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D E C I S I O N
of 15 July 2003

Case Number: T 0864/01 - 3.4.3

Application Number: 97924285.6

Publication Number: 0844674

IPC: H01L 33/00

Language of the proceedings: EN

Title of invention:
Semiconductor light emitting device and method for manufacturing the same

Applicant:
ROHM CO., LTD.

Opponent:
-

Headword:
AlGaN light emitting diode/ROHM

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (no)"

Decisions cited:
-

Catchword:
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Case Number: T 0864/01 - 3.4.3

D E C I S I O N
of the Technical Board of Appeal 3.4.3
of 15 July 2003

Appellant: ROHM CO., LTD.
21, Saiin Mizosaki-cho
Ukyo-ku
Kyoto-shi
Kyoto 615 (JP)

Representative: Pellmann, Hans-Bernd, Dipl.-Ing.
Patentanwaltsbüro
Tiedtke-Bühling-Kinne & Partner
Bavariaring 4-6
D-80336 München (DE)

Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 12 March 2001 refusing European application No. 97924285.6 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. K. Shukla
Members: G. L. Eliasson
J. P. B. Seitz

Summary of Facts and Submissions

I. European patent application No. 97 924 285.6 was refused in a decision of the examining division dated 12 March 2001. The ground for the refusal was that the claims according to the main request and first, second and third auxiliary requests did not meet the requirements of Articles 54, 56, and 123(2) EPC. In the decision the following prior art document was cited to support the findings of lack of novelty and inventive step.

D2: GB 2 293 919 A.

II. The appellant (applicant) lodged an appeal on 11 May 2001, paying the appeal fee the same day. A statement of the grounds of appeal was filed on 19 July 2001 together with new claims.

III. At the oral proceedings held on 15 July 2003, the appellant requested that the decision under appeal be set aside and a patent be granted on the basis of the new claims 1 to 3 filed with the statement of the grounds of appeal on 19 July 2001.

IV. Claim 1 reads as follows:

"1. A semiconductor light emitting device comprising:

a semiconductor substrate (1) of a first conductivity type;

a light emitting layer forming portion (10) formed overlying said semiconductor substrate (1) to have

an active layer (4) sandwiched between an n-type cladding layer (3) and a p-type cladding layer (5), said p-type cladding layer being formed in a carrier concentration of $1x10^{16}$ to $5x10^{16}$ cm^{-3};

a window layer (6) of a second conductivity type provided on said light emitting layer forming portion (10) and having a carrier concentration of $1x10^{18}$ to $3x10^{19}$ cm^{-3};

electrodes (8,9) respectively provided in electrical connection with said window layer (6) and said semiconductor substrate (1); and

a p-type second cladding layer (5a) provided on the opposite side to said p-type cladding layer (5) with respect to said active layer (4) and formed by a semiconductor layer of the same material basis as said p-type cladding layer (5) to have a carrier concentration of $5x10^{17}$ to $2x10^{18}$ cm^{-3},

wherein said light emitting layer forming portion is formed by overlying layers of AlGaInP-based compound semiconductors, and said window layer (6) of a p-type AlGaAs-based compound semiconductor being provided overlying said p-type cladding layer through said second p-type cladding layer of an AlGaInP-based compound semiconductor."

The only other independent claim 2 relates to a method of manufacturing a semiconductor light emitting device which, when manufactured according to the method, has the same features as the light emitting device according to claim 1.

V. The reasons given in the decision under appeal with regard to inventive step can be summarized as follows:

(a) The claimed device differs from that of document D2 in that (i) the second p-type cladding layer is provided directly on the first p-type cladding layer, whereas in document D2 a plurality of cladding layers having gradually increasing carrier concentration are formed over the active layer; and (ii) an AlGaAs-based window layer is formed on the cladding layers, whereas in document D2 an AlGaInP-based layer with gradually changing doping concentration and bandgap is used as a combined cladding and window layer.

(b) Difference (i) is considered an obvious simplification, since the skilled person confronted with providing an optimum but sophisticated solution to a given problem, which in the case of document D2 is to ensure effective injection of carriers while at the same time preventing the diffusion of impurities into the active layer, would recognise that less complicated alternatives generally entail less perfect results, and consequently, would envisage such alternatives at least in situations in which the advantages of decreased complexity can reasonably be expected to outweigh the resulting reduction in performance.

(c) As to difference (ii), AlGaAs-based window layers are well-known and are acknowledged as prior art in document D2. Thus, going back to the prior art of document D2 does not involve an inventive step.

VI. In support of inventive step, the appellant presented essentially the following arguments:

(a) Document D2 which starts from the same prior art device as the application in suit, teaches away from the claimed invention, since it explicitly teaches against using a window layer made of AlGaAs. Instead, it is taught in document D2 to replace the window layer with a thick cladding layer made of AlGaInP.

(b) Furthermore, document D2 does not teach the claimed two-layer structure for the p-type cladding layer. Instead, document D2 teaches to use a p-type cladding layer having a continuously varying concentration. The claimed structure has the advantages that the low-doped further p-type cladding layer prevents diffusion of zinc into the active layer, whereas the higher doped p-type cladding layer prevents a voltage drop between the cladding layer and the window layer due to the heterojunction between the two layers. The latter effect is not derivable from document D2, since such a heterojunction is not present in the device of document D2, due to the omission of a window layer made of AlGaAs.

Reasons for the Decision

1. The appeal meets the requirements of Articles 106 to 108 and Rule 64 EPC and is therefore admissible.

2. *Inventive step*

2.1 The application in suit relates to a double-heterostructure light emitting diode (LED) employing AlGaInP-based materials and discloses a prior art device known from JP 4 212 479 A, in the following referred to as document D4, in which an undoped active layer 13 is sandwiched between an n-doped 12 and a p-doped cladding layer 14, where all three layers are made of AlGaInP-based materials and are formed over a substrate 11 of n-type GaAs (cf. Figure 4; column 1, lines 15 to 49 of the application as published). Both cladding layers have a doping concentration of $5x10^{17}$ to $2x10^{18}$ cm^{-3}. A p-doped window layer 15 made of AlGaAs-based material is formed on the p-type cladding layer 14 for spreading the current over the entire active device area, and is usually referred to as a "current spreading layer" in the art. Two electrodes, 17, 18 are in contact with the window layer 15 and the substrate 11, respectively.

The application in suit does not provide any information as to the doping concentration of the window layer of the device of document D4. Document D4 itself, however, discloses a doping concentration of $3x10^{18}$ cm^{-3} for the window layer 15 (cf. D4, Table in column 6, which corresponds to the Table bridging columns 6 and 7 in the patent family member US-A-5 153

889), a value thus falling within the claimed range of $1x10^{18}$ to $3x10^{19}$ cm^{-3}.

2.1.1 The problem addressed by the application in suit is to improve the intensity of the emitted light of the prior art device known from document D4 which is not sufficiently high for applications such as outdoor displays and automobile lights (cf. column 1, line 50 to column 2, line 7).

2.1.2 The device according to claim 1 differs from that of document D4 in that it comprises a first p-doped cladding layer 5 adjacent the active layer 4 and having a doping concentration of $1x10^{16}$ to $5x10^{16}$ cm^{-3}, and a second p-doped cladding layer 5a between the first cladding layer 5 and the window layer 6 and having a doping concentration of $5x10^{17}$ to $2x10^{18}$ cm^{-3}, whereas in the known device, a single, p-doped cladding layer having a doping concentration of $5x10^{17}$ to $2x10^{18}$ cm^{-3} is used.

2.1.3 According to the application in suit, the problem of low light emitting efficiency is caused by diffusion of p-type dopant, such as zinc, from the p-type cladding layer into the active layer (cf. column 4, lines 34 to 55). The reduced dopant concentration in the first cladding layer 5 adjacent to the active layer of the claimed device prevents diffusion of dopants into the active layer, thereby enhancing the light emitting efficiency. The second cladding layer 5a has a higher doping concentration in order to prevent voltage drop due to the heterojunction between the second cladding layer 5a and the window layer 6 (cf. Figure 3; column 2,

lines 21 to 31 and column 2, line 50 to column 3, line 5; column 7, lines 41 to 58).

2.2 Document D2 refers to the same prior device as that of the application in suit (cf. D2, Figure 12; page 1, line 21 to page 2, line 19, referring to US-A-5 153 889 which is a patent family member of document D4), and is concerned with improving the intensity of the emitted light (i.e. the problem addressed in the application in suit) and additionally improving the device reliability.

The problem of the low light intensity, according to document D2, is caused by diffusion of zinc into the active layer (cf. D2, page 3, line 35 to page 4, line 8). The reliability problem, on the other hand, is in document D2 attributed to the tendency of the window layer to oxidize, since the window layer of AlGaAs-type material must have a high concentration of Al to ensure transparency to the emitted light (cf. D2, page 2, lines 3 to 15).

2.2.1 As a solution to the problem of increasing the light intensity, document D2 suggests to provide a p-type cladding layer with a varying doping concentration such that the doping concentration is low in a region adjacent to the active layer. The low-doped region of the p-type cladding layer prevents diffusion of zinc into the active layer (cf. page 3, line 35 to page 4, line 8; page 13, line 19 to page 14, line 10). The doping profile of the p-type cladding layer is preferably continuously increasing with distance from the active layer (cf. Figures 5 and 11 with accompanying text).

2.2.2 In order to improve the reliability of the device, the window layer of AlGaAs-type material is replaced by a thick (about 3 to 50 µm) p-type cladding layer made of AlGaInP-type material with a graded composition (cf. page 3, lines 21 to 31; page 9, line 28 to page 11, line 28).

2.2.3 The device of claim 1 differs from that of document D2 in that (i) the doping concentration in the p-type cladding varies step-wise, such that the dopant concentration in a first sublayer formed adjacent the active layer lies between $1x10^{16}$ cm^{-3} to $5x10^{16}$ cm^{-3}, the carrier concentration in the rest of the p-type cladding layer lies between $5x10^{17}$ cm^{-3} and $2x10^{18}$ cm^{-3}, whereas in document D2, the doping concentration in the p-type cladding layer varies gradually within the range of $1x10^{16}$ cm^{-3} and $1.10x10^{18}$ cm^{-3}; and (ii) a window layer made of p-type AlGaAs-based compound semiconductor is formed on the p-type cladding layer and the anode electrode is formed on the window layer, whereas in document D2, the p-type cladding layer is formed to have a thickness greater than in a conventional device, so that it will act as a window layer, i.e. being able to spread the current from the anode electrode over the entire active device area.

2.3 In the decision under appeal, document D2 was considered the closest prior art, and the appellant initially agreed with this assessment of the prior art. Following a discussion at the oral proceedings before the Board, however, it was agreed that document D4, which is the prior art referred to in both the application in suit and document D2, more properly represents the closest prior art, since firstly it has

more features in common with the claimed device than that of document D2. Secondly, the objective definition of the technical problem to be solved should normally start from the problem as described in the application in suit. If document D2 was to be considered as closest prior art, the technical problem would have to be completely reformulated.

2.4 As discussed under 2.1.1 and 2.2 above, the device known from document D4 has the problem that the light emitting efficiency is small due to the diffusion of zinc from the p-type cladding layer into the active layer (cf. application as published, column 1, line 50 to column 2, line 7). Thus, the problem addressed by the application in suit relates to improving the light emitting efficiency.

2.5 It is known from document D2 that the low light emitting efficiency of the device of document D4 is due to zinc diffusing into the active layer, and that this problem can be solved by reducing the concentration of zinc in a region of the p-type cladding layer adjacent to the active layer (cf. D2, page 13, line 19 to page 14, line 10). For this purpose, document D2 recommends to form the p-type cladding layer with a continuously varying impurity concentration (cf. D2, Figure 11 with accompanying test).

2.5.1 Although the appellant correctly observes that document D2 does not disclose two-layer structure of the p-type cladding layer (cf. item VI(b) above), the Board follows the argument made by the examining division in the decision under appeal, that the skilled person would also consider less sophisticated solutions than

that suggested in document D2, in particular the insertion a low-doped p-type layer between the p-type cladding layer and the active layer, in order to solve the problem of zinc diffusion (cf. item V(b) above).

2.5.2 As to the argument that the doping concentration of the second cladding layer has to be high in order to prevent a voltage drop between the cladding layer and the window layer (cf. item V(b) above), the Board notes firstly that it is well-known in the art that the voltage drop at a heterojunction can be reduced by increasing the doping concentration. Secondly, in the device of document D4, the doping concentrations are high at the heterojunction formed by the p-type cladding layer and the window layer.

Incidentally, it is also worthwhile to remark that document D4 discloses that the voltage drop at the cladding layer/window layer heterojunction is strongly influenced by the respective doping concentrations of the cladding layer and the window layer (cf. column 16, lines 31 to 45 of the patent family member US-A-5 153 889).

2.6 Thus, the skilled person faced with the problem of increasing the emitted light intensity of the device of document D4 would arrive at the claimed subject matter by taking a measure (using two p-type cladding layers with different doping concentrations) which is known to solve the problem addressed by the application in suit (diffusion of zinc).

2.7 The appellant argued that since document D2 explicitly teaches against using a window layer made of AlGaAs and provides a unique solution of a sole upper clad layer on top of the active layer, the skilled person would be led away from the claimed structure of having two p-type cladding layers made of AlGaInP and a p-type window layer made of AlGaAs (cf. item VI(a) above).

The Board finds however that a skilled person faced with the problem of reducing the effects of zinc diffusion into the active layer would not contemplate modifying the window layer of the device of document D4, since this would not be relevant for solving the technical problem at issue. As discussed under item 2.2.2 above, document D2 only discloses the replacement of a window layer made of AlGaAs-based material with a thick p-type cladding layer for the purpose of improving the reliability of the device, and there is nothing in document D2 which would suggest that this measure would improve the light emitting efficiency.

2.8 For the above reasons, in the Board’s judgement, the subject matter of claim 1 does not involve an inventive step within the meaning of Article 56 EPC.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

U. Bultmann R. K. Shukla