out-diffusion. A second problem addressed in document D3 is that of acceptor energy level of Cr, which is intermediate the valence band and conduction band of the GaAs substrate crystal.

No combination of documents D4 and D3, therefore, could lead to the crystal construction defined by claim 1.

The present invention provides an epitaxial crystal for use in high-speed electronic elements which exhibits little hysteresis and kink phenomenon, as can be seen from the differences between the results shown in present Figures 6(a) and (b) (Examples 1, 2) and those of Figure 6(c) (Comparative Example 1). Examples 1, 2 use oxygen-containing TMA (trimethylaluminum) in the production process, leading in turn to an oxygen-doped lower buffer layer (A), whereas in Comparative Example 1 this step is omitted, as see the present description, page 22, second paragraph. Therefore, the present application is directed to a non-obvious form of construction for an epitaxially grown semiconductor crystal giving rise in turn to surprising benefit.

For the sake of completeness, a subsequently published document,

D5: Journal of Crystal Growth 124 (1992), pages 427 to 432, "The effects of oxygen impurity in TMA on AlGaAs layers grown by MOVPE", Hata et al,

is filed. The document concerns the research work embodied in the present application.

Reasons for the Decision

1. The appeal is admissible.

2. *Admissibility of the amendments*

In the present claim 1, the AlGaAs or AlGaInP layer of the buffer layer formed on the substrate is doped with oxygen of 1 x 10^{17} to 1 x 10^{21} atoms/cm^3 , and the alternative doping, with a transition metal, as in claim 1 forming the basis of the impugned decision or

the original claim 1 has been deleted. The above-mentioned concentration range of oxygen has a basis in the original description (see column 6, lines 34 to 45 of the published specification).

Therefore, the Board is satisfied that the present claims meet the requirements of Article 123(2) EPC that a European patent application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed.

3. *Clarity*

The Board is satisfied that the present claims define correctly the matter for which protection is sought and that the description has been adapted to the new text of the claims, so that the claims are clear, concise and supported by the description, as required by Article 84 EPC.

4. *Novelty*

Having examined the cited prior art documents, the Board is satisfied that the subject-matter of present claim 1 is not comprised in the state of the art and, consequently, is new in the sense of Article 54 EPC.

5. *Inventive step*

5.1 The Board agrees with the appellant's submission (see item IV) that the results shown in the curves of the electrical characteristics of the Figures 6(a) and (b) (Examples 1, 2) and those of Figure 6(c) (Comparative Example 1) and in the drain current - drain voltage characteristics of Example 2 according to the invention and of Comparative Example 1 as shown in Figures 7 and 8 respectively, clearly show that the present invention provides an epitaxial crystal for use in high speed

electronic elements which exhibit little hysteresis and kink phenomenon in their drain current - drain voltage characteristics.

Examples 1, 2 according to the present invention use oxygen-containing TMA (trimethylaluminum) in the production process, leading in turn to an oxygen-doped lower buffer layer (A), whereas in Comparative Example 1 this step is omitted, as see the present description, page 22, second paragraph. Therefore, the present application is directed to a non-obvious form of construction for an epitaxially grown semiconductor crystal giving rise in turn to surprising benefit.

The effects of oxygen impurity in TMA on AlGaAs layers grown by MOVPE, i.e. metal organic vapour phase epitaxy, are discussed in the subsequently published document D5 of Hata et al (see the title and the abstract) provided by the appellant and representing an academic publication relating to the research work embodied in the present application, as can be seen from the list of the authors which comprises inter alia the names of the present inventors. It is derivable from this document that electrical properties of layers of AlGaAs were modified by incorporation of oxygen impurities. Thus, document D5 confirms the results shown in the curves of the Figures 6, 7 and 8 of the present application.

5.2 The Board also follows the applicant as regards the disclosure in documents D4 and D3 (see item IV, here above) in that the problems solved by the present invention and by documents D4 and D3, respectively, are different. In particular, both the documents D3 and D4 deal with the problems arising from Cr-doping of the substrate, whereas the present invention is concerned with the problem arising from oxygen doping of Al-containing high-resistivity epitaxial layer. Moreover,

the impurities in the buffer layers of documents D4 and D3 respectively are different, namely oxygen and chromium respectively, so that a direct combination of the corresponding teachings of these documents would not lead to the present invention.

5.3 The remaining prior art documents are less relevant because they concern structures and problems different from those of the present application.

5.4 For the foregoing reasons, in the Board's judgement, the subject-matter of claim 1 is not obvious to a skilled person having regard to the state of the art and, consequently, it involves an inventive step in the sense of Article 56 EPC.

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

5.5 Claims 12 and 13 express the same invention in terms of a field-effect transistor or semiconductor integrated circuit and in terms of a method, and are patentable for the same reasons.

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 application documents:

Description:
Pages 1 to 3, 5, 7 to 9, 14 and 16 to 26 as filed;
Pages 4, 4a, 6, 10 to 13 and 15 filed with letter dated 16 December 1999;

Claims:
Nos. 1 to 7 (first part) filed with letter dated 16 December 1999;
Nos. 7 (second and last part) to 13 as filed with appellant's letter dated 26 November 1998 (statement of the grounds of appeal);

Drawings:
Sheets 1/7 to 7/7.

The Registrar: The Chairman:

D. Spigarelli

R. Shukla