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Application Number: 09010817.6

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Title of invention:
Light emitting device

Applicant:
Seoul Semiconductor Co., Ltd.

Headword:

Relevant legal provisions:
EPC Art. 54

Keyword:
Novelty (no) - implicit disclosure in prior art (yes)

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Catchword:

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Case Number: T 0937/17 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 8 June 2021

Appellant: (Applicant)	Seoul Semiconductor Co., Ltd. 97-11, Sandan-ro 163 Beon-gil Danwon-gu Ansan-si, Gyeonggi-do 425-851 (KR)
Representative:	Isarpatent Patent- und Rechtsanwälte Behnisch Barth Charles Hassa Peckmann & Partner mbB Postfach 44 01 51 80750 München (DE)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 18 October 2016 refusing European patent application No. 09010817.6 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	M. Papastefanou
Members:	M. Stenger
	T. Bokor

Summary of Facts and Submissions

I. The appeal concerns the decision of the Examining Division to refuse European patent application No. 09010817.6. The Examining Division concluded that the subject-matter of claim 1 was not new compared to D3.

II. At the end of the oral proceedings before the Board, the appellant requested that the decision be set aside and that a patent be granted on the basis of a main request or an auxiliary request, both filed with the grounds of appeal. The main request corresponds to the one on which the contested decision is based.
The requests for interlocutory revision, remittal to the Examining Division and reimbursement of the appeal fee, submitted with the grounds of appeal, were not upheld.

III. The following documents are referred to:

D3: US 2007/108888 A1

D9: S.Pereira: "On the interpretation of structural and light emitting properties of InGaN/GaN epitaxial layers grown above and below the critical layer thickness", Thin Solid Films 515 (2006), 164-169

IV. Claim 1 of the main request has the following wording (labelling 1), 2), ... added by the Board):

1) *A light emitting device comprising:*
2) *a substrate (11);*
3) *a first semiconductor layer(15) on the substrate (11);*

4) *a second semiconductor layer (19) on the first semiconductor layer (15); and*

5) *a multi-quantum well structure (17) including a plurality of well layers (17b) and barrier layers (17a) between the first and second semiconductor layers (15, 19), at least one InGaN weil [sic] layer (17b) within the multi-quantum well structure (17)including at least one carrier trap portion (27) formed therein, characterized by*

6) *the at least one carrier trap portion (27) having a band-gap energy decreasing from a periphery of the carrier trap portion (27) to a center of the carrier trap portion (27), in the growth direction of the multi-quantum well structure (17),*

7) *and the carrier trap portion (27) containing indium in an amount gradually increasing from the periphery of the carrier trap portion (27) to the center thereof, in the growth direction of the multi-quantum well structure (17).*

V. Claim 1 of auxiliary request 1 differs from claim 1 of the main request in that it comprises, at its end, additional feature 8) as follows (labelling 8) added by the Board):

8) *and a carrier trap cluster formed by clustering at least two carrier trap portions (27).*

VI. The relevant arguments of the appellant may be summarized as follows:

(a) Main request

According to the invention, the creation of the carrier trap portions with a gradual change of the Indium content was based on a spontaneous phase separation during growth.

In contrast to the application, D3 did not mention any gradual change of the Indium content from the periphery of the nanoparticles to the center thereof.

Further, the purpose of D3 was to provide different nanoparticles with well-defined different emission wavelengths in one and the same well layer of the multi-quantum well structure. For that purpose, it was indispensable that the nanoparticles in that well layer had different but well-defined boundaries, sizes and compositions. This required a precise control of the growth process parameters and excluded the creation of a gradual change of the Indium content as claimed by spontaneous phase separation. The growth of nanoparticles that complied with the purpose of D3 could thus not involve such a spontaneous phase separation.

According to the first example given in paragraph [80] of D3, nanoparticles with two well-defined different emission wavelengths λ_1 and λ_2 were grown on the same layer as shown in figure 8. In a similar manner, the example shown in figure 9 showed two different emission wavelengths.
Both these examples were thus incompatible with a growth involving a spontaneous phase separation and/or the SK growth mechanism, despite the wording of paragraph [80].

(b) Auxiliary request

D3 disclosed nanoparticles emitting at different wavelengths. Providing nanoparticles with different emission wavelengths in clusters, i.e. in close proximity to each other, would lead, by means of non-radiative dipole-dipole coupling, to the shorter wavelengths not being emitted at all. The aim of D3 to provide different nanoparticles with different emission wavelengths in one and the same well layer would then not be achieved. The multi-well structure of D3 could thus not contain *clusters* of nanoparticles.

Reasons for the Decision

1. The appeal is admissible.

2. The application

The application relates to a light emitting device employing a multi-quantum well structure consisting of a stack of alternating barrier layers 17a and InGaN well layers 17b (see figure 1). The well layers comprise carrier trap portions 27 (see figure 3) which can use carriers for light emission (see paragraph [36]). Such carriers would normally be lost for emission due to dislocations (see paragraph [25]). The formation of the carrier trap portion is achieved by a method described in paragraph [27] of the application as "three-dimensional growth".

3. D3

D3 also discloses a light emitting device employing a multi-quantum well structure (*multi-stacked active layer structure*, see abstract). The well layers 4 contain nanoparticles acting as carrier traps to reduce non-radiative recombination caused by dislocations (see paragraphs [11] and [12]; the use of the obviously wrong term "radioactive" instead of "radiative" amounts to an obvious error in D3 not posing any problem to the skilled person). The nanoparticles can e.g. be formed in "SK mode" (see paragraph [25], SK mode referring to Stransky-Krastanov). One aim of D3 is to produce a device that emits a plurality of wavelengths that together yield white light (see paragraph [15]).

4. Main request, claim 1, Novelty

4.1 Features 1) to 5)

D3 (see in particular paragraph [80] and figures and figure 8(a), 8(b), 9(a) and 9(b)) discloses the pre-characterizing portion of claim 1 of the main request, namely

1) a light emitting device (paragraph [80]) comprising
2) a substrate 1;
3) a first semiconductor layer 2 on the substrate;
4) a second semiconductor layer 8 on the first semiconductor layer 2; and
5) a multi-quantum well structure 3, 4 including a plurality of well layers 4 and barrier layers 3 between the first and second semiconductor layers 2, 8, at least one InGaN well layer 4 (see paragraph [80]) within the multi-quantum well structure including at least one carrier trap portion (nanoparticles) formed therein.

This was not disputed by the appellant.

4.2 Features 6) and 7)

4.2.1 The term "gradual"

The Examining Division interpreted the term "gradual" in a broad manner as meaning "not abrupt" (see point 17 of the contested decision). The appellant accepted this interpretation in the grounds of appeal (page 1, last paragraph) and during the oral proceedings.

The application does not indicate the form of the gradual changes of the Indium concentration claimed (i.e. there is no indication of the slope of the variation of the Indium concentration from the periphery to the center of the carrier trap). The same applies to the band gap, which, for InGaN, depends on the Indium content (e.g., there is no indication of the value of the slope of the variation of the band gap with the thickness shown in the left-hand part of figure 4 (a)). Generally, figure 4 and the corresponding parts of the description do not represent actual measurements but only give a very schematic idea of which band gap variations could possibly be achieved, without indicating *how* that could be done.

The Board thus adheres to the broad interpretation of the term "gradual" used by the Examining Division and accepted by the appellant.

4.2.2 D3

The Board accepts that D3 does not explicitly disclose a "gradual" increase of the Indium content from the periphery of the nanoparticles to the center thereof, or a corresponding change of the band gap in the nanoparticles, in line with the submissions of the appellant.

However, the only teaching in the application relating to how carrier trap portions with such properties can be formed is found in paragraph [27] of the published application. According to this paragraph, the formation of carrier trap portions involves a transition from two-dimensional to three-dimensional growth at a predetermined thickness or more and makes use of the "phase separation characteristics of Indium".

In the example shown in figures 8(a) and 8(b) of D3, the nanoparticles are grown by "phase separation commonly appearing in InGaN materials" (see paragraph [80]).
The nanoparticles of the example shown in figures 9(a) and 9(b) of D3 are grown "with SK mode" (see paragraph [80]), i.e. by a self-organized (so-called "Stransky-Krastanov") transition from a two-dimensional growth to a three-dimensional growth at a critical thickness of the layers (see D3, paragraphs [25] and [80] and D9, abstract and section 1.).

Contrary to the submission of the appellant, D3 does not aim at providing nanoparticles of at least two different well-defined sizes and emission wavelengths. Instead, although D3 aims at controlling the elemental composition and geometric size of the nanoparticles to produce white light by combining emissions of different wavelengths, these different wavelengths need not originate all from nanoparticles. For instance, in the embodiment of figures 9(a) and 9(b), wavelength λ_1 is generated by the wetting layer and only the second wavelength λ_2 is created by the nanoparticles (see paragraph [80]).

Further, D3 does not indicate any particular maximum value for the bandwidths of these emissions at different wavelengths. On the contrary, figure 4 gives the impression that to produce white light within the context of D3, different types of nanoparticles would be acceptable that have relatively broad emission bandwidths (broader than the emission of the AlGaN buffer layer) and overlap each other.

In a manner similar to the application, D3 does not indicate to which degree of precision the elemental composition and the geometric size of the nanoparticles should be controlled.

Thereby, the Board does not believe that the growth mechanisms mentioned in paragraph [80] of D3 for the embodiments shown in figures 8(a), 8(b), 9(a) and 9(b) would result in emission characteristics, elemental compositions or geometrical sizes that were incompatible with the aim of D3 as a whole and these embodiments in particular, contrary to the submissions of the appellant. Hence, the Board sees no reason to assume that the nanoparticles of these embodiments would have to be formed by other mechanisms as the ones explicitly mentioned in paragraph [80].

It follows therefrom that the manner of forming carrier trap portions in the application, as far as it is disclosed, corresponds to the manner in which the nanoparticles are formed according to the examples shown in figures 8(a), 8(b), 9(a) and 9(b) of D3.

Since these nanoparticles are grown by the same growth mechanisms as the carrier trap portions of the application, both must possess the same structural properties.

The Board therefore concludes that the nanoparticles mentioned with respect to figures 8(a), 8(b), 9(a) and 9(b) as described in paragraph [80] of D3 must contain

Indium in an amount "gradually" increasing from the periphery of the nanoparticles to the center thereof in the growth direction of the multi-quantum well structure to the same extent, i.e. in the same "not abrupt" manner, as the carrier trap portions of the application as defined in feature 7). The same applies to the decrease of the band gap energy defined in feature 6).

D3 thereby discloses features 6) and 7) as well.

4.3 Conclusion

The Board thus comes to the conclusion that the subject-matter of claim 1 of the main request is not new in the sense of Article 54 EPC in view of D3.

5. Auxiliary request

In each of the examples shown in figures 8(a), 8(b), 9(a) and 9(b) of D3, a plurality of nanoparticles is present in each of the well layers 4.

Dipole-dipole interaction between nanoparticles with different emission wavelengths in one of these well layers might arguably take place under certain circumstances, e.g. if two such nanoparticles were in close proximity to each other, as submitted by the appellant.

However, no minimum or maximum distance of the at least two carrier trap portions forming the cluster is defined in feature 8) or the rest of claim 1, in absolute terms or relative to the size of the carrier trap portions. This finding also applies to the distance between two clusters.

Instead, the wording of feature 8) does not require more than that at least two carrier trap portions are somehow not too far away from each other, for example by being arranged in the same (InGaN) well layer.

Thus, even if the skilled person concluded from the aim of D3 to produce white light that nanoparticles with different emission wavelengths would have to be arranged at a minimum distance from each other to avoid non-radiative dipole-dipole interaction, the resulting well layers each comprising a plurality of nanoparticles at that minimum distance to each other would still fall under the wording of feature 8).

The Board thus comes to the conclusion that the subject-matter of claim 1 of auxiliary request 1 is not new according to Article 54 EPC in view of D3, either.

6. None of the requests fulfills the requirements of Article 54(1) EPC. Thus, the appeal must fail.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

S. Sánchez Chiquero M. Papastefanou

Decision electronically authenticated