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Datasheet for the decision of 13 December 2006

Case Number: T 0993/05 - 3.4.03

Application Number: 98109371.9

Publication Number: 0881666

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Language of the proceedings: EN

Title of invention:
P-type nitrogen compound semiconductor and method of manufacturing same

Patentee:
SONY CORPORATION

Opponent:
OSRAM Opto Semiconductors GmbH & Co. OHG

Headword:
-

Relevant legal provisions:
EPC Art. 100(a)(b), 84, 56

Keyword:
"Inventive step (yes)"
"Clarity (yes)"
"Sufficiency of disclosure (yes)"

Decisions cited:
-

Catchword:
-

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Case Number: T 0993/05 - 3.4.03

D E C I S I O N
of the Technical Board of Appeal 3.4.03
of 13 December 2006

Appellant: (Opponent)
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Decision under appeal:
Interlocutory decision of the Opposition Division of the European Patent Office posted 11 May 2005 concerning maintenance of the European patent No. 0881666 in amended form.

Composition of the Board:

Chair: R. G. O'Connell
Members: V. L. P. Frank
T. Bokor

Summary of Facts and Submissions

I. This is an appeal by the opponent as sole appellant against the maintenance of European patent 881 666 in amended form (Article 102(3) EPC).

Grounds of opposition were *inter alia* lack of inventive step (Article 100(a) and 56 EPC) and insufficient disclosure (Article 100(b) EPC). During the opposition procedure an objection based on the lack of clarity of an amendment to claim 3 was also raised by the opponent (Article 84 EPC).

II. The claims of the patent as maintained by the opposition division read as follows:

> "1. A p-type nitrogen compound semiconductor comprising a plurality of first layers made of AlGaN and a plurality of second layers made of GaN alternately stacked, wherein said first layers include only aluminum (sic) but no magnesium and said second layers include only magnesium but include no aluminum."
>
> "2. A p-type gallium-nitrogen compound semiconductor comprising: a plurality of first layers and a plurality of second layers alternately stacked, wherein said first layers and said second layers are formed of p-type AlGaN layers including magnesium, wherein the said first layers each include aluminum, of which the concentration is higher than that of each of the second layers and the second layers each include

magnesium, of which the concentration is higher than that of each of the first layers."

"3. A method of manufacturing the p-type nitrogen compound semiconductor of claim 2 comprising the steps of:
stacking a plurality of the first layers made of AlGaN and of the second layers made of GaN alternately stacked, wherein said first layers include only aluminum but no magnesium and said second layers include only magnesium but include no aluminum, and
performing a heat treatment so that aluminum in the first layers and magnesium in the second layers are thereby partly diffused into each other."

III. The following prior art documents *inter alia* were cited in the opposition procedure:

E2: JP 09 116234 A; in this decision reference is made to the English translation on file.

D2: US 5 005 057 A

D3: US 5 146 465 A

On appeal the appellant opponent filed the following documents:

E4: US 5 468 678 A

E5: S. Nakamura, G. Fasol, "The Blue Laser Diode", Springer-Verlag 1997. pp. 103-110

IV. In the decision under appeal the opposition division found that:

- the expression "partly diffused" used in claim 3 was clear, as it expressed the fact that the magnesium and aluminium concentrations remained different in the resulting semiconductor;

- the objections of insufficient disclosure raised by the opponent against claims 2 and 3 were not convincing, as the skilled person would have immediately recognized the concentration ranges in which the invention of claim 2 and the conditions under which the heat treatment of claim 3 should be carried out; and

- the skilled person would not have combined documents D2 and E2, since the former document disclosed the unsuitability of p-type GaN and disclosed instead that p-type BP and GaAlN should be used for forming a superlattice structure. Moreover, there were no incentives in the prior art to modify the superlattice structure of document D3. For these reasons the compound semiconductors of claims 1 and 2 involved an inventive step. As claim 3 was a method of manufacturing the semiconductor of claim 2 it inherited the inventiveness of the latter.

V. The appellant opponent argued essentially as follows:

- The problem addressed by the patent was obtaining a p-type doped AlGaN:Mg semiconductor. This was difficult to achieve, as Al and Mg reacted with each

other when present in high concentrations. However, the structure of claim 2 did not specify any concentration ranges and comprised therefore structures which would not solve the above mentioned problem.

– The expression "partly diffused" used in claim 3 was not clear and the claim did not specify any parameters of the heat treatment for achieving this partial diffusion. The skilled person was left in the dark on the degree of the required partial diffusion, since in any epitaxial growth partial diffusion occurs in any case between adjacent layers due to the high temperatures involved in the process.

– Document E2 disclosed a p-type doped GaN/AlGaN:Mg structure which differed from the semiconductor of claim 1 in that the AlGaN layers were apparently also doped with Mg. Document D2 disclosed however a BP/AlGaN structure in which only the BP layers were selectively doped with Mg, as it was difficult to dope the AlGaN layers with this material. The fact that D2 also disclosed that p-type GaN layers should not be employed would not prevent the skilled person from doing so, as the later documents E4 and E5 disclosed how to obtain p-type GaN:Mg layers with good conductivity. Moreover, p-type GaN:Mg layers were already used in the structure of E2. Document D2 was from the early days of the development of III-V semiconductors and was partly rendered obsolete by the rapid development in this field during the 90's (see eg documents E4 and E5). In consequence, the semiconductor of claim 1 did not involve an inventive step.

– The semiconductor structure of claim 1 differed from the one disclosed in document D2 in that a p-type GaN:Mg layer was used instead of a p-type BP:Mg layer. The reasons mentioned in D2 for not using a GaN layer were low electrical conductivity and a Wurzite crystal structure. Documents E2 and E4 disclosed GaN layers with sufficient conductivity. Document E2 disclosed in addition a solution to the problem of growing layers on a sapphire substrate which induced a Wurzite structure. For these reasons the semiconductor of claim 1 did not involve an inventive step.

– The semiconductor of claim 2 did not involve an inventive step over the combination of documents E2 and D2, since E2 disclosed that the semiconductor was subjected to a heat treatment for stabilizing the structure. This had as direct consequence a partial diffusion between adjacent layers.

– Document D3 disclosed a semiconductor structure formed of p-type AlGaN layers having different aluminium concentrations. It was not disclosed in this document whether the dopant was magnesium nor whether the dopant level was different for layers with a different amount of aluminium. Magnesium was however the most common dopant for AlGaN. The opposed patent moreover disclosed that magnesium and aluminium reacted with each other. In consequence, the amount of magnesium necessarily depended on the amount of aluminium present unless special precautions were taken. No such precautions were disclosed in D3.

VI. The respondent proprietor argued essentially as follows:

– Documents E4 and E5 were belatedly introduced by the appellant opponent and should be disregarded by the board as they were not *prima facie* highly relevant.

– The disclosure of document E2 aimed at a different problem from the one of the patent and for this reason the person skilled in the art would disregard it. Document D2 rejected p-type GaN:Mg layers and concentrated on finding ways of avoiding a Wurzite-type crystal structure and of creating or retaining a zinc blend-type crystal structure. The teachings of both documents, even in the event that the skilled person would have considered them, were not combinable.

– Documents E4 and E5 did not overcome the clear teaching of D2 not to use p-type GaN:Mg layers, as they were totally silent on the use of these layers in a stacked structure and on the resulting crystal structure.

– Document D3 related to a mirror layer of a surface emitting LED. There was nothing in the teaching of this document which could have assisted the skilled person in solving the problem addressed in the opposed patent.

– Claims 2 and 3 were clear and enabled the skilled person to carry out the invention, as the skilled person was aware of the concentration ranges in which the invention should be carried out as well as

the parameters of the heat treatment required to obtain a partial diffusion between adjacent layers.

VII. At the oral proceedings before the board the parties made the following requests:

– the appellant opponent: that the decision under appeal be set aside and that the patent be revoked.

– the respondent proprietor: that the appeal be dismissed.

Reasons for the Decision

1. The appeal is admissible.

2. *Admissibility of documents E4 and E5*

2.1 The appellant opponent submitted documents E4 and E5 together with the statement of grounds of appeal in order to show that the prejudice expressed in document D2 on using p-type GaN:Mg layers had been overcome.

2.2 The respondent proprietor contested the relevance of these documents and requested that they be disregarded as not submitted in due time (Article 114(2) EPC).

2.3 The board, exercising its discretion under Article 114(2) EPC, decided to admit both documents into the proceedings, since they can be regarded as a direct response by the losing party to the reasoning of the appealed decision. They were submitted at the earliest possible moment, ie the filing of the

statement of grounds of appeal, giving the other party and the board adequate time to become acquainted with them. It is moreover in the interest of the public that all prior art which might be harmful to the patent be considered in the appeal if it is reasonable to expect so from the parties and the board, ie if this can be done without complication or protraction of the procedure.

3. *Claim 1 – Inventive step (Article 100(a) and 56 EPC).*

3.1 A feature of the p-type nitrogen compound semiconductor specified in claim 1 is that it comprises alternating layers of AlGaN and GaN in which only the GaN layers are doped with magnesium (Mg).

3.2 Document E2 discloses a superlattice layer 38, comprising alternating layers of AlGaN and GaN, which is doped with Mg as p-type impurity and which functions as a layer blocking the diffusion of the metal of the p-side electrode and/or the propagation of crystal defects ([0058] and Figure 7). Although this document does not explicitly disclose whether both types of layers or whether only one type is doped with Mg, the appellant opponent did not dispute that the skilled person would interpret this disclosure as meaning that both layers were Mg doped.

3.3 It follows that the semiconductor of claim 1 differs from the structure of document E2 in that only the GaN layers are doped with Mg.

3.4 The appellant opponent has argued that this feature improved the crystallinity and the electrical

conductivity of the structure, as the skilled person knew from document D2 that defects arise in AlGaN layers when doped with Mg due to the self compensation effect of AlGaN (column 11, line 44 to column 12, line 20). They would therefore have followed the teaching of D2 to dope only the other layers, ie in the structure of D2 the BP layers, and would accordingly have doped only the GaN layer in the structure disclosed in E2 in order to improve its properties. The reservation expressed in D2 concerning the use of GaN layers owing to its high resistivity was overcome by the teachings of the more recent documents E4 and E5 disclosing p-type doped GaN layers having low resistivity.

3.5 The board is not persuaded by this argument.

3.5.1 The aim of document D2 is to provide a blue light emitting diode (LED) made from a compound semiconductor material (column 2, lines 5 to 8). To this effect different III-V group-based compounds having a wide band gap are discussed in the introduction ("Background of the Invention"). Although GaN is recognized as a suitable material for short wavelength emission, it is discarded from further consideration since it has (i) a Wurzite (WZ) type crystal structure, (ii) a high ionizing property, which favours the formation of lattice defects, and (iii) cannot be obtained with low resistivity when doped p-type (column 1, lines 18 to 40). It is emphasized throughout this document that a zinc blend (ZB) type crystal structure is essential for obtaining a compound semiconductor having the desired wide band gap characteristic (eg column 1, lines 54 to 61; column 2, lines 32 to 50; column 11, lines 40 to 44

and all the independent claims). For these reasons, BP layers are used instead of GaN layers to form an AlGaN/BP superlattice in which only the BP layers are doped p-type (column 11, line 51 to column 12 line 18).

3.5.2 Although document E4 and E5 disclose how to obtain p-type doped GaN layers having a remarkably reduced resistivity (ie nearly six orders of magnitude; E4, Figure 1; E5, Figure 7.1), they are silent on the crystal structure of these layers and on their ionizing properties. Moreover, the thickness of the GaN layers disclosed in documents E4 and E5 is about 4 μm (E4, column 5, line 41 to 45; E5, Table 7.1) while the AlGaN/BP superlattice disclosed in document D2 has a period of only 2 nm, ie each layer has a thickness of about 1 nm (D2, column 6, lines 4 to 7; lines 36 to 40). It is not unreasonable to expect a very different behaviour in layers having three orders of magnitude thickness difference, in particular when going from a macroscopic level to a submicroscopic one in which quantum phenomena play an essential role.

3.5.3 It therefore cannot be deduced from the disclosure of E4 and E5 which properties an AlGaN/GaN compound semiconductor may have and, in particular, if the reservations expressed in document D2 are overcome.

3.5.4 These reservations are not deprived of their cogency by the disclosure of document E2, since this document does not disclose any details either of the doping of the AlGaN/GaN layers (ie whether both or only one, and in this case which one, of the layers was doped) or of their crystal structure. Moreover, document E2 discloses an AlGaN/GaN blocking layer for blocking the

diffusion of metal from the p-side electrode of the device and/or for blocking the propagation of crystal defects originating at the interface between the sapphire substrate and the semiconductor material ([0007], [0013] – [0014], [0017], [0022], [0058]). This is a different use of a superlattice from the one disclosed in document D2 in which the AlGaN/BP superlattice forms the active pn-junction of the LED.

3.6 The board does not share the view of the respondent proprietor that claim 1 should be construed as being limited to a cladding layer, ie a layer adjacent to the active layers of an LED or laser for confinement of the carriers and the emitted light, since the subject-matter of the claim merely specifies a nitrogen compound semiconductor. Such a semiconductor could be used eg for a blocking layer, as in document E2, or for an active layer, as in document D2. Nevertheless the board does not consider that a person skilled in the art would combine the teachings of document E2 and D2 in an obvious manner, since they relate to different uses of superlattices which require that the superlattices have different properties from each other.

3.6.1 The board therefore judges that the compound semiconductor according to claim 1 is to be considered as involving an inventive step within the meaning of Article 56 EPC.

4. *Claim 2 – Sufficiency of disclosure (Article 100(b) EPC)*

4.1 Claim 2 may be paraphrased as directed to a p-type gallium-nitrogen compound semiconductor comprising first and second alternately stacked p-type AlGaN:Mg

layers, the first layers having a higher aluminium concentration as well as a lower magnesium concentration than the second.

4.2 The appellant opponent has argued that claim 2 comprised stacks of alternating AlGaN layers having arbitrarily high concentrations of aluminium and magnesium so that the problem addressed by the patent, namely to improve the crystalline structure and electrical conductivity, was not solved by all the structures covered by the claim.

4.3 The board, however, agrees with the respondent proprietor that the skilled person knows the aluminium and magnesium concentration ranges required to achieve a desired effect and would have no difficulty in obtaining semiconductor structures solving the problem posed.

5. *Claim 2 – Inventive step*

5.1 As already mentioned when discussing the inventiveness of the semiconductor according to claim 1, the board is not persuaded that the skilled person would combine documents E2 and D2 in an obvious manner. Since the same is true for the semiconductor of claim 2, it remains to be decided whether document D3 would alone or in combination with the other documents on file render the semiconductor of claim 2 obvious.

5.2 Document D3 discloses a p-type mirror formed by two types of alternately stacked AlGaN layers having different aluminium compositions (column 6, lines 34 to

54; Figure 2). D3 does not disclose the p-type dopant used or the amount of dopant present in the layers.

5.3 The appellant opponent argued that Mg was the most common p-type dopant employed for AlGaN layers and that, according to the opposed patent, Al and Mg reacted in the gaseous phase so that less Mg was incorporated in the layer when more Al was present. Consequently, the layers with the higher Al concentration would have a lower Mg content if no special measures were taken to prevent it. No such special measures were however disclosed in document D3.

5.4 The board agrees with the appellant opponent that Mg is an obvious choice as p-type dopant for an AlGaN layer. It is however not persuaded that the stack of document D3 would possess a relation between the Al and Mg concentrations as required by claim 3. Document D3 does not disclose the p-type dopant concentrations. Therefore it cannot be concluded from this disclosure whether this concentration is the same or different in the two AlGaN layers or in which one of these layers it is higher.

5.5 The only prior art document disclosing a relation between Al and Mg in AlGaN layers is D2 (column 11, lines 44 to 60), which states that when a p-type impurity is doped in AlGaN a large number of defects occur due to self compensation and that therefore AlGaN should not be doped at all. This disclosure does not help the skilled person in deciding what the doping concentration in the layers of D3 might be.

5.5.1 The board therefore judges that the compound semiconductor according to claim 2 is to be considered as involving an inventive step within the meaning of Article 56 EPC.

6. *Claim 3 – Clarity (Article 84 EPC) and sufficiency of disclosure*

6.1 The appellant opponent objected that the expression "partly" introduced into claim 3 during the opposition procedure was not clear, since an epitaxial deposition of the layers required high temperatures and produced some interdiffusion between them. It was thus not clear how the heat treatment had to be performed so that the layers were further "partly diffused into each other".

6.2 The board however agrees with the respondent proprietor that the concept of being "partly diffused" by a heat treatment is clear to the skilled person, as it requires that further diffusion of aluminium and magnesium takes place into the adjacent layers while keeping the concentrations of these elements different, ie the non-homogeneous concentrations profiles for the two elements is maintained. The expression "partly diffused" is therefore considered to be clear.

6.3 The board is also not persuaded by the objection raised by the appellant opponent that the skilled person is unable to perform the invention owing to the lack of specific parameters for the heat treatment. The skilled person can determine by routine experiments the temperature and treatment time required for achieving a desired degree of interdiffusion. The board therefore

judges that the invention of claim 3 has been sufficiently disclosed.

7. *Claim 3 – Inventive step*

The method claimed is for obtaining the compound semiconductor of claim 2 and essentially performs a heat treatment on the compound semiconductor of claim 1. It therefore inherits the inventiveness of these products, as it can hardly be obvious to process a new and inventive product to obtain another new and inventive product.

Order

For these reasons it is decided that:

The appeal is dismissed.

Registrar Chair

S. Sánchez Chiquero R. G. O'Connell