

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

RAYVIO CORPORATION,
Petitioners,

v.

NITRIDE SEMICONDUCTORS CO., LTD,
Patent Owner.

IPR2018-01139
Patent 6,861,270 B2

Before BARBARA A. BENOIT, FRANCES L. IPPOLITO, and
JOHN D. HAMANN, *Administrative Patent Judges*.

IPPOLITO, *Administrative Patent Judge*.

JUDGMENT

Final Written Decision

Determining Some Challenged Claims Unpatentable

35 U.S.C. § 318(a)

I. INTRODUCTION

Petitioner RayVio Corporation filed a Corrected Petition (Paper 3, “Pet.”) requesting *inter partes* review of claims 1, 2, 8, and 9 of U.S. Patent No. 6,861,270 B2 (Ex. 1001, “the ’270 patent”). Patent Owner filed a Preliminary Response. Paper 8 (“Prelim. Resp.”). Based on these submissions, we instituted trial on all challenged claims and all grounds as follows:

References	35 U.S.C.	Claims Challenged
Ozaki ¹	§ 102(b)	1, 8
Ozaki, Stringfellow ²	§ 103(a)	1, 8
Ozaki, Stringfellow, Smith ³	§ 103(a)	1, 2, 8, 9
Tanaka, ⁴ Ozaki	§ 103(a)	1, 2, 8, 9

Paper 15 (“Dec.”).

After institution, Patent Owner filed a Patent Owner Response. Paper 25 (“PO Resp.”). Petitioner filed a Reply to the Patent Owner Response.

¹ JP Patent Application Publication No. H10-215029, published Aug. 11, 1998 (Exhibit 1041) (“Ozaki”). After filing the Petition, Petitioner submitted a corrected version of Ozaki as Exhibit 1041. See Paper 14. Citations in this Decision are to Exhibit 1041. We note, however, the Petition and Dr. Fitzgerald’s Declaration cite Ozaki as Exhibit 1007, which is substantively identical to Exhibit 1041.

² Stringfellow and Craford, *High Brightness Light Emitting Diodes*, Semiconductors and Semimetals, Vol. 48 Academic Press Ltd. (1997) (Exhibit 1010) (“Stringfellow”).

³ Kurt Vernon Smith, “Structural and Electronic Properties of III-V Nitride Heterostructures,” 2000 (Exhibit 1008) (“Smith”).

⁴ Japanese Patent Publication No. JP 10-79501A, published March 24, 1998 (Exhibit 1013) (“Tanaka”).

Paper 28 (“Pet. Reply”). Patent Owner filed a Sur-reply to the Reply. Paper 35 (“Sur-reply.”).

A consolidated oral hearing was conducted on September 5, 2019, for this proceeding and proceeding IPR2018-01141, and the record includes a transcript of the hearing. Paper 39 (“Tr.”).

The Board has jurisdiction under 35 U.S.C. § 6. This Final Written Decision is issued pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73 (July 2017). For the reasons that follow, we conclude that Petitioner demonstrates, by a preponderance of the evidence, that claims 1 and 8 are unpatentable. Further, we determine that Petitioner has not demonstrated, by a preponderance of the evidence, that claims 2 and 9 are unpatentable.

A. Related Matters

According to Petitioner, the ’270 patent is the subject of *Nitride Semiconductors Co., Ltd. v. RayVio Corporation*, Case No. 5:17-cv-02952 in the U.S. District Court for the Northern District of California. Pet. 1. The ’270 patent is also the subject of a petition in IPR2018-01141. *Id.*

B. The ’270 Patent

Generally, light emitting elements (e.g., light emitting diodes (LED)) may be created using a sapphire substrate, upon which layers of n-type and p-type GaN semiconductors are added. *See* Ex. 1001, 1:18–20. If the spacing of the atoms in the sapphire substrate differs from the spacing of the atoms in the GaN semiconductor, then a “lattice mismatch” occurs between the two layers that causes “dislocations” within the GaN semiconductor layer. *See id.* When an electron recombines with a “hole” at a “dislocation,” it does not produce a photon, which reduces the efficiency of the light emitting element. *Id.* at 1:22–25.

The '270 patent purports to address this problem by providing a “method for manufacturing a gallium nitride [GaN] compound semiconductor” which provides “improved light emitting efficiency.” *Id.* at 1:9–12. The '270 patent does so through a “spatial fluctuation in the band gap” at the point where the electrons and holes recombine. *Id.* at 1:55–58. According to the '270 patent, in some embodiments, a spatial fluctuation is created in the band gap by producing a change in compositional ratio in the second gallium nitride based semiconductor by the composition material. *Id.* at 1:56–58. The '270 patent teaches that

[w]hen the composition material is present, the solid phase composition of the composition material is increased in a gallium nitride based semiconductor when it is formed on the composition material. Because of this, the compositional ratio in the region where the composition material is present differs from that in the region where the composition material is not present. *Due to the difference in the compositional ratio, a spatial fluctuation is produced in the band gap. By forming the spatial fluctuation in the band gap, recombination of the carriers are facilitated at the region where the band gap is narrow, and, thus, the light emitting efficiency can be increased even when such dislocations are present.*

Id. at 1:59–2:3 (emphasis added). The '270 patent discloses different methods of introducing “spatial fluctuation in the band gap.”

One of these methods is described in Figures 1A and 1B reproduced below.

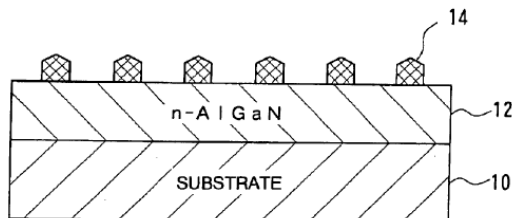


Fig. 1A

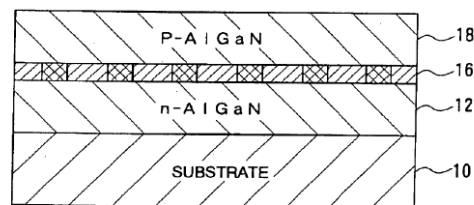


FIG. 1B

Figures 1A and 1B are diagrams showing a method for manufacturing a gallium nitride based conductor according to one of the methods described in the '270 patent. Ex. 1001, 3:9–12. In Figure 1A, n-type $\text{Al}_y\text{Ga}_{1-y}\text{N}$ layer 12 is grown on sapphire substrate 10. Ex. 1001, 3:34–36. Gallium droplets 14 are formed on n-type $\text{Al}_y\text{Ga}_{1-y}\text{N}$ layer 12 using MOCVD (metal organic chemical vapor deposition). *Id.* at 3:36–40. Figure 1B shows $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer 16 grown on n-type $\text{Al}_y\text{Ga}_{1-y}\text{N}$ layer 12, which also contains the Ga droplets 14. *Id.* at 3:41–44. In the regions where the Ga droplets are present, the solid phase composition of gallium within $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer 16 becomes high, and thus, a spatial fluctuation is formed in the band gap of $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer 16. *Id.* at 3:44–48. According to the '270 patent, the phenomenon of compositional variation within the $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer 16 due to Ga droplets 14 produces a spatial fluctuation in the band gap, that is, widening and narrowing of the band gap. Ex. 1001, 3:46–54. After $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer 16 is grown, a p-type $\text{Al}_y\text{Ga}_{1-y}\text{N}$ layer 18 is grown to produce a double hetero structure. *Id.* at 3:54–57.

The '270 patent provides Figure 4, reproduced below, to illustrate a spatial fluctuation in a band gap. Ex. 1001, 3:21–22.

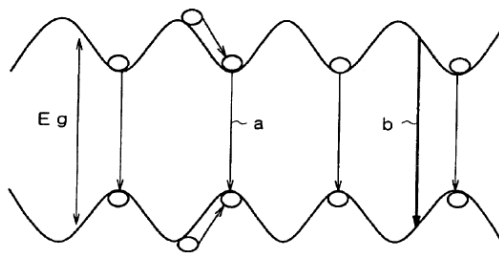


Fig. 4

Figure 4 schematically shows the band gap E_g of a material for a light emitting element. Ex. 1001, 1:26–27. Referring to Figure 4, the '270 patent teaches that

when there is a spatial fluctuation in the band gap of the light emitting element material, light emission occurs only at the locations where the band gap is narrow (gap “a” in the figure). Therefore, if the density of the light emitting points based on the spatial fluctuation of the band gap can be set to exceed the density of dislocations in the light emitting element materials, it is possible to obtain a percentage of the luminous recombination occurring at the points where the band gap is narrow which is higher than the percentage of the non-luminous recombination of an electron and a hole at the dislocations (gap “b” in the figure), and, therefore, degradation in the light emitting efficiency can be inhibited.

Id. at 1:26–39.

C. Challenged Claims

Petitioner challenges claims 1, 2, 8, and 9. Claims 1 and 8 are independent claims. Independent claim 1 is reproduced below:

1. A method for manufacturing a gallium nitride based semiconductor, comprising the steps of:

(a) forming a first gallium nitride based semiconductor on a substrate, the first gallium nitride based semiconductor having a first surface;

(b) forming on less than a total area of the first surface a composition material of the first gallium nitride based semiconductor; and

(c) forming a second gallium nitride based semiconductor on the first gallium nitride based semiconductor on which the composition material is formed; wherein a spatial fluctuation is created in the band gap by variation in the compositional ratio in the second gallium nitride based semiconductor created by the composition material, and the second gallium nitride based semiconductor is a light emitting layer.

Ex. 1001, 5:29–44.

D. Prior Art and Instituted Grounds

We instituted *inter partes* review on the following grounds of grounds of unpatentability:

Claims Challenged	35 U.S.C. §	References
1, 8	102(b)	Ozaki
1, 8	103(a)	Ozaki, Stringfellow
1, 2, 8, 9	103(a)	Ozaki, Stringfellow, Smith
1, 2, 8, 9	103(a)	Tanaka, Ozaki

Dec. 35. In addition to the references listed above, Petitioner relies on the Declaration of Dr. Eugene Fitzgerald. Ex. 1029⁵. Patent Owner relies upon the Declaration of Dr. Alan Doolittle. Ex. 2053.

II. ANALYSIS

A. Claim Construction

For petitions filed before November 13, 2018, we interpret the claims of an unexpired patent that will not expire before issuance of a final written decision using the broadest reasonable interpretation in light of the specification. See 37 C.F.R. § 42.100(b) (2016); *Cuozzo Speed Techs., LLC v. Lee*, 136 S. Ct. 2131, 2144–46 (2016).

1. “*spatial fluctuation is created in the band gap*” (claim 1)

In the Petition, Petitioner proposes that the broadest reasonable interpretation of “spatial fluctuation . . . created in the band gap” is

⁵ This Decision cites Exhibit 1029, which is a corrected declaration for Dr. Fitzgerald. Exhibit 1029 is identical in substance to originally filed Exhibit 1002. We note, however, that the Petition cites to Exhibit 1002.

“widening and narrowing of the band gap” as defined in the Specification. Pet. 9 (citing Ex. 1001, 3:53–55). Petitioner argues that based on the Specification and extrinsic dictionary definitions, the broadest reasonable interpretation of the term should not include “continuous.” *Id.* at 10 (citing Ex. 1001, 3:52–54); Ex. 1005; Ex. 1006).

In its Response, Patent Owner proposes that the district court’s construction in the related litigation should be adopted. PO Resp. 12–14. Specifically, Patent Owner construes the claim phrase “a spatial fluctuation . . . in the band gap” to mean “continuous widening and narrowing of the band gap laterally within the second gallium nitride based semiconductor is created by changes in the ratio of the elements in the second gallium nitride based semiconductor created by the composition material.” PO Resp. 12 (citing Ex. 1004, 27). Patent Owner further contends that Petitioner did not contest this construction in district court. *Id.* at 13. Additionally, Patent Owner asserts that Figure 4 of the ’270 patent depicts continuous widening and narrowing of the band gap. *Id.* (citing Ex. 1001, 3:21–22).

In its Reply, Petitioner responds that based on the Specification and extrinsic dictionary definitions, the broadest reasonable interpretation of the term should not include “continuous.” Pet. Reply 1 (Ex. 1001, 3:52–54; Ex. 1005; Ex. 1006). Petitioner further contends that, at the district court, “[g]iven the number of terms and limited briefing space, Petitioner focused its briefing on other terms and indefiniteness.” *Id.* Further, at the oral hearing, Petitioner indicated that it does not contest including “laterally” in the BRI construction, but that the Specification does not define the spatial fluctuation this way. Tr. 4:24–5:2 (“MR. TONKOVICH: Laterally is part of the District Court construction, and we don’t have a problem with laterally.

Again, that's not how the Patent Owner defined it, so I think there is a legitimate point in not having laterally in there either."").

Based on the complete record, we understand the parties' dispute to rest principally on whether a broadest reasonable construction of "spatial fluctuation . . . in the band gap" requires *continuous* widening and narrowing of the band gap. We determine that it does not.

Turning to the '270 patent, we find that the Specification does not require that the spatial fluctuation in the band gap be continuous. *See generally* Ex. 1001. For example, the '270 patent teaches that, in some embodiments, a spatial fluctuation is created in the band gap by producing a change in compositional ratio in the second gallium nitride based semiconductor by the composition material. Ex. 1001, 1:56–58. For one embodiment, the '270 patent teaches that

[w]hen the composition material is present, the solid phase composition of the composition material is increased in a gallium nitride based semiconductor when it is formed on the composition material. Because of this, the compositional ratio in the region where the composition material is present differs from that in the region where the composition material is not present. Due to the difference in the compositional ratio, a spatial fluctuation is produced in the band gap. By forming the spatial fluctuation in the band gap, recombination of the carriers are facilitated at the region where the band gap is narrow, and, thus, the light emitting efficiency can be increased even when such dislocations are present.

Id. at 1:59–2:3. Referring to Figures 1A and 1B, reproduced below, the '270 patent teaches that in the regions where the Ga droplets are present, the solid phase composition of gallium within $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer 16 becomes high, and thus, a spatial fluctuation is formed in the band gap of $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer 16.

Id. at 3:44–48.

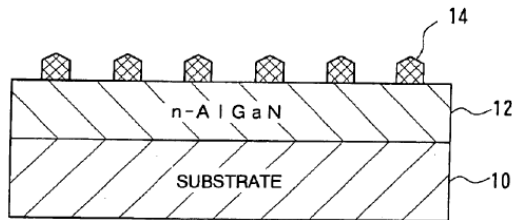


Fig. 1A

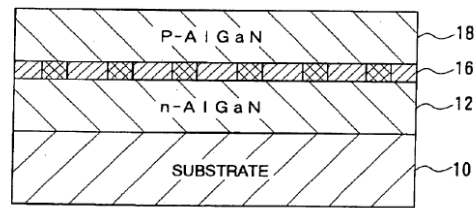


FIG. 1B

Figures 1A and 1B are diagrams showing a method for manufacturing a gallium nitride based conductor according to one of the methods described in the '270 patent. The '270 patent teaches explicitly that “[s]uch compositional variation *produces a spatial fluctuation in the band gap, that is, widening and narrowing of the band gap.*” Ex. 1001, 3:52–54 (emphasis added).

In describing a “second” embodiment, the '270 patent further teaches that “a spatial fluctuation in the band gap can easily be created with a density greater than or equal to the dislocation density, and, thus, the light emitting efficiency can be improved.” *Id.* at 4:40–44. Further, for another embodiment shown in Figure 3, the '270 patent teaches that “although FIG. 3 shows a lattice mismatch layer 21 formed on the AlGaN layer 20, it is also possible to form the lattice mismatch layer 21 on the GaN layer 22 and form a spatial fluctuation in the band gap of the AlGaN layer 20.” *Id.* at 5:18–21. The term “continuous” is not used to describe the spatial fluctuation present in any of these embodiments.

Additionally, the '270 patent provides Figure 4, reproduced below, to illustrate a spatial fluctuation in a band gap. Ex. 1001, 3:21–22.

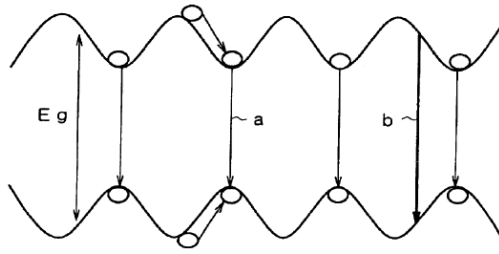


Fig. 4

Figure 4 schematically shows the band gap E_g of a material for a light emitting element. Ex. 1001, 1:26–27. Referring to Figure 4, the '270 patent teaches that

when there is a spatial fluctuation in the band gap of the light emitting element material, light emission occurs only at the locations where the band gap is narrow (gap “a” in the figure). Therefore, if the density of the light emitting points based on the spatial fluctuation of the band gap can be set to exceed the density of dislocations in the light emitting element materials, it is possible to obtain a percentage of the luminous recombination occurring at the points where the band gap is narrow which is higher than the percentage of the non-luminous recombination of an electron and a hole at the dislocations (gap “b” in the figure), and, therefore, degradation in the light emitting efficiency can be inhibited.

Id. at 1:26–39. Here, we observe that the '270 patent also does not expressly describe the spatial fluctuation as continuous. *Id.*

With regard to Figure 4, Patent Owner relies on the testimony of Dr. Doolittle, who testifies that “Figure 4 . . . is a generic depiction of the potential energy, and shows that the electron (colored green) and hole (uncolored) move to seek the lowest energy available.” Ex. 2053 ¶ 97. Dr. Doolittle’s annotated Figure 4 is reproduced below:

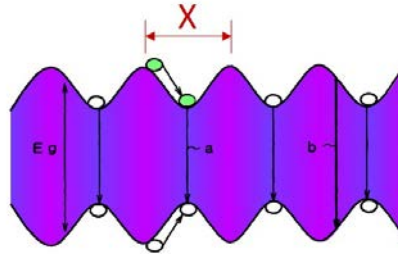


Fig. 4

Annotated Figure 4 of the '270 patent from Dr. Doolittle's Declaration shows the electron outside the low-bandgap region and moving down the conduction band edge toward the low bandgap region, according to Dr. Doolittle. Ex. 2053 ¶ 98. Referring to annotated Figure 4, Dr. Doolittle asserts that

Figure 4 shows the electron outside the low-bandgap region and moving down the conduction band edge toward the low bandgap region. *That the electron is outside the low bandgap area suggests no quantum confinement.* Additionally, no quantized states are shown in Figure 4. Instead, *the arrow (showing the movement of the electron and the hole) informs a POSA that there is a continuous movement in position (lateral directions in figure 4) and energy (vertical directions in Figure 4), and from that, a POSA would conclude that Figure 4 is showing a smoothly varying change in both position and energy.* Critically, electrons in a quantum state moving laterally do so without varying energy, i.e., they move straight across because the quantized energy is independent of position inside the quantum dot. Electrons in a non-quantized state moving laterally fluctuate in energy as the band gap fluctuates, as shown above.

Ex. 2053 ¶ 98 (emphases added).

Additionally, Dr. Doolittle relies on extrinsic evidence to show that a PHOSITA would have read Figure 4 to teach smooth continuous energy variations rather than the “abrupt changes in energy of quantum dots.” Ex. 2053 ¶ 99 (Figure 4 “stands in stark contrast to quantum dots, which involve

abrupt changes in energy that a person of ordinary skill in the art would have easily recognized as discontinuous energy jumps and a constant energy, E_n , within the quantum dot.”) (citing Ex. 2038); *see also* ¶ 124 (citing Exhibits 2047–2048 as schematics showing continuous potential fluctuation).

Although we agree that Figure 4 provides, in Dr. Doolittle’s words, a “simplified approximation of potential energy fluctuation,” Dr. Doolittle’s testimony strays from the express disclosure in the ’270 patent. The Specification does not teach expressly that Figure 4 shows a *continuous* fluctuation. Further, the Specification states explicitly that the that the “compositional variation” shown in Figures 1A and 1B “*produces a spatial fluctuation in the band gap, that is, widening and narrowing of the band gap.*” Ex. 1001, 3:52–54 (emphasis added). Here, the intrinsic evidence supports Petitioner’s position that the construction of “spatial fluctuation . . . in the band gap” is reasonably broader than Patent Owner’s proposal.

Moreover, Patent Owner acknowledges that the ’270 patent describes Figure 4 as being “an *explanatory diagram* illustrating spatial fluctuation in a band gap.” Ex. 1001, 3:21–22 (emphasis added). As such, Figure 4 serves to explain the concept of spatial fluctuation, rather than to further limit spatial fluctuation, which we find the ’270 patent defines as “widening and narrowing of the band gap.” *Id.* at 3:51–54. Further, to the extent that Figure 4 depicts spatial fluctuation that is continuous, such a depiction is a specific example of “widening and narrowing of the band gap,” rather than serving to limit the claims to that example, when viewed in light of the entire disclosure of the ’270 patent. E.g., Ex. 1001, 1:26–39, 3:21–22, 3:51–54, Fig. 4; *see also Phillips v. AWH Corp.*, 415 F.3d 1303, 1321 (Fed. Cir. 2005) (en banc) (“Properly viewed, the ‘ordinary meaning’ of a claim term is its meaning to the ordinary artisan after reading the entire patent.”); *MBO*

Labs., Inc. v. Becton, Dickinson & Co., 474 F.3d 1323, 1333–34 (Fed. Cir. 2007) (citing *Gart v. Logitech, Inc.*, 254 F.3d 1334, 1342 (Fed. Cir. 2001)) (“[P]atent coverage is not necessarily limited to inventions that look like the ones in the figures.”). Rather, the express language of the ’270 patent is broader and states that a spatial fluctuation in the band gap is “widening and narrowing of the band gap.” Ex. 1001, 3:51–54.

Additionally, we are not persuaded that the ’270 patent considered as a whole excludes irregular or discontinuous fluctuations that may characterize energy variations on the quantum level. See Ex. 2053 ¶¶ 99, 123. Referring to Figure 3, the ’270 patent expressly teaches that

[b]ecause the thickness of the GaN layer 22 in the portion of the unevenness differs from that of the other portions, the thickness of the layer becomes non-uniform. Due to this non-uniformity, the *quantum level based on the quantum effect spatially varies and the band gap is spatially fluctuated*.

Ex. 1001, 4:63–5:1 (emphasis added). At a minimum, the ’270 patent contemplates that quantum level effects, including spatial variation, which undercuts Dr. Doolittle’s testimony that the ’270 patent excludes any discontinuous spatial fluctuations on the quantum level.

Also, at the very least, Dr. Doolittle’s testimony does not address “continuous” with respect to the third embodiment’s teaching that “the quantum level . . . spatially varies and the band gap is spatially fluctuated.” Nor does Dr. Doolittle address how continuous relates to transitions between spatially varying quantum levels and lateral position, for this third embodiment. We also find Dr. Doolittle’s testimony that “[t]he ’270 discusses a range of sizes (i.e., up to a micron distance between narrow band gap regions) that cannot result in a quantized state” unavailing. *Id.* ¶ 97 (citing Ex. 1001, 2:5–8). This testimony does not change that the ’270

patent also teaches an embodiment having a quantum well and that the quantum level spatially varies. Ex. 1001, 4:63–5:1. Thus, we find insufficient justification for a construction that would exclude the ’270 patent’s third embodiment. *Starhome GmbH v. AT & T Mobility LLC*, 743 F.3d 849, 857 (Fed. Cir. 2014) (quoting *Vitronics Corp.*, 90 F.3d at 1583) (“[A] construction that excludes a preferred embodiment ‘is rarely, if ever, correct and would require highly persuasive evidentiary support.’”). Thus, to the extent that we would have considered Dr. Doolittle’s testimony for this construction, we would have given it little weight in light of the express teachings in the Specification that contradict his testimony.

We further note that because we construe spatial fluctuation in the band gap in light of the intrinsic evidence in the record, we need not resort to extrinsic evidence, such as the dictionary definitions offered by the parties. *See Power Integrations, Inc. v. Fairchild Semiconductor Int’l, Inc.*, 711 F.3d 1348, 1360 (Fed. Cir. 2013); *Vitronics Corp.*, 90 F.3d at 1583 (“In most situations, an analysis of the intrinsic evidence alone will resolve any ambiguity in a disputed claim term. In such circumstances, it is improper to rely on extrinsic evidence.”). Nonetheless, we determine also that the parties’ reliance on dictionary definitions is consistent with our construction. Dr. Doolittle asserts that, based on dictionary definitions, the plain and ordinary meaning of “fluctuate” or “fluctuation” is: “1. To change continually; vary irregularly; shift back and forth or up and down 2. To move in waves; undulate,” (Ex. 2035, 310), and “1. constant change; vacillation; instability. 2. undulation,” (Ex. 2046, 627). Ex. 2053 ¶ 123. Petitioner submits a similar definition from the American Heritage Dictionary: “1. To vary irregularly. . . 2. To rise or fall in or as if in waves; undulate....” Ex. 1005, 310. We find that these definitions support our

determination that the plain and ordinary meaning of “fluctuate” may include a broad range of variation that is not limited to Patent Owner’s narrower proposal of *continuous* fluctuation.

Further, we are not persuaded that Petitioner has conceded the construction of this term in this proceeding because “Petitioner never argued to the District Court that its construction conflicted with the specification.” PO Resp. 13. Petitioner has explained that it did not agree with Patent Owner’s proposal in the related litigation, but opted to present different arguments in this proceeding. Reply 1. Indeed, the district court’s claim construction order indicates that it adopted Patent Owner’s construction without having considered any of Petitioner’s arguments that have been presented in this proceeding. Ex. 1004, 16 (“Nitride proposes that ‘spatial fluctuation . . . in the band gap’ should be construed as ‘continuous widening and narrowing of the band gap laterally within the second gallium nitride based semiconductor.’ RayVio does not appear to disagree with this proposed construction. Responsive Br. 11. Accordingly, the Court adopts Nitride’s proposed construction of this phrase.”). Thus, we determine that the record here is different from that in the related litigation, and when our complete record is considered, Petitioner’s arguments are better supported by and consistent with the Specification.

For the reasons discussed above, we determine that the broadest reasonable construction of “spatial fluctuation . . . in the band gap” means “widening and narrowing of the band gap.”⁶

⁶ Separately, Patent Owner argues that the Applicant’s statements during prosecution confirm a lateral variation for the spatial fluctuation. See PO Resp. 14 (citing Ex. 2053 ¶¶ 123–127); see Ex. 2053 ¶ 126. However, as discussed above, Petitioner does not contest including “laterally” in the BRI

2. Other Terms

Petitioner also proposes constructions for other terms. See Pet. 7–10. We determine that, for the purposes of this Final Written Decision, it is unnecessary to expressly construe other claim terms. See *Vivid Techs., Inc. v. Am. Sci. & Eng’g, Inc.*, 200 F.3d 795, 803 (Fed. Cir. 1999) (Only terms in controversy must be construed and only to the extent necessary to resolve the controversy); see also *Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017) (citing *Vivid Techs* in the context of an *inter partes* review).

B. Obviousness

In *Graham v. John Deere Co. of Kansas City*, 383 U.S. 1 (1966), the Supreme Court set out a framework for assessing obviousness under § 103 that requires consideration of four factors: (1) the “level of ordinary skill in the pertinent art,” (2) the “scope and content of the prior art,” (3) the “differences between the prior art and the claims at issue,” and (4) “secondary considerations” of non-obviousness such as “commercial success, long-felt but unsolved needs, failure of others, etc.” *Id.* at 17–18. “While the sequence of these questions might be reordered in any particular case,” *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 407 (2007), the Federal Circuit has “repeatedly emphasized that an obviousness inquiry requires examination of all four *Graham* factors and that an obviousness

construction, but notes that the Specification does not define the spatial fluctuation this way. Tr. 4:24–5:2. Because the parties do not dispute this aspect of the claim construction, we do not expressly address these arguments. We do note, however, that the ’270 patent does not require that the spatial fluctuation occurs laterally within the second gallium nitride based semiconductor. Ex. 1001, 3:53–54.

determination can be made only after consideration of each factor.” *Nike, Inc. v. Adidas AG*, 812 F.3d 1326, 1335 (Fed. Cir. 2016).

We note that, with respect to the fourth *Graham* factor, the record in this proceeding does not include any argument or evidence directed to secondary considerations of nonobviousness. The analysis below addresses the first three *Graham* factors.

C. Level of Ordinary Skill in the Art

In determining the level of skill in the art, we consider the type of problems encountered in the art, the prior art solutions to those problems, the rapidity with which innovations are made, the sophistication of the technology, and the educational level of active workers in the field. *Custom Accessories, Inc. v. Jeffrey-Allan Indus. Inc.*, 807 F.2d 955, 962 (Fed. Cir. 1986); *Orthopedic Equip. Co. v. U.S.*, 702 F.2d 1005, 1011 (Fed. Cir. 1983).

Petitioner contends that an ordinarily skilled artisan at the time of the invention of the '270 patent would have had the following education and experience:

[A] Bachelor's degree in physics, electrical engineering, materials science, or the equivalent thereof, and 3-5 years of professional experience working in the field of nitride semiconductors. Ex. 1002, ¶ 17.

Pet. 7. Patent Owner does not dispute this level of skill. PO Resp. 16 (“There is no material difference between Petitioner’s and Patent Owner’s definitions of a POSA.”). We determine that Petitioner’s description of an ordinarily skilled artisan is supported by the record and we apply that definition here. We note also that the applied prior art reflects the appropriate level of skill at the time of the claimed invention (*see Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001)).

D. Obviousness based on Ozaki—Claims 1 and 8

Petitioner asserts independent claims 1 and 8 would have been obvious based on the teachings of Ozaki and Stringfellow. Pet. 30–33. Petitioner relies primarily on Ozaki’s disclosure for each limitation recited in claims 1 and 8. *Id.* For the reasons discussed below, we are persuaded that Petitioner has established, by a preponderance of the evidence, that claims 1 and 8 would have been obviousness over the combination of Ozaki and Stringfellow.

1. Summary of Ozaki (Ex. 1041)

Ozaki describes a laminated semiconductor structure that includes a nitride semiconductor layer between a substrate and an active layer. Ex. 1041 ¶ 13. Examples of this structure are shown in Figures 2 and 3, which are reproduced below.

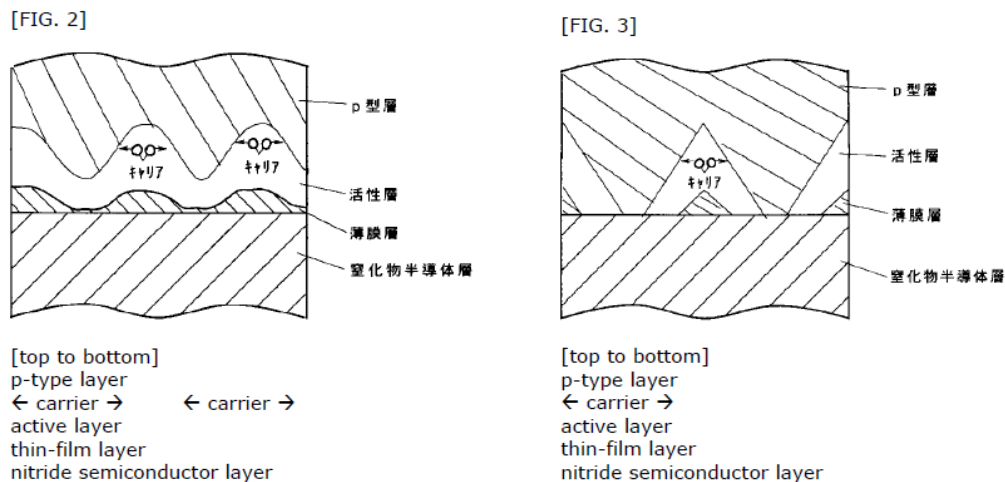


Figure 2 and Figure 3 are cross-sectional views of laminated structures with a n-type nitride semiconductor layer, a thin-film layer with a lattice constant irregularity difference of $\pm 3\%$ or more, an active layer, and a p-type layer on top. Ex. 1041 ¶ 15.

Ozaki teaches that when a thin-film layer is very thin, there are spots in the film where metal atoms are present and spots in the film where metal atoms are absent from a microscopic viewpoint. Ex. 1041 ¶ 16. The presence or absence of these atoms in the film cause the film thickness to be uneven. *Id.* According to Ozaki, when the thickness of the thin-film layer is uneven, the properties of the crystals will be different. *Id.* Ozaki further teaches:

The crystal component constituting the thin-film layer is selected depending on the atoms or compound present in the crystals constituting the nitride semiconductor layer in contact with the thin-film layer so that the lattice constant irregularity difference of the thin-film layer is $\pm 3\%$ or more relative to that of the nitride semiconductor layer. There are no particular restrictions on this in the present invention. When the thin-film layer in the present invention is a nitride semiconductor, there are no particular restrictions on the metal atoms contained in the nitride semiconductor. However, at least one type of atom from Group 2 or Group 3 of the periodic table is preferred, and Mg, Zn, Cd, Ga, or In is especially preferred . . . The thin-film layer may be a layer with only metal atoms (sometimes referred to below as a metallic layer).

Ex. 1041 ¶ 11.

Further, Ozaki teaches that when an active layer is grown on top of the thin-film layer, the active layer selectively forms quantum boxes or quantum dots and the output improves significantly. *Id.*

Ozaki additionally discloses an InGaN active layer grown very thin to form a quantum structure in which strain energy causes the indium (“In”) content to be entirely uneven with indium-rich regions with a larger amount of In and indium-poor regions with a smaller amount of In. Ex. 1041 ¶ 16. Ozaki observes that when a nitride semiconductor containing In is grown with an uneven thickness in the in-plane direction, In compositional

separation tends to occur. *Id.* “Quantum dots formed due to the In compositional separation and dots formed due to the uneven thickness of the well layer in the in-plane direction both act to form quantum dots, quantum disks, or quantum boxes.” *Id.* “In other words, the indium-rich regions constitute quantum dots or quantum boxes. By forming a thin-film layer, the InGaN active layer readily forms quantum dots or quantum boxes, and this is believed to significantly improve the output.” Ex. 1041 ¶ 17.

2. Summary of Stringfellow

Stringfellow is a reference titled “High Brightness Light Emitting Diodes” that discloses, among other things, band gap energies of various materials. For example, Figures 1 and 19 are reproduced below.

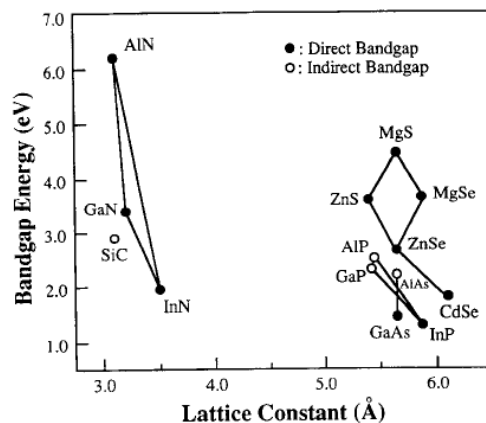


FIG. 1. Bandgap energy of various materials for visible emission devices as a function of their lattice constant. AlN, aluminum nitride; GaN, gallium nitride; InN, indium nitride; SiC, silicon carbide; MgS, magnesium sulfide; ZnS, zinc sulfide; MgSe, magnesium selenide; AlP, aluminum phosphide; ZnSe, zinc selenide; GaP, gallium phosphide; AlAs, aluminum arsenide; CdSe, cadmium selenide; GaAs, gallium arsenide; InP, indium phosphide. Reprinted from Nakamura (1995b) with the permission of the IEEE.

Figure 1 shows the relationship between band gap energy of particular nitride compounds relative to the lattice constant. Ex. 1010, 7.⁷

⁷ Citation refers to pagination at the bottom of each page.

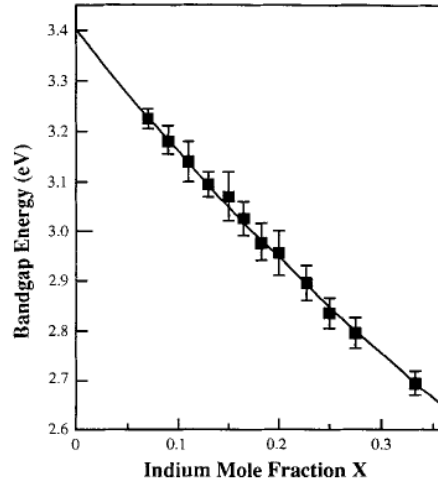


FIG. 19. Bandgap energy of $\text{In}_x\text{Ga}_{1-x}\text{N}$ films as a function of the indium (In) mole fraction x . The In mole fraction x was determined by measurements of the X-ray diffraction peaks. Solid curve represents values obtained by Eq. (1) as discussed in the text, assuming that the bandgap energy for gallium nitride and indium nitride is 3.40 and 1.95 eV, respectively. Reprinted from Nakamura (1995a) with the permission of the American Institute of Physics.

Figure 19 shows the bandgap energy of grown InGaN films as a function of the In mole fraction. Ex. 1010, 9.

3. Claims 1 and 8

a. “[a] method for manufacturing a gallium nitride based semiconductor, comprising the steps of”

Petitioner argues that to the extent that the preamble is limiting, Ozaki teaches “[a] method for manufacturing a gallium nitride based semiconductor,” as recited in claim 1. Pet. 14. More specifically, Petitioner relies on Ozaki’s teaching that “[t]he method for manufacturing a nitride semiconductor element of the present invention is a method for forming a nitride semiconductor using metalorganic vapor phase epitaxy in which a nitride semiconductor layer is grown on a substrate.” *Id.* at 14–15 (citing Ex. 1041 ¶ 19). Petitioner further argues that “Ozaki teaches ‘an element made of a nitride semiconductor ($\text{In}_x\text{Al}_y\text{Ga}_{1-x-y}\text{N}$, where $0 \leq x, 0 \leq y$, and $x + y \leq 1$) used in a light-emitting element.’” *Id.* at 14. In addition, Petitioner argues that the “examples and embodiments in Ozaki teach

methods for manufacturing a gallium nitride based semiconductor.” *Id.* at 15.

We find that Ozaki teaches a method for manufacturing a gallium nitride based semiconductor. Ex. 1041 ¶¶ 1, 19; *see also id.* ¶¶ 22–36, 41–52. Our finding is further supported by Dr. Fitzgerald’s declaration testimony that Ozaki teaches, in the paragraphs identified above, “a method for manufacturing a gallium nitride based semiconductor.” Ex. 1002 ¶ 92. As we find that Ozaki teaches the preamble, we need not determine whether the preamble is limiting.

- b. *“forming a first gallium nitride based semiconductor on a substrate, the first gallium nitride based semiconductor having a first surface” (claim 1); “a first gallium nitride based semiconductor layer formed on the substrate, the first gallium nitride based semiconductor layer having a first surface” (claim 8)*

Independent claim 1 recites a method for manufacturing a gallium nitride semiconductor that includes the step of “(a) forming a first gallium nitride based semiconductor on a substrate, the first gallium nitride based semiconductor having a first surface[.]” Ex. 1001, 5:29–33. Similarly, independent claim 8 recites “[a] light emitting element comprising a gallium nitride based semiconductor, the light emitting element comprising . . . a first gallium nitride based semiconductor layer formed on the substrate, the first gallium nitride based semiconductor layer having a first surface[.]” *Id.* at 6:18–23.

i. Petitioner’s Contentions

For these limitations, Petitioner asserts that “Ozaki discloses this element for the same reasons discussed in relation to Ground 1, claim element 1[a]. Ex. 1002, ¶125.” Pet. 31. Because Petitioner incorporates

arguments from “Ground 1” that Ozaki anticipates challenged claims 1 and 8, found on pages 15–17 of the Petition, into its obviousness challenges, we address those arguments and evidence below. Pet. 31.

Petitioner maps the “nitride semiconductor layer” in Figure 3 of Ozaki to the “first gallium nitride based semiconductor.” Pet. 15 (citing Ex. 1029 ¶ 93); *see id.* at 30 (“Ozaki discloses this element for the same reasons discussed in relation to Ground 1, claim element 1[a]. Ex. 1029, ¶120.”) According to Petitioner, Ozaki teaches that the nitride semiconductor layer can be a three-element mixed crystal or a two-element mixed crystal such as GaN, InGaN, AlGaN, InN, or AlN. Pet. 15 (citing Ex. 1041 ¶ 8); *see* Pet. Reply 2. Petitioner further asserts that Ozaki teaches the nitride semiconductor layer is formed on a substrate and that the disclosed buffer layer is optional and can be “omitted” such that the nitride semiconductor (i.e., “first gallium nitride based semiconductor”) is in contact with and above the substrate. Pet. 16–17 (citing Ex. 1041 ¶¶ 8, 19, 25, Figure 3, claim 1; Ex. 1029 ¶¶ 93–99); *see* Pet. Reply 3.

ii. Patent Owner’s Contentions

In its Response, Patent Owner relies on arguments made against Petitioner’s “Ground 1” based on anticipation. Specifically, Patent Owner states that “Petitioner relies solely on the same arguments addressed above for the claim limitations ‘forming a first gallium nitride based semiconductor on a substrate’ and ‘forming on less than a total area....’ PO Resp. 45. Those arguments fail for the reasons Patent Owner explained above. *See* Section V.B *supra*.” *Id.*

In Section V.B. of Patent Owner’s Response, Patent Owner argues that “there is no disclosure—express or inherent—that a buffer layer is omitted in any embodiment(s) in Ozaki. To the contrary, all of Ozaki’s

examples have a buffer layer, and Ozaki only leaves open a possibility that a buffer layer might be omitted under unspecified conditions.” PO Resp. 23. Patent Owner adds that every embodiment disclosed in Ozaki “involves a ‘nitride semiconductor’ and a ‘substrate’ includes ‘buffer layer’ between them.” *Id.* at 18. Patent Owner explains that in Ozaki: (1) the prior art Figure 1 includes a GaN buffer layer between the sapphire substrate and the n-GaN; (2) the laser element of Figure 4 and Figure 5 include buffer layer 2 between substrate 1 and n-type contact layer 3; and (3) Examples 1–14 include buffer layer 2. PO Resp. 18 (citing Ex. 1041 ¶¶ 3, 22–23, 42–43, 72, 81, Figs. 1, 4–5; Ex. 2053 ¶¶ 180–192).

Patent Owner adds that Figure 3, paragraph 19, and claim 1 of Ozaki (relied upon by Petitioner) also do not teach the omission of the buffer layer. PO Resp. 20–22; see Sur-reply 5–7. This is because Figure 3 does not show what is below the nitride semiconductor layer and provides no disclosure on whether a buffer layer is present on the substrate. PO Resp. 18–20. Further, “[c]aim 1 of Ozaki specifically recites layers ‘formed in contact’ with one another and, by contrast, uses the broader phrase ‘provided on’ in referring to ‘the nitride semiconductor layer provided on the substrate.’” *Id.* at 20 (citing Ex. 2053 ¶ 204) (internal citations omitted). Patent owner adds, “[T]he broader phrase ‘provided on’ encompasses the possibility of having a buffer layer in between the nitride semiconductor layer and the substrate or omitting it.” *Id.* According to Patent Owner, paragraph 19 also uses the broad phrase “grown on” in stating “a nitride semiconductor layer is grown on a substrate,” in contrast to more specific “forming ... in contact” language used to describe direct contact between other layers. *Id.* at 21 (citing Ex. 1041 ¶ 19; Ex. 2053 ¶ 205).

In its Sur-reply, Patent Owner adds that Ozaki never specifies the particular combinations of growing method(s) and substrate(s) that permit omitting a buffer layer. Sur-reply 8. (citing Ex. 1041 ¶ 25). Patent Owner further contends that

[o]nly Dr. Doolittle has addressed the issue of whether nitrides were grown on GaN substrates with reference to specific growth methods (HVPE and MOCVD) for nitrides. He explained that suitable GaN substrates were not available at the relevant time and that, even when such substrates became available, it was a standard practice to use buffer layers with these substrates. *Id.* at 9 (internal citations omitted).

iii. Discussion

Based on the complete record, we find that the cited portions of Ozaki and other evidence of record support Petitioner's contentions. *See, e.g.*, Ex. 1007 ¶¶ 8, 25. In particular, Ozaki expressly teaches that "there are no particular restrictions on the nitride semiconductor layer, however, it is preferably a three-element mixed crystal or a two-element mixed crystal such as *GaN*, *InGaN*, *AlGaN*, *InN*, or *AlN*." Ex. 1041 ¶ 8 (emphasis added). In this way, we find that Ozaki expressly teaches a nitride semiconductor layer that is, e.g., GaN, InGaN, or AlGaN.

We find that Ozaki expressly teaches or suggests the omission of a buffer layer. *See* Ex. 1041 ¶ 25. In paragraph 25, Ozaki teaches that

[t]he buffer layer 2 is, for example, AlN, GaN, or AlGaN formed to a thickness from tens of angstroms to hundreds of angstroms at a temperature of 900°C or less. *The buffer layer 2 is formed to relax the lattice constant mismatch between the substrate 1 and the nitride semiconductor. This can be omitted depending on the nitride semiconductor growing method and type of substrate 1.* Ex. 1041 ¶ 25 (emphasis added). We note that the parties dispute whether the express statements in paragraph 25 apply generally to all or, more specifically, to some embodiments disclosed in Figure 3, Figure 5, Examples

1–14, claim 1, or paragraph 19 in Ozaki. Patent Owner takes the position that Ozaki only teaches the possibility that the buffer layer can be removed, but does not ascribe the omission of the buffer layer to any disclosed embodiment. *See* Tr. 10:23–12:4; PO Resp. 20 (“Such use of broad language which allows for the possibility of omitting a buffer layer is not a disclosure of actually omitting a buffer layer, and therefore cannot anticipate even if ‘a skilled artisan would immediately envision’ the possibility of omitting the buffer layer.”).

In the context of obviousness, we find that Patent Owner’s arguments are misplaced. Even assuming that the statements in paragraph 25 of Ozaki are not tied explicitly to other embodiments shown in Figure 3, claim 1, etc., obviousness may be premised on the combination of multiple embodiments disclosed in a single reference, as here. *See Boston Scientific Scimed, Inc. v. Cordis Corp.*, 554 F.3d 982, 991 (Fed. Cir. 2009) (“Combining two embodiments disclosed adjacent to each other in a prior art patent does not require a leap of inventiveness.”).

Here, Petitioner relies on the testimony of Dr. Fitzgerald (*see* Pet. 17 (citing Ex. 1029 ¶¶ 93–99)), who explains that “[i]n the context of Ozaki as a whole, a PHOSITA would understand that the buffer layer is optional and that the nitride semiconductor layer can be in direct contact with and above the substrate.” Ex. 1029 ¶ 95. Dr. Fitzgerald further explains that “[i]f using a GaN substrate, no buffer layer would necessarily be required.” *Id.* ¶ 97. In this regard, we credit Dr. Fitzgerald’s testimony because his testimony is consistent with and supported by the express statements in Ozaki that teach (1) different substrates may be used (e.g., SiC, ZnS, ZnO, GaAs, and GaN); and (2) the buffer layer may be omitted depending on the substrate used and technique employed. Ex. 1041 ¶¶ 24–25.

Further, in considering and weighing the testimony of the experts on this issue, we determine that Dr. Doolittle's testimony is entitled to less weight than Dr. Fitzgerald's because Dr. Doolittle's testimony contradicts Ozaki's express disclosure. For example, Dr. Doolittle testifies a PHOSITA would not have understood Ozaki to disclose any nitride semiconductor layers formed on a substrate without a buffer layer because the figures, examples, and claims all include a buffer. *See* Ex. 2053 ¶¶ 181–195. However, as discussed above, Ozaki's teaching is not as narrow as Dr. Doolittle asserts. Rather, Ozaki expressly contemplates other embodiments that omit a buffer layer when a different substrate and/or process is used. Ex. 1041 ¶¶ 24–25. Indeed, although Ozaki discloses the use of sapphire substrates, Ozaki also teaches the use of GaN substrates, which Dr. Fitzgerald explains would not require a buffer layer. *See* Ex. 1041 ¶ 24. Further, we disagree with Dr. Doolittle's assertion that “Dr. Fitzgerald did not explain *when* the buffer layer can be omitted[.]” *See* Ex. 2053 ¶ 195. Contrary to Dr. Doolittle's testimony, Dr. Fitzgerald has testified that “[i]f using a GaN substrate, no buffer layer would necessarily be required[.]” (Ex. 1029 ¶ 97), and under cross-examination, Dr. Fitzgerald explained “[s]o there's, you know, just a lot of ways that people were growing materials, so it makes sense that Ozaki doesn't want to specify that because there's people saying that, you know, high-temperature layers don't require buffer layers, but, you know, lower temperature may[.]” (Ex. 2037, 58:10–15).

Additionally, we note that Dr. Doolittle testifies that GaN substrates “were rarely used at the relevant time (early 2002)” and “that at the time (1990s), only one group in the world . . . provided true ‘bulk GaN’ substrates created by the high-pressure methods.” Ex. 2053 ¶¶ 199–201 (citing Exs. 2001, 2002, 2024); *see id.* ¶ 207 (“While Ozaki states that a GaN substrate

may be used (although Dr. Fitzgerald and I agree that none were available at the time, as discussed above), Ozaki does not disclose actually *using* one in any particular device, much less with the specific combination of layers (including omission of a buffer layer) that Dr. Fitzgerald discusses in his opinion.”); *see also id.* ¶ 176 (“A POSA would not have immediately understood how to make such combinations for each and every potential combination anticipated by Ozaki without additional explanation within the disclosure of Ozaki.”). In this context, Patent Owner’s argument is akin to an enablement argument that a POSITA would not have been able to use a suitable GaN substrate without a buffer layer based on Ozaki’s teachings. However, this argument is unpersuasive because even “[a] non-enabling reference may qualify as prior art for the purpose of determining obviousness, . . . and even an inoperative device . . . is prior art for all that it teaches.” *ABT Sys., LLC v. Emerson Elec. Co.*, 797 F.3d 1350, 1360 n.2 (Fed. Cir. 2015) (quoting *Beckman Instruments, Inc. v. LKB Produkter AB*, 892 F.2d 1547, 1551 (Fed. Cir. 1989) and *Symbol Tech., Inc. v. Opticon, Inc.*, 935 F.2d 1569, 1578 (Fed. Cir. 1991)). Moreover, Dr. Doolittle only testifies that GaN substrates were *rarely* used or “effective only for research.” Ex. 2053 ¶¶ 199–200. As such, Dr. Doolittle’s testimony acknowledges that GaN substrates, though “rare,” were nonetheless available for some uses. *See id.*

Further, we are not persuaded by Dr. Doolittle’s testimony that even if a suitable GaN substrate were available, “it is often desirable to grow a buffer layer on GaN . . . to bury any contamination or damage to the substrate.” Ex. 2053 ¶ 202 (citing Ex. 2023); *see id.* ¶ 203 (“So even if a ‘GaN substrate’ could have been used, a person of ordinary skill in the art would have still known to grow an additional buffer layer of GaN for the

purpose of cleaning up the surface of the substrate from damage and/or contaminants. In my opinion, there would have been no commonly encountered conditions in which a POSA, making a real device, would have excluded a buffer layer, even in the homoepitaxial case.”). Even assuming there were advantages to using a buffer layer, as Dr. Doolittle proposes, we do not find that these advantages alter our finding. “[O]ur case law does not require that a particular combination must be the preferred, or the most desirable, combination described in the prior art in order to provide motivation for the current invention.” *Novartis Pharm. Corp. v. W.-Ward Pharm. Int’l Ltd.*, 923 F.3d 1051, 1059 (Fed. Cir. 2019) (citing *In re Fulton*, 391 F.3d 1195, 1200 (Fed. Cir. 2004)). Indeed, the existence of better alternatives in the prior art does not mean that an inferior combination is inapt for obviousness purposes. *In re Mouttet*, 686 F.3d 1322, 1333 (Fed. Cir. 2012) (citing *In re Gurley*, 27 F.3d at 553).

In sum, the record as a whole supports Petitioner’s argument that Ozaki expressly discloses the omission of a buffer layer, and that a PHOSITA would have understood this express teaching, when combined with other described embodiments, such as the embodiment shown in Figure 3, teaches or suggests “forming a first gallium nitride based semiconductor on a substrate, the first gallium nitride based semiconductor having a first surface” (claim 1) and “a first gallium nitride based semiconductor layer formed on the substrate, the first gallium nitride based semiconductor layer having a first surface” (claim 8).

- c. *“forming on less than a total area of the first surface a composition material of the first gallium nitride based semiconductor” (claim 1) and “a composition material of the first gallium nitride based semiconductor formed on less than a total area of the first surface” (claim 8)*

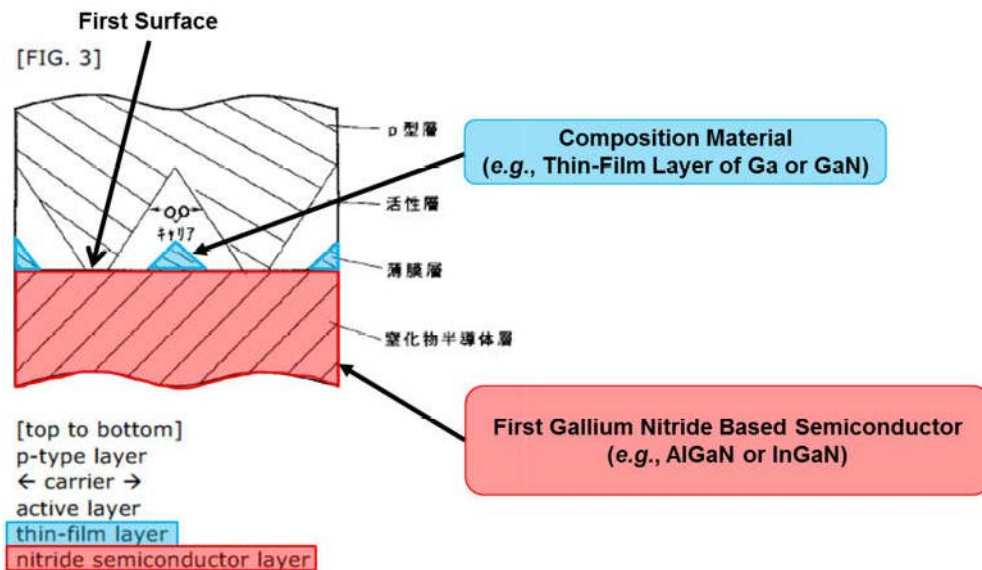
Claim 1 recites a method for manufacturing a gallium nitride semiconductor that includes “(b) forming on less than a total area of the first surface a composition material of the first gallium nitride based semiconductor.” Ex. 1001, 5:34–36. Claim 8 recites “a composition material of the first gallium nitride based semiconductor formed on less than a total area of the first surface[.]” *Id.* 6:24–26.

i. Petitioner’s Contentions

Petitioner argues also that Ozaki’s disclosed thin-film layer of GaN and AlN, or InN and GaN teaches a “composition material” as recited in claim 1 when the nitride semiconductor layer is either AlGaN or InGaN respectively. Pet. 17. According to Petitioner, Ozaki teaches that “when the thin-film layer is a nitride semiconductor, it should preferably have a Group 3 element thereby including GaN, InN, and AlN.” Pet. 18 (citing Ex. 1041 ¶ 11). Petitioner adds that Ozaki teaches that the thin-film layer also may be a metallic layer comprised only of metal atoms. *Id.* Petitioner asserts also that Ozaki’s thin-film layer is described as a “three dimensional island-like growth” that is part of a “quantum dot,” which would cover less than a total area of a surface. Pet. 19 (citing Ex. 1041 ¶¶ 9, 11).

Further, Petitioner refers to Ozaki Figure 3 and Dr. Fitzgerald’s testimony for the argument that “[a]fter forming the nitride semiconductor layer (‘first gallium nitride based semiconductor’), Ozaki teaches that the thin-film layer (‘composition material’) is formed on ‘less than a total area

of the first surface' of the nitride semiconductor layer ('first gallium nitride based semiconductor')[.]” Pet. 19 (emphases omitted) (citing Ex. 1029 ¶ 102). Dr. Fitzgerald’s Declaration provides an annotated Figure 3 shown below.



Petitioner’s annotated Figure 3 shows added coloring and text to denote the alleged “first gallium nitride based semiconductor” layer and the “composition material.” See Ex. 1029 ¶ 102. Petitioner further asserts that “Ozaki describes the thin-film layer (‘composition material’) as a ‘three dimensional island-like growth’ that is part of a ‘quantum dot,’ which cover[s] less than a total area of a surface.” Pet. 19 (citing Ex. 1041 ¶¶ 9, 11; Ex. 1029 ¶¶ 100–103).

ii. Patent Owner’s Contentions

In its Response, Patent Owner asserts that “Petitioner relies solely on the same arguments addressed above for the claim limitations . . . ‘forming on less than a total area....’ Pet. 31-33. Those arguments fail for the reasons Patent Owner explained above. See Section V.B supra.” PO Resp. 45.

In Section V.B. of Patent Owner's Response, Patent Owner contends that "there is no disclosure anywhere in Ozaki of either an embodiment where Ozaki's nitride semiconductor layer is AlGa_N and the thin-film layer is Al, Ga, AlN, or GaN or an embodiment where Ozaki's nitride semiconductor layer is InGa_N and the thin film-layer is In, GaN, GaN, or InN." PO Resp. 24 (citing Ex. 2053 ¶¶ 215–218). Patent Owner adds that "the only specific combinations of nitride layers and thin-film layers disclosed in Ozaki, the nitride semiconductor layer is not AlGa_N or InGa_N and the thin-film layer is not composed of some, but not all, of the elements of the nitride semiconductor layer." *Id.* at 25 (citing Ex. 1041 ¶¶ 45–73).

Patent Owner further argues that there is no disclosure in Ozaki of a small genus of combinations that encompasses any of Petitioner's combinations. PO Resp. 25. According to Patent Owner, Ozaki teaches that there are no restrictions on the particular nitride semiconductor layer and thin-film layer, other than the 3% lattice mismatch to the nitride semiconductor layer. PO Resp. 26. Based on this, Patent Owner argues that "Ozaki thus allows for a virtually boundless universe of potential nitride semiconductor layer/thin-film layer combinations that are *not* within the scope of the '270 patent claims. Doolittle ¶¶238-252." *Id.* at 27. Patent Owner adds that

even focusing on the five specifically listed preferred candidates for the nitride semiconductor layer (Ga_N, InGa_N, AlGa_N, InN, and AlN) and the nine thin-film layer candidates listed in the table in paragraph 12 (which include Ozaki's especially preferred metal atoms as part of the compounds), this yields 45 combinations that do not meet the requirements of the '270 patent.

Id. Patent Owner further contends that Petitioner's proposed combination of Ga_N and AlGa_N or InGa_N would not satisfy the lattice mismatch required

by Ozaki. *Id.* at 30 (citing Ex. 1029 ¶ 196; Ex. 2051 ¶ 93 n.4, ¶ 119 n.9, ¶ 145 n.13, ¶ 170 n.19, ¶ 203 n.25, ¶ 260 n.40, ¶ 280 n.45; Ex. 2053 ¶¶ 223–224).

iii. Discussion

Based on the complete record, we determine that Ozaki expressly teaches materials and compounds that are preferably used in the described methods and structures. For example, Ozaki expressly teaches that “[t]here are no particular restrictions on the nitride semiconductor layer, however, it is *preferably a three-element mixed crystal or a two-element mixed crystal such as GaN, InGaN, AlGaN, InN, or AlN.*” Ex. 1041 ¶ 8 (emphasis added). Ozaki further teaches that

[t]he crystal component constituting the thin-film layer is selected depending on the atoms or compound present in the crystals constituting the nitride semiconductor layer in contact with the thin-film layer so that the lattice constant irregularity difference of the thin-film layer is $\pm 3\%$ or more relative to that of the nitride semiconductor layer. There are no particular restrictions on this in the present invention. When the thin-film layer in the present invention is a nitride semiconductor, there are no particular restrictions on the metal atoms contained in the nitride semiconductor. However, at least one type of atom from Group 2 or Group 3 of the periodic table is preferred, and Mg, Zn, Cd, Ga, or In is especially preferred. The concentration of atoms in the thin-film layer is $1 \times 10^{19}/\text{cm}^3$ or more, preferably $1 \times 10^{20}/\text{cm}^3$ or more, and more preferably $1 \times 10^{21}/\text{cm}^3$ or more. When the concentration of atoms in the thin-film layer is $1 \times 10^{19}/\text{cm}^3$ or more, the active layer can have a good quantum well structure, quantum disk structure, quantum wire structure, or quantum dot structure. The thin-film layer may be a layer with only metal atoms (sometimes referred to below as a metallic layer).

Ex. 1041 ¶ 11 (emphases added). Ozaki also expressly discloses the use of an $\text{In}_x\text{Ga}_{1-x}\text{N}$ active layer, as shown in Figure 3 of Ozaki, which Ozaki

teaches exhibits “phase separation, forming indium-rich regions with a larger amount of indium and indium-poor regions with a smaller amount of indium.” Ex. 1041 ¶ 14. Thus, we find the record supports Petitioner’s arguments that Ozaki expressly teaches a nitride semiconductor layer (e.g., preferably a three-element mixed crystal or a two-element mixed crystal such as GaN, InGaN, AlGaN, InN, or AlN) and a crystal component constituting the thin-film layer that is selected depending on the atoms or compound present in the crystals constituting the nitride semiconductor layer in contact with the thin-film layer (e.g., preferred metal atoms Mg, Zn, Cd, Ga, or In). Ex. 1041 ¶¶ 8, 11.

Additionally, we agree with Patent Owner “that the disclosure of a genus in the prior art is not necessarily a disclosure of every species that is a member of that genus.” *Atofina v. Great Lakes Chem. Corp.*, 441 F.3d 991, 999 (Fed. Cir. 2006). Rather, of “critical importance” in conducting this analysis is “how one of ordinary skill in the art would understand the relative size of a genus or species in a particular technology.” *OSRAM Sylvania, Inc. v. Am. Induction Techs., Inc.*, 701 F.3d 698, 706 (Fed. Cir. 2012).

“[W]hen the class of compounds that falls within the genus is so limited that a person of ordinary skill in the art can ‘at once envisage each member of this limited class,’ ... a reference describing the genus anticipates every species within the genus.” *In re Gleave*, 560 F.3d 1331, 1338 (Fed. Cir. 2009) (quoting *Eli Lilly & Co. v. Zenith Goldline Pharm., Inc.*, 471 F.3d 1369, 1376 (Fed. Cir. 2006)). However, where “the number of compounds actually disclosed by [the asserted prior art] numbers in the millions (including all proposed alternative substituents),” the prior art genus cannot anticipate a later species claim. *Eli Lilly*, 471 F.3d at 1376. A person of ordinary skill in the art would have understood to look at any expressed

“pattern of preferences” in the prior art, such as preferred embodiments, in assessing the scope of the generic disclosure. *See, e.g., Sanofi-Synthelabo v. Apotex, Inc.*, 470 F.3d 1368, 1377 (Fed. Cir. 2006).

Nonetheless, we do not agree that the record supports Patent Owner’s position that Ozaki teaches a virtually boundless universe of potential nitride semiconductor layer/thin-film layer combinations that are not within the scope of the ’270 patent claims. PO Resp. 27; *see* Ex. 2053 ¶ 250. Patent Owner acknowledges that the prior art expressly teaches a preference for GaN, InGaN, AlGaN, InN, or AlN as the nitride semiconductor layer and a Mg, Zn, Cd, Ga, or In nitride in the thin film layer. PO Resp. 26–27. With these preferences in mind, Patent Owner contends that Ozaki discloses forty-five (45) combinations that do not fall within the scope of the ’270 patent claims. *Id.* at 27–28; *see id.* at 29 (“[H]ere Ozaki’s ‘specific preferences’ for five nitride semiconductor layers and nine thin-film layers (at best) lead to 45 different combinations that all fail to satisfy claim 1 of the ’270 patent.”).

Patent Owner’s calculation of combination is consistent with Petitioner’s argument that Ozaki teaches forty-seven (47) preferred combinations from ten (10) thin-film layer alternatives (i.e., Mg, Zn, Cd, Ga, In, MgN, ZnN, CdN, GaN, InN) and five (5) alternatives for the nitride semiconductor layer (e.g., GaN, InGaN, AlGaN, InN, or AlN). Pet. Reply 7–8. Petitioner explains that the preferred materials yield 50 combinations; however, “[b]ecause the nitride semiconductor layer and the thin-film layer must be different, the actual number of preferred ‘nitride semiconductor layer-thin film layer’ combinations disclosed is 47, excluding InN-InN, GaN-GaN, and AlN-AlN.” *Id.* at 8. Of these 47 preferred combinations, Petitioner argues that nine (9) of the preferred embodiments, including

InGaN-GaN, AlGaN-AlN, and AlGaN-GaN, teach “forming on less than a total area of the first surface a composition material of the first gallium nitride based semiconductor” (claim 1) and “a composition material of the first gallium nitride based semiconductor formed on less than a total area of the first surface” (claim 8). *See id.* at 8–9. Thus, far from a “virtually unlimited number of potential nitride semiconductor/thin film layer combinations,” we find that Ozaki, as discerned by the parties, teaches a limited set of about 45–47 preferred combinations as identified by both Petitioner and Patent Owner.

Further, we are not persuaded that the 45–47 preferred combinations (including the proposed combinations relied upon by Petitioner) disclosed in Ozaki constitute a fatally large genus. For comparison, we note that in *Eli Lilly & Co. v. Zenith Goldline Pharmaceuticals, Inc.*, 471 F.3d 1369, 1376–77 (Fed. Cir. 2006), the prior art reference disclosed millions of potential compounds (including all Markush group alternative substituents) and listed several “preferred compounds and substituents, none of which resemble [the claimed compound].” *Id.* at 1376. Similarly, in *Sanofi–Synthelabo v. Apotex, Inc.*, 470 F.3d 1368 (Fed. Cir. 2006), the prior art disclosure of hydrochloride salt of racemic compound was found to be insufficient to anticipate later-claimed bisulfate salt of the compound’s enantiomer, in the absence of a “pattern of preferences” that would further limit the prior art disclosure. And, in *Impax Laboratories, Inc. v. Aventis Pharmaceuticals Inc.*, 468 F.3d 1366, 1383 (Fed. Cir. 2006), the disclosure of prior art genus (formula 1) included a genus of “hundreds of compounds” that was insufficient to anticipate later-claimed treatment method using single compound. In contrast, in *In re Petering*, 301 F.2d 676, 681–82 (CCPA 1962) and *In re Schaumann*, 572 F.2d 312, 315 (CCPA 1978), two seminal

cases in the art of chemistry, the prior art expressly taught a definite and limited class of compounds that enabled a person of ordinary skill in the art to at once envisage each member of this limited class. *Petering*, 301 F.2d at 681–82; *Schaumann*, 572 F.2d at 315). Here, we have a limited size of combinations, 45–47 combinations, derived from Ozaki’s expressed preferences for the nitride semiconductor layer and thin layer. Given Ozaki’s express disclosure, we are persuaded that a person of ordinary skill in the art would have at once envisaged each member of this limited class, which includes members that fall within the scope of claims 1 and 8.

Additionally, considering Patent Owner’s arguments regarding a 3% lattice mismatch requirement disclosed in Ozaki does not alter our finding. Specifically, Patent Owner argues that Petitioner’s proposed combinations of GaN and AlGa_N or InGa_N would not satisfy Ozaki’s preferred 3% or more lattice mismatch requirement between the nitride semiconductor layer and the thin film layer. PO Resp. 29–30 (citing Ex. 2051 ¶ 93 n.4, ¶ 119 n.9, ¶ 145 n.13, ¶ 170 n.19, ¶ 203 n.25, ¶ 260 n.40, ¶ 280 n.45; Ex. 2051 ¶ 93; Ex. 2053 ¶¶ 223–237; Ex. 2037, 24:12–24, 129:15–19). Patent Owner contends that the maximum lattice mismatch between AlN and GaN in their primary crystal structures is only 2.4%, and because the lattice constant for AlGa_N must fall between those endpoints, the lattice mismatch in Petitioner’s proposed combination would be even lower. PO Resp. 30 (citing Ex. 2053 ¶¶ 223–224). Patent Owner further contends that Dr. Fitzgerald has stated numerous times that the lattice mismatch between AlGa_N and GaN can be minimal. *Id.* at 30.

We note that, while Dr. Fitzgerald has testified the lattice mismatch between AlGa_N and GaN *can* be minimal, (see Ex. 2051 ¶ 93 n.4), Dr. Fitzgerald has also explained that the calculation of the lattice mismatch

depends on the growth orientation used. For example, an excerpt of his cross-examination is provided below:

Q: And what's the lattice mismatch between gallium nitride and aluminum gallium nitride?

A: So in the -- it depends on the growth orientation that you're doing, you know. So -- do you know what I mean by that, "growth orientation"? So you know which crystal plane you're going on. So like gallium nitride, aluminum nitride is in the C direction, it's about a 5 percent mismatch. And then in the A direction, I think it's about 3.1 percent or something like -- no, 2.5 percent mismatch or something like that.

Q: And you're referring there to the hexagonal crystal structures?

A: That's one form of gallium nitride, right, the common one, right, which is the wurzite form. So there's two defining lattice counts. There's actually three. But, you know, the two in plane are the same. So the "a" is the in-plane lattice constant if you're growing on the basal plane, and then "c" is the perpendicular one. But then if you're growing on other orientations of sapphire, then the planes can be in between the two.

Ex. 2037, 24:25–25:23. Dr. Doolittle's testimony also supports that the lattice mismatch calculation depends on the shape and orientation of the crystals compared. Ex. 2053 ¶¶ 23–24 ("[T]he person using the [Lattice mismatch (f)] formula must know the crystals' in-plane orientation so that the correct lattice constants are used. In other words, the above lattice mismatch calculation can be used only if the shape and orientation of the two crystals are the same. . . . [T]etragonal crystals have *two* lattice constants, and orthorhombic crystals have *three*[.] . . . And many common III-Nitrides may have a hexagonal (wurtzite) structure[.]"); *see also id.* ¶ 25 ("When comparing two different shapes (e.g., a cubic crystal to a hexagonal crystal), the single-value equation above is not applicable because the two shapes differ significantly and there is no physical way to get the atomic

bonds of the two crystals to align for bonding.”). Dr. Doolittle further testifies that “[v]arious methods of arriving at a measure of the lattice mismatch exist for cases of two different crystal structures, but they all require two or more lattice mismatch calculations[.]” *Id.* ¶ 26. And, Patent Owner acknowledges also that the “[c]rystals of the materials at issue here (e.g., AlGaN) have more than one polytype (a crystalline form, such as cubic, tetragonal, orthorhombic, and hexagonal), and thus have different lattice structures.” Pet. Reply 13 (citing PO Resp. at 25).

Further, we agree with Petitioner’s position, that although Ozaki may express a preference (or arguably a requirement) for a 3% lattice mismatch, Ozaki does not otherwise require that the materials are grown in the same plane or with the same crystal structure. See Pet. Reply 13–14. Thus, we are not persuaded that Petitioner has failed to address the 3% lattice mismatch taught in Ozaki or that Petitioner’s proposed combination contradicts Ozaki’s disclosure. Accordingly, we find that Petitioner has shown by a preponderance of the evidence that Ozaki teaches or suggests these limitations recited in claims 1 and 8.

- d. *“a spatial fluctuation is created in the band gap by variation in the compositional ratio in the second gallium nitride based semiconductor created by the composition material, and the second gallium nitride based semiconductor is a light emitting layer.” (claim 1) and “a second gallium nitride based semiconductor layer having a varied compositional ratio and formed on the first gallium nitride based semiconductor layer onto which the composition material is formed, and the second gallium nitride based semiconductor is a light emitting layer.” (claim 8)*

Claim 1 further recites the step of:

- (c) forming a second gallium nitride based semiconductor on the first gallium nitride based semiconductor on which the

composition material is formed, wherein a spatial fluctuation is created in the band gap by variation in the compositional ratio in the second gallium nitride based semiconductor created by the composition material, and the second gallium nitride based semiconductor is a light emitting layer.

Ex. 1001, 5:37–44. Claim 8 recites “a second gallium nitride based semiconductor layer having a varied compositional ratio and formed on the first gallium nitride based semiconductor layer onto which the composition material is formed, and the second gallium nitride based semiconductor is a light emitting layer.” For claim 8, Petitioner relies on the same arguments presented for claim 1. Pet. 30. For the purposes of this Decision, we address Petitioner’s arguments as presented; however, we note that claim 8 does not recite a “spatial fluctuation.” Thus, to prevail, Petitioner need not demonstrate, for claim 8, that Ozaki teaches or suggests the spatial fluctuation recited in claim 1.

i. Petitioner’s Contentions

For this limitation, Petitioner maps Ozaki’s active layer to the “second gallium nitride based semiconductor.” Pet. 21 (citing Ex. 1041 ¶¶ 14–16; Ex. 1029 ¶ 105). Petitioner asserts that Ozaki teaches changes in the ratio of the elements (i.e., “indium-rich” and “indium poor” regions) in the $\text{In}_x\text{Ga}_{1-x}\text{N}$ active layer (“second gallium nitride based semiconductor”) are caused by the thin-film layer (“created by the composition material”) and thus discloses “variation in the compositional ratio in the second gallium nitride based semiconductor created by the composition material.” Pet. 23–24 (citing Ex. 1041 ¶ 16, Ex. 1029 ¶ 109).⁸ Referring to Figure 3 of Ozaki,

⁸ Some of the annotated figures referenced in the “Corrected Petition” appear to be missing from the version in filed in PTAB E2E. See Pet. 17 (showing blank space for annotated Fig. 3). The Corrected Petition refers to the Dr. Fitzgerald Declaration, which includes the annotated figures. See

Petitioner asserts that a skilled artisan would have understood that the changes in the ratio of the elements within the $\text{In}_x\text{Ga}_{1-x}\text{N}$ active layer (“second gallium nitride based semiconductor”) means that “a spatial fluctuation is created in the band gap.” Pet. 24–25 (citing Ex. 1029 ¶ 111). According to Petitioner, it was widely known and well understood that changes in the composition (i.e., changes in “x” in $\text{In}_x\text{Ga}_{1-x}\text{N}$) result in changes in the band gap. Pet. 25–27 (citing Ex. 1010, 410 (Figure 19); Ex. 1029 ¶ 112)). Petitioner argues:

one of ordinary skill in the art would have understood Ozaki’s disclosure of indium rich (i.e., higher “x” value) and indium poor (i.e., lower “x” value) regions in the $\text{In}_x\text{Ga}_{1-x}\text{N}$ active layer to mean that there was a “spatial fluctuation in the band gap” in the $\text{In}_x\text{Ga}_{1-x}\text{N}$ active layer (“second gallium nitride based semiconductor”) wherein the indium rich regions (i.e., higher “x” value) have a lower (i.e., narrower) band gap than indium poor regions (i.e., lower “x” value) have a higher (i.e., wider) band gap. Ex. 1029, ¶112.

Pet. 26–27. Petitioner adds that this same principle applies to AlGa_N and that if the relative amount of Al increases (i.e., “x” increases), the band gap

Pet. 22 (citing Ex. 1029 ¶ 107). Further, we note that the originally filed Petition (Paper 2) includes annotated figures. For this Decision, we refer to annotated figures (e.g., Ozaki Figure 3) to address Patent Owner’s arguments concerning the figures and to the extent the annotated figures provide support for Dr. Fitzgerald’s testimony. We, however, do not rely on Petitioner’s missing annotated figures themselves for our determinations because the annotated figures are not in the Petition. 35 U.S.C. § 312(a)(3) (requiring *inter partes* review petitions to identify “with particularity . . . the evidence that supports the grounds for the challenge to each claim”); 37 C.F.R. § 42.6(a)(3) (“Arguments must not be incorporated by reference from one document into another document. Combined motions, oppositions, replies, or other combined documents are not permitted.”).

increases and if the relative amount of Al decreases, then the band gap decreases. Pet. 27–28 (citing Ex. 1010, 392; Ex. 1029 ¶ 112).

Petitioner further argues that a PHOSITA would have combined the basic material science knowledge of Stringfellow as foundational knowledge for understanding better how the ratio of elements creates “a spatial fluctuation in the band gap.” Pet. 31 (citing Ex. 1029 ¶ 123). According to Petitioner, Stringfellow represents the general knowledge of one of ordinary skill in the field of III-V semiconductors and their use in LEDs and other light emitting devices prior to the invention of the ’270 patent. *Id.*

ii. Patent Owner’s Contentions

Patent Owner contends that Petitioner has not shown that Ozaki discloses a “spatial fluctuation . . . in the band gap” because Ozaki’s quantum dots exhibit discrete band gap transitions with discontinuities rather than the claimed spatial fluctuations. PO Resp. 31; *see id.* at 36 (citing Ex. 1041 ¶¶ 14, 16–18; Ex. 2037, 35:5–8; Ex. 2053 ¶¶ 254–260). Patent Owner contends that

[q]uantum dots have a discrete, well-defined band structure that is quite different from the irregular variations, or “widening and narrowing of the band gap” required to have the claimed “spatial fluctuation . . . in the band gap.” The experts agree that quantum dots are characterized by a sharp, discrete transitions in the band gap that create discontinuities in potential energy. Doolittle ¶¶ 260–267; Fitzgerald Dep. 46:22–47:1 (quantum dots have “a discrete boundary at the edge of the dot”).

PO Resp. 37. Patent Owner further explains that a quantum dot exhibits sharp, discrete transitions in the band gap, shown below in Patent Owner’s annotated Figures 1 and 6 from Exhibit 2038, titled “Study on the Energy-Band Structure of Indium-Rich InGa_N/Ga_N Quantum Dot System”(“Kim”), that are not “widening and narrowing of the band gap.” *Id.*; *see also id.* at

42 (“Ozaki’s quantum dots cause a very different kind of change in the band gap—sharp, discrete transitions with well-defined floors[.]”).

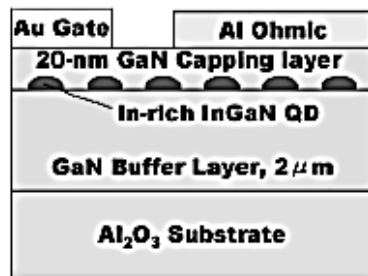


Fig. 1. Sample structure of the In-rich InGaN/GaN single-layer quantum-dot system.

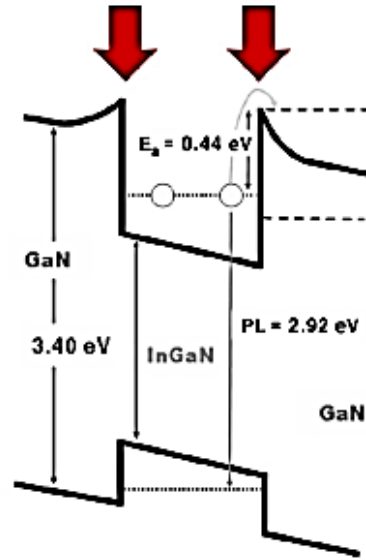


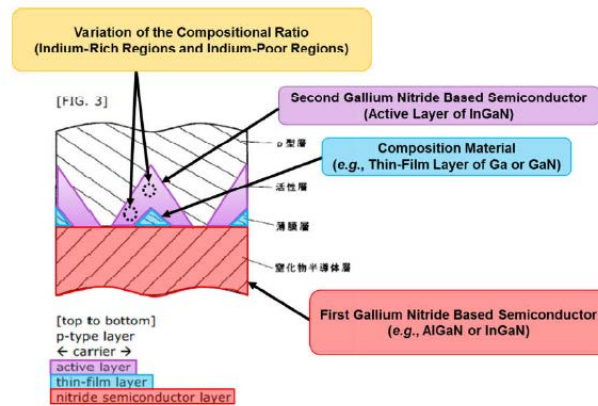
Fig. 6. Energy band diagram of the InGaN/GaN QD system. The band-to-band transition energy can be determined from the PL result and an offset of the ground-state energy-level can be confirmed by using DLTS measurement.

Figure 1 shows a semiconductor structure with In-rich InGaN quantum dots. Ex. 2038, Fig. 1. Figure 6 is an energy band diagram of the quantum dot system. *Id.* at Fig. 6.

Additionally, Patent Owner asserts that “Ozaki’s focus on enhancing the formation of quantum dots in his InGaN active layer is understandable . . . [because] [i]t was well-understood . . . that indium in an InGaN active layer would naturally segregate into quantum dots on the order of nanometers[.]” PO Resp. 40 (Ex. 1041 ¶ 14; Ex. 2039, 1741). Patent Owner argues that “[u]nlike InGaN, which naturally segregates due to a miscibility gap between InN and GaN at growth temperatures, AlGaN does not naturally segregate because AlN and GaN are fully miscible at growth temperatures.” PO Resp. 41 (citing Ex. 2053 ¶¶ 33–38, 278–289, 330; Ex. 2043 ¶¶ 37–38; Ex. 2003, 1–3). In other words, according to Patent Owner, a quantum dot

cannot be easily formed in the active layer of AlGa_N. *Id.* at 41 (citing Ex. 2040, 4451–52).

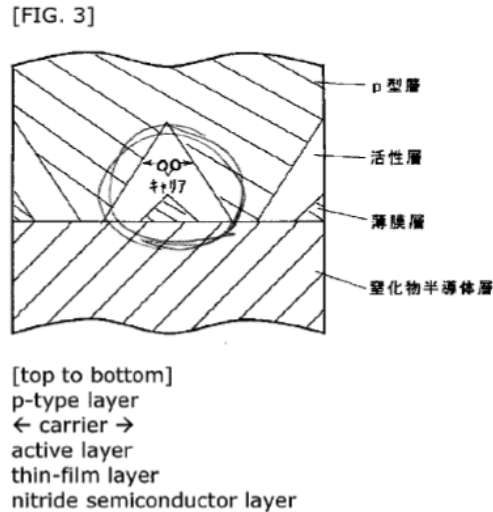
Patent Owner further contends that Petitioner and Dr. Fitzgerald have identified Ozaki's indium-rich quantum dots inconsistently. For this argument, Patent Owner compares Petitioner's annotated Ozaki Figure 3 with Dr. Fitzgerald's marked Figure 3 from his deposition (shown below).



Ozaki at Figure 3 (annotated).

The above figure shows the structure near the active layer in a nitride semiconductor element, as annotated by Petitioner. Ex. 1041, 21 (“Brief Description of the Drawings”). For the purposes of addressing Patent Owner’s arguments, Petitioner’s annotated Figure 3 from Ozaki is provided above. See Pet. 22 (citing Ex. 1029 ¶ 107).⁹

⁹ As noted, Petitioner’s “Corrected Petitioner” is missing some annotated figures, including annotated Figure 3 from Ozaki. However, we refer to annotated figures (e.g., Ozaki Figure 3) to address Patent Owner’s arguments concerning the figures and to the extent the annotated figures provide support for Dr. Fitzgerald’s testimony. See PO Resp. 43.



The above figure shows the structure near the active layer in a nitride semiconductor element, as annotated by Petitioner, as annotated by Dr. Fitzgerald during his deposition. PO Resp. 43; Ex. 2041; Ex. 2037, 42–43. In the annotated figure, Patent Owner contends Dr. Fitzgerald’s circled portion indicates what Dr. Fitzgerald considers to be the quantum dot. PO Resp. 43–44. Patent Owner argues that “Ozaki never describes the thin-film layer as part of the quantum dot. . . [and] [t]hat would make no sense because the thin-film layer does not confine electrons to emit light.” *Id.* at 44 (citing Ex. 2053 ¶¶ 370–377). Further, Patent Owner contends that Dr. Fitzgerald’s testimony is not credible because he lacks experience with gallium-nitride semiconductors and defines Ozaki’s quantum dots inconsistently. *Id.* at 44.

e. Discussion

Based on the complete record, we determine first that Petitioner has explained sufficiently how Ozaki teaches a “variation in the compositional ratio in the second gallium nitride based semiconductor created by the composition material” as recited in claim 1. This is because Ozaki teaches explicitly that

[w]hen an active layer is grown on top of this thin-film layer, the active layer grows selectively. . . . When the active layer for example is an InGaN layer, and the InGaN layer is grown very thin to form a quantum structure, *the strain energy causes the In content to be entirely uneven, which tends to form indium-rich regions with a larger amount of In and indium-poor regions with a smaller amount of In.*

Ex. 1003 at ¶ 16 (emphasis added). Ozaki further teaches that an active layer will also grow *selectively* when the *thickness* of the thin film layer is uneven, i.e., when the thin film layer is thick in some places and thin in other places. *Id.*; see also Ex. 2053 ¶ 259. Thus, in this way, we understand Ozaki to teach that the selective growth of the active layer (e.g., “variation in compositional ratio in the second gallium nitride based semiconductor”) is, for example, created by the uneven thickness or content of the thin film layer (e.g., “composition material”).

Further, we are not persuaded that Dr. Fitzgerald and Petitioner have misread or, inconsistently relied upon, Ozaki’s disclosed quantum structures. See PO Resp. 42–44; see Ex. 2053 ¶¶ 370–377. Petitioner explicitly asserts that Ozaki teaches that the quantum dot structure has the pattern shown in Fig. 3 in which an active layer with the thin film layer is a quantum dot grown in the shape of islands. Pet. 22 (citing Ex. 1041 ¶ 14); See Tr. 22:3–5 (“And to be perfectly clear, when we say Ozaki’s quantum dots we’re talking about both the thin-film layer and the active layer[.]”).

Further, we find that Ozaki expressly teaches that the active layer may form a quantum dot. Specifically, Ozaki teaches that

[i]n the present invention, when a thin-film layer is grown that is very thin, there are spots in the film where metal atoms are present and spots in the film where metal atoms are absent from a microscopic viewpoint, and the presence or absence of these atoms in the film cause the film thickness to be uneven. When

the thickness of the thin-film layer is uneven, that is, when the thin-film layer is thick in places and thin in other places, the properties of the crystals will be different. When an active layer is grown on top of this thin-film layer, the active layer grows selectively. *When the active layer grows selectively, the active layer itself forms quantum boxes or quantum dots, and the output improves significantly.*

Ex. 1041 ¶ 16 (emphasis added). Additionally, paragraph 9 of Ozaki teaches that

[i]n the present invention, when the lattice constant irregularity difference is $\pm 3\%$ or more relative to that of a nitride semiconductor layer, the thin-film layer is subjected to a significant amount of lattice strain, and *the strain energy causes three-dimensional island-like growth to occur in the thin-film layer instead of flat two-dimensional growth. The active layer grown on top also grows in the form of islands or dots, and the active layer readily assumes an advantageous quantum well structure or quantum dot structure.*

Ex. 1041 ¶ 9 (emphases added). Further, paragraph 18 teaches that

[w]hen an active layer made of InGaN is grown on top of this thin-film layer, *the crystal growth state of the InGaN active layer is selective depending on the underlying thin-film layer. As a result, the formation of quantum dots occurs.* When InGaN is grown, *In compositional separation occurs in addition to dot formation and quantum dots are formed by both effects.* The InGaN active layer becomes uneven, indium-rich regions and indium-poor regions are formed, and quantum boxes or quantum dots are formed, producing a high-output element.

Ex. 1041 ¶ 18 (emphases added). Based on Ozaki's entire disclosure, including the sections discussed above, we agree with Petitioner and Dr. Fitzgerald that Ozaki (e.g., Figure 3) teaches that the active layer forms a quantum dot structure with the thin film layer, as shown by the island shape growths in Figure 3, which Ozaki teaches expressly is the quantum dot structure. See Ex. 1041 ¶ 14 ("A quantum dot structure has the pattern

shown in FIG. 3 *in which an active layer is grown in the shape of islands.*”) (emphasis added). Moreover, to the extent that Petitioner argues, as Patent Owner contends, that only the active layer forms a quantum dot, we determine that this reading of Ozaki is also consistent with Ozaki’s express disclosure. Specifically, Ozaki teaches that

[i]n the present invention, when a thin-film layer is grown that is very thin, there are spots in the film where metal atoms are present and spots in the film where metal atoms are absent from a microscopic viewpoint, and the presence or absence of these atoms in the film cause the film thickness to be uneven. When the thickness of the thin-film layer is uneven, that is, when the thin-film layer is thick in places and thin in other places, the properties of the crystals will be different. When an active layer is grown on top of this thin-film layer, the active layer grows selectively. *When the active layer grows selectively, the active layer itself forms quantum boxes or quantum dots, and the output improves significantly.*

Ex. 1041 ¶ 16 (emphasis added).

Additionally, we are not persuaded by Patent Owner’s argument that an AlGaIn active layer with a GaN or AlN thin film layer would not easily form quantum dots. Patent Owner argues that Ozaki’s quantum dots would not form in the same way with AlGaIn and GaN/AlN because there is no phase separation like that experienced for InGaIn and InN and GaN. PO Resp. 41 (citing Ex. 2053 ¶¶ 33–38, 278–289, 330; Ex. 2043 ¶¶ 37–38; Ex. 2003, 1–3). Even assuming this to be correct, we determine, as Petitioner points out, that Ozaki teaches quantum dot formation in more than one way. See Pet. Reply 22. For example, Ozaki teaches that

when the lattice constant irregularity difference is $\pm 3\%$ or more relative to that of a nitride semiconductor layer, the thin-film layer is subjected to a significant amount of lattice strain, and *the strain energy causes three-dimensional island-like growth to occur in the thin-film layer instead of flat two-dimensional*

growth. The active layer grown on top also grows in the form of islands or dots, and the active layer readily assumes an advantageous quantum well structure or quantum dot structure.

Ex. 1041 ¶ 9 (emphasis added); Pet. Reply 22. In other words, aside from phase separation, the strain energy created from a lattice mismatch between the nitride semiconductor layer and the thin film layer can also form the quantum dot. *Id.* As discussed above, Petitioner has explained that lattice mismatch between AlGa_N and Ga_N can arise from differences in growth orientation. See Ex. 2037, 24:25–25:23; see Ex. 2053 ¶¶ 23–24.

Next, we determine that, based on the complete record, Petitioner has explained sufficiently how Ozaki combined with Stringfellow teaches “spatial fluctuation . . . in the band gap.” Petitioner explains that “[a] PHOSITA would have understood that the changes in the ratio of the elements within the In_xGa_{1-x}N active layer (“second gallium nitride semiconductor”) means that “a spatial fluctuation is created in the band gap.” Pet. 24 (citing Ex. 1029 ¶ 111). Petitioner supports these arguments with reference to Figure 19 and accompanying description from Stringfellow. Pet. 25–26. Figure 19 is reproduced below.

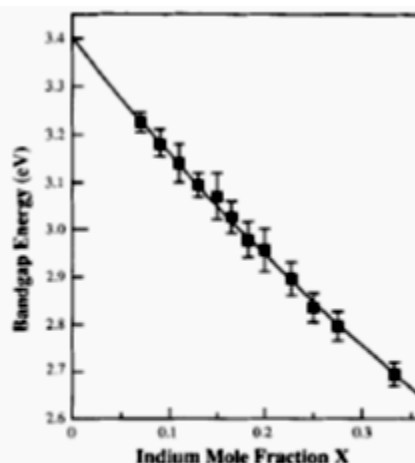


FIG. 19. Bandgap energy of In_xGa_{1-x}N films as a function of the indium (In) mole fraction x . The In mole fraction x was determined by measurements of the X-ray diffraction peaks. Solid curve represents values obtained by Eq. (1) as discussed in the text, assuming that the bandgap energy for gallium nitride and indium nitride is 3.40 and 1.95 eV, respectively. Reprinted from Nakamura (1995a) with the permission of the American Institute of Physics.

Figure 19 shows the bandgap energy of InGaN films as a function of the In mole fraction x . Ex. 1010, 9. Referring to Figure 19, Stringfellow further teaches that

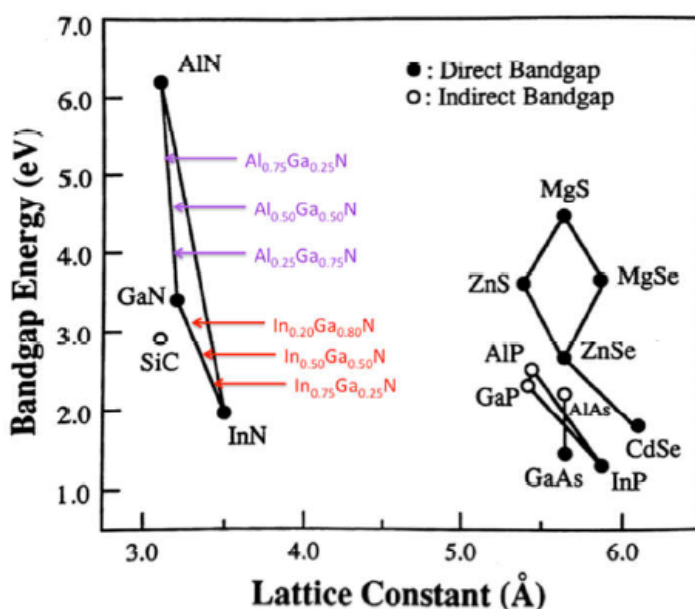
[i]t has been shown that E_g in $\text{In}_x\text{Ga}_{(1-x)}\text{N}$ obeys a parabolic form:

$$E_g(x) = xE_{g, \text{InN}} + (1-x)E_{g, \text{GaN}} - bx(1-x) \quad (1)$$

where $E_g(x)$ represents the bandgap energy of $\text{In}_x\text{Ga}_{(1-x)}\text{N}$, $E_{g, \text{InN}}$ and $E_{g, \text{GaN}}$ represent the bandgap energies of InN and GaN, respectively, and b is the bowing parameter.

Id. Based on this disclosure, we determine that Stringfellow supports Petitioner's general position that compositional variation can change band gap. See Pet. 26. As shown in Figure 19, $\text{In}_x\text{Ga}_{(1-x)}\text{N}$ (" $E_g(x)$ ") depends on the value of " x ," which is the relative amount of indium as compared to Ga (" $1-x$ "). Ex. 1010, Fig. 19.

Further, we note Petitioner argues that Stringfellow teaches the compositional variation of Al in AlGaIn also affects the band gap for AlGaIn. Pet. 27–28 (citing Ex. 1010, 412; Ex. 1029 ¶ 112). In paragraph 112 of his Declaration, cited in the Petition, Dr. Fitzgerald testifies that a POSITA would have understood that the spatial fluctuation experienced by in band gap of the active layer of InGaIn in Ozaki also would be experienced by other ternary alloys such as AlGaIn. Ex. 1029 ¶ 112. Referring to annotated Figure 1 of Stringfellow (reproduced below), Dr. Fitzgerald explains that the band gap vs. lattice constant diagram in Figure 1 shows the tie-lines between the binary semiconductors. *Id.* ¶ 113. According to Dr. Fitzgerald, the tie-lines show how the ternary band gaps change with composition. *Id.*



Annotated Figure 1 of Stringfellow is a diagram showing bandgap energy (eV) graphed against lattice constant (Å). Dr. Fitzgerald further testifies that

the binary compound end-points for the $\text{In}_x\text{Ga}_{1-x}\text{N}$ are InN and GaN, and in the figure the compositions of $x=0.2, 0.5$, and 0.75 are approximately indicated, and correspond to $\text{In}_x\text{Ga}_{1-x}\text{N}$ alloys in which 20, 50, and 75% of the Ga atoms on group III sites in the crystal structure have been replaced with In atoms. The corresponding band gap of $\text{In}_x\text{Ga}_{1-x}\text{N}$ decreases as the In concentration increases as indicated by the arrows pointing to the tie-line between InN and GaN end points. In analogous fashion, compositions of $\text{Al}_x\text{Ga}_{1-x}\text{N}$ have also been indicated along the tie-line between AlN and GaN. As the Al composition increases, the band gap increases along the tie-line as indicated.

Ex. 1029 ¶ 113 (emphasis added). As such, we understand Petitioner to argue that a POSITA would have read Stringfellow as teaching that both InGaN and AlGaN exhibit a relationship between compositional variation and bandgap. Pet. 27–28. In this way, we understand Petitioner relies on Stringfellow to support its position that a POSITA would have used InGaN (or AlGaN) as the active layer in Ozaki because Stringfellow teaches compositional variation affects band gap energy. *Id.* at 31 (“[A] PHOSITA

would have combined the basic material science knowledge of Stringfellow as foundational knowledge for understanding better how the ratio of elements creates ‘a spatial fluctuation in the band gap.’”).

Referring to Figure 1 from Stringfellow that Petitioner relies upon, Dr. Doolittle testifies that Petitioner has not explained which crystalline structures and which faces are graphed in that figure of Stringfellow. Ex. 2053 ¶ 170. Dr. Doolittle adds that the lattice constants shown in Figure 1 of Stringfellow do not match the lattice constants listed in Ozaki for GaN, InGaN, AlGaN, InN, and AlN because Ozaki teaches the values for the cubic polytype rather than the hexagonal (wurtzite) polytypes graphed in Stringfellow. *Id.* ¶¶ 170, 294–295. Further, Patent Owner contends that

Stringfellow, however, only addresses overall bandgap energy as a function of indium mole fraction in InGaN for individual “grown InGaN films” with different In mole fractions. Ex. 1010 at 412; Doolittle ¶¶ 169-171, 294-296. *Stringfellow does not address any compositional variations within an InGaN layer or how any such differences affect the band gap.* Doolittle ¶ 296. *More importantly, Stringfellow does not address the band gap structure of quantum dots formed within an InGaN layer, as disclosed in Ozaki.* Quantum dots by their nature have a well-defined, discrete band structure which is very different from the claimed “spatial fluctuation ... in the band gap,” as explained above.

PO Resp. 45 (emphases added).

To Patent Owner’s point, Stringfellow does not explicitly discuss compositional variation in quantum dots. Nonetheless, Stringfellow’s disclosure reflects a more generalized concept that band gap may be affected by changes in compositional variation. This general concept is consistent with Ozaki’s teaching that the “output improves significantly” due to the “selective” growth of the active layer on the uneven thickness of the thin

film layer due to compositional variation. *See* Ex. 1041 ¶ 16. We understand Ozaki to teach that the uneven thickness or selective growth of the quantum dot can affect the output, which is confirmed by Ozaki's disclosure that "[a]n element of the present invention with very high output can be realized due to the effect of the two different types of quantum dots formed in the active layer of the element by In compositional separation and *unevenness of the well layer in the in-plane direction.*" *Id.* (emphasis added).

Turning to the expert testimony provided, we determine that Dr. Fitzgerald's and Dr. Doolittle's testimony also support our finding. Specifically, Dr. Fitzgerald testifies that

[i]f you have changing thickness within the realm that we're talking about, the quantum realm, right, then in most cases, you're going to have a fluctuation in the band gap. Because of the relationship between quantum confinement, it's inversely proportional. So the smaller you make the confinement, the higher the energy goes. So you change the band gap.

The other thing is the composition, right, which, if we keep on going, we'll see the composition change in the structure related to what, in this particular case, is phase separation, and then the band gap is inherently connected to composition as well. Because if you change the indium concentration, say, in indium gallium nitride, the band gap changes as well.

Ex. 2037, 74:14–75:2. Patent Owner argues that Dr. Fitzgerald's testimony is insufficient to show Ozaki teaches a band gap fluctuation because it is not enough that "in most cases, you're going to have a fluctuation in the band gap." PO Resp. 33. In its Reply, Petitioner explains that "in most cases" was accidentally and incorrectly included in Dr. Fitzgerald's testimony. Instead, Petitioner argues "[a]s stated in his declaration, when using quantum confinement as in Ozaki, changes in thickness always change the

band gap because, mathematically, band gap and thickness are always inversely proportional in quantum structures like quantum dots.” Pet. Reply 20. We agree with Petitioner that the complete record supports its reading of Dr. Fitzgerald’s testimony. For example, Dr. Fitzgerald testifies in his declaration that

[t]he thin-film layer (*e.g.*, Ga or GaN) has two beneficial effects on the InGaN above it. First, the thin-film layer (*e.g.*, Ga or GaN) causes compositional variation within the InGaN leading to Indium rich and Indium poor regions. Ex. 1007, ¶18. Second, the thin-film layer (*e.g.*, Ga or GaN) causes uneven thickness in the InGaN active layer. *Id.* . . . Therefore, the thin film layer, which can be Ga or Al droplets, causes both compositional variation and unevenness in the material above it. *Id.* *These are beneficial effects in a LED or laser because compositional and thickness variation necessarily cause spatial fluctuation in the band gap resulting in improved light emission.*

Ex. 1029 ¶¶ 135–136 (emphasis added).

Moreover, Dr. Doolittle’s testimony is consistent with the principle that thickness affects band gap energy. For quantum structures, the band gap is inversely proportional to the thickness of the layer as shown in the mathematical relationship between thickness (L) and the energy band gap E_n (i.e., $E_n = h^2 n^2 / 8m^* L^2$, where “ h is Planck’s constant, n is a positive integer, L is the ‘quantum well’ thickness, and m^* is the effective mass of the electron”). See Ex. 1022 (Solymar), 5–6. Dr. Doolittle does not dispute a portion of Dr. Fitzgerald’s testimony that explains the mathematical equation $E_n = h^2 n^2 / 8m^* L^2$ teaches h is Planck’s constant, n is an integer marking the number of half-wavelengths of the confined electron, M^* is the effective mass, and L is the well thickness. Ex. 2053 ¶ 172. In this context, we understand Dr. Doolittle to agree that the thickness of the quantum well affects the band gap. *Id.* In describing an example heterostructure of

$\text{Al}_x\text{Ga}_{1-x}\text{N}/\text{GaN}/\text{Al}_x\text{Ga}_{1-x}\text{N}$, Dr. Fitzgerald provides similar testimony that “the expected energy of the emitted light in a quantum well heterostructure would be: $E_{\text{well}}=E_g(x)+E_n+E_p$.” Ex. 1029 ¶ 65. Dr. Fitzgerald further explains that

E_n and E_p are very sensitive to L , the quantum well (active layer) thickness. Under thin film growth conditions where the GaAs thickness varies, the thicker regions result in localized areas having lower band gaps than others. Thus, lateral fluctuations in film thickness in the film plane can further confine carriers, allowing them to emit at only localized places along the GaAs layer. If thickness variations are large enough, these localized confinement spots can be referred to as quantum dots. If the fluctuations in the lateral direction are on the order of the wavelength of the electron and/or hole, then E_{well} can be also changed slightly from the additional confinement.

Ex. 1029 ¶ 68; *see also id.* ¶¶ 64–65 (referring to $E_n = h^2n^2/8m^*L^2$).

We find that this mathematical relationship establishes that the corresponding band gap spatially fluctuates (i.e., widens and narrows by changing values of E_n / changing quantum levels) based on the thickness.

Id. In other words, due to the uneven thickness, “the quantum level based on the quantum effect spatially varies and the band gap is spatially fluctuated.”

Ex. 1001, 4:63–5:1.

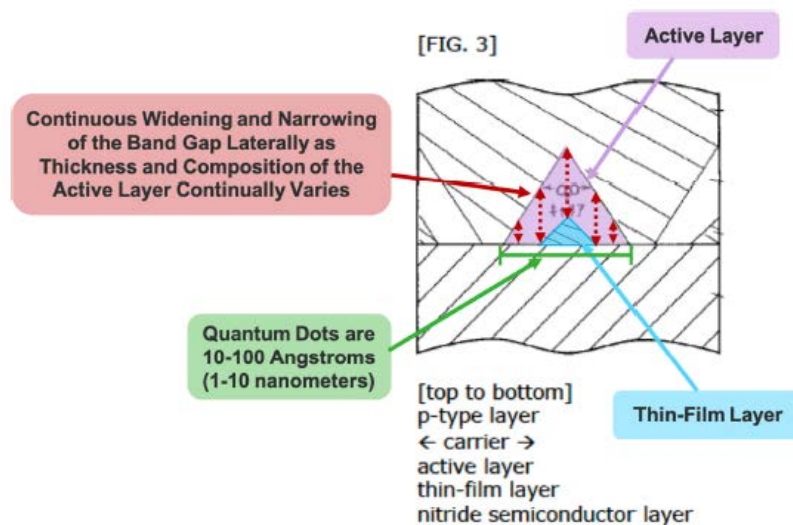
Additionally, we determine that this same principle applies to quantum dots. In his Declaration, Dr. Doolittle provides the band gap energy mathematical equation for a quantum dot. *Id.* at 36 n.7. This equation is provided below:

$$E_n=[h^2n_x^2/(8m^*L_x^2)]+[h^2n_y^2/(8m^*L_y^2)]+[h^2n_z^2/(8m^*L_z^2)]$$

Id. Dr. Doolittle testifies that “ L_x , L_y and L_z are the quantum dot dimensions.” *Id.* Notably, the quantum dot band gap energy equation is also affected by variable “ L ,” which for a quantum dot takes into account the

thickness in three dimensions. *Id.*; *see also* Tr., 40:9–14 (Patent Owner agreeing that Dr. Doolittle’s equation has three terms, each of which is Solymar’s equation), 41:5–11 (Patent Owner agreeing that there are three instances of Solymar’s equation for a quantum dot’s three dimensions). Additionally, we note that the quantum dot’s band gap energy, as expressed by this equation, has an inverse relationship to the thickness of the confinement barrier for each of the three dimensions.

Returning to the disclosure in Ozaki, we determine that at least the testimony of both experts supports Petitioner’s position that the uneven thickness in the active layer (selective growth) created by the compositional variation in Ozaki’s thin film layer affects the band gap energy. Petitioner provides an annotated Figure 3 to show varying thicknesses and composition in Ozaki’s quantum dot. Pet. Reply 25. Annotated Figure 3 is provided below:



Annotated Figure 3 shows changes in the thickness and composition laterally along the island-growth. *Id.* The red arrows indicate “abrupt” changes in the composition/thickness and the band gap. *Id.*

Given, at least, the uneven thickness in the quantum dot, shown in Figure 3 of Ozaki, we determine that the band gap equations relied upon by both experts indicate changes in thickness would also affect the band gap at different thicknesses within the quantum dot. *See* Ex. 2053 ¶ 172; *see id.* at 36 n.7. Further, while Dr. Doolittle states throughout his Declaration that there are unvarying energies inside a quantum dot, Dr. Doolittle, nevertheless, states that “[b]ecause carriers may only exist within the quantum dot at specified discrete *energies*, carriers can move laterally without any energy fluctuations at all *or alternatively have to ‘jump’ between discrete bandgap energies both within the quantum dot itself* and to escape the quantum dot. Ex. 2053 ¶ 270 (emphases added). Thus, we understand Dr. Doolittle to testify that there can be varying discrete bandgap *energies* within the quantum dot itself.

Accordingly, for the reasons discussed above, we are persuaded that Petitioner has sufficiently explained how Ozaki in combination with Stringfellow discloses this limitation recited in claim 1. Claim 8 does not require a “spatial fluctuation . . . in the band gap.” Ex. 1001, 6:27–32. Claim 8 recites “a second gallium nitride based semiconductor layer having a varied compositional ratio and formed on the first gallium nitride based semiconductor layer onto which the composition material is formed, and the second gallium nitride based semiconductor is a light emitting layer.” *Id.* For the same reasons as discussed with regard to claim 1, we determine that Ozaki teaches a second gallium nitride based semiconductor layer (i.e., active layer) having a varied compositional ratio (e.g., InGaN layer with In rich and In poor regions) and formed on the first gallium nitride based semiconductor layer (e.g., nitride semiconductor layer). Ex. 1041 ¶ 16, Fig. 3.

4. Conclusion

For the reasons discussed above, Petitioner has shown sufficiently that the combination of Ozaki and Stringfellow teaches or suggests all the limitations of claim 1 and has articulated a sufficient rationale for combining the teachings of the references. More specifically, as discussed above, Petitioner has explained persuasively that a POSITA would have selected InGaN (or AlGaIn) as the active layer in Ozaki because Stringfellow teaches the compositional variation of these materials affects band gap energy. *Id.* at 31 (“[A] PHOSITA would have combined the basic material science knowledge of Stringfellow as foundational knowledge for understanding better how the ratio of elements creates ‘a spatial fluctuation in the band gap.’”); see Ex. 1010, 412.

Accordingly, Petitioner has shown by a preponderance of the evidence that claim 1 would have been obvious over the combination of Ozaki and Stringfellow. For the same reasons, Petitioner has shown by a preponderance of the evidence that claim 8 would have been obvious over the combination of Ozaki and Stringfellow.

E. Obviousness based on Ozaki, Stringfellow, and Smith – Claims 1, 2, 8, and 9

Petitioner asserts that claims 1, 2, 8, and 9 of the '270 patent would have been obvious over the combination of Ozaki, Stringfellow, and Smith. Pet. 33–51.

1. Summary of Smith (Ex. 1008)

Smith is a dissertation titled “Structural and Electronic Properties of III-V Nitride Heterostructures” that is authored by Kurt Vernon Smith. Smith discloses the physics and material science regarding epitaxial growth

of gallium nitride based semiconductors. Ex. 1008, 8.¹⁰ According to Smith, the dissertation describes “detail[ed] studies of sub micron to nanometer scale structural and electronic properties of III-V nitrides, in particular $\text{Al}_x\text{Ga}_{1-x}\text{N}/\text{GaN}$ [heterostructure field effect transistors] (HFET) epitaxial layer structures.” Ex. 1008, 23. The dissertation discusses comparisons made to assess the influence of different growth modes, doping levels and Al concentration. *Id.* Further, Smith notes that the MOCVD grown samples described in the dissertation exhibit a relatively uniform surface structure, while the MBE grown sample shows significant variations related to Ga droplets that formed during growth in the Ga-rich regime. Ex. 1008, 107.

2. *Petitioner’s Contentions*

Petitioner asserts that a POSITA would have understood that Smith relates to the “characterization and growth of gallium nitride based semiconductors including GaN and AlGa_N which are commonly used in LEDs and lasers[,]” which is relevant to the LEDs and lasers described in Ozaki that employ the same GaN based materials. Pet. 34 (citing Ex. 1008, 1; Ex. 1029 ¶¶ 133). Petitioner asserts that

it would have been obvious to a PHOSITA to substitute the metal thin-film layer (*e.g.*, Ga) and InGa_N active layer in Ozaki with Ga droplets and AlGa_N based on the teachings of Smith. Ex. 1002, ¶¶ 134-141. A PHOSITA understands that III-V semiconductor materials (*e.g.*, AlGa_N and InGa_N) are expected to behave similar to one another in semiconductor devices. Ex. 1029, ¶ 137. Ozaki and Smith describe physical phenomenon achieving the same results (*i.e.*, compositional and thickness variation) in very similar III-V alloys (*i.e.*, InGa_N and AlGa_N). Ex. 1007, Fig. 3, ¶¶ 11, 14, 18; Ex. 1008, p.27, 127, 140; Ex. 1002, ¶ 138. A PHOSITA would understand that replacing

¹⁰ Citation refers to pagination at the bottom of each page.

InGaN with AlGaN is a simple, predictable substitution that would simply change the emission spectrum from visible to UV emission, which has several commercially valuable applications. Ex. 1002, ¶138.

If the teachings in Smith were used in the structure of Ozaki, the thin-film layer (“*composition material*”) would be a Ga droplet and the active layer (“*second gallium nitride based semiconductor*”) would be AlGaN. Smith teaches that the Ga droplet will cause compositional fluctuation in AlGaN. Ex. 1008, 27, 127, 140. A PHOSITA would recognize that such a compositional variation in AlGaN will necessarily result in a spatial fluctuation in the band gap (as discussed below), which is beneficial for an active layer as fluctuations in the band gap were very well known to improve light emission. Ex. 1002, ¶152.

Pet. 42–43.

3. Patent Owner’s Contentions

Patent Owner makes several arguments in response. First, Patent Owner contends that a POSITA would not have combined Ozaki and Smith because the references are directed to very different and incompatible subject matter. PO Resp. 48. Patent Owner contends that “Ozaki relates to making a ‘light-emitting’ or ‘light-receiving element’ . . . [and] [b]y contrast, Smith is directed to “characterization” of structures that do not emit light—an HFET transistor.” PO Resp. 48 (citing Ex. 1007 ¶ 1; Ex. 1008, 8; Ex. 2037, 75:23–77:13; *see also id.* (“One would not thrust aspects of Smith’s structure into Ozaki because this would defeat Ozaki’s approach of improving the performance of light emitting/receiving elements. Doolittle ¶¶298-303, 307-318, 334-339.”)).

Second, Patent Owner contends that Smith teaches the removal of unwanted droplets, which Patent Owner contends teaches away from the proposed combination with Ozaki. PO Resp. 50 (citing Ex. 1008, 28, 30, 102; Ex. 2053 ¶¶ 325–330). According to Patent Owner, Petitioner’s

proposed retention of Smith's droplets in Ozaki's structure is based on impermissible hindsight. PO Resp. 48–49 (citing Ex. 1008, 102; Ex. 2037, 84:11–25, 78:9–79:13; Ex. 2053 ¶¶ 320–328).

Third, Patent Owner contends that Smith, unlike Ozaki, does not teach a lattice mismatch in the AlGa_N/Ga_N heterostructure. PO Resp. 49 (citing Ex. 1007 ¶¶ 9–10, 18; Ex. 1008, 103; Ex. 2053 ¶¶ 313, 315–320, 323–326). Patent Owner adds that it is impossible to form quantum dots using structures the size of Smith's droplets. PO Resp. 50–51 (citing Ex. 1007 ¶ 18; Ex. 2053 ¶¶ 323–325, 334–335). Patent Owner argues that “[a] POSA seeking to follow Ozaki's teachings to form quantum dots therefore would have avoided using Smith's far larger liquid Ga droplets (which Smith removes) that Dr. Fitzgerald testified have no lattice (and thus no lattice mismatch).” *Id.* at 51 (citing Ex. 2037, 24:12–24, 129:15–19; Ex. 2053 ¶ 336).

Fourth, Patent Owner further contends that a POSITA would not have replaced Ozaki's InGa_N active layer with AlGa_N based on Smith because because InGa_N and AlGa_N exhibit very different behavior with respect to a critical issue—phase separation to form quantum dots. PO Resp. 51. Patent Owner argues that Petitioner's arguments and Dr. Fitzgerald's testimony asserting otherwise are conclusory. *Id.* at 51–52.

Fifth, Patent Owner contends that “Smith does not disclose or suggest depositing any material on top of droplets (because Smith first etches them away), and further does not disclose or suggest that any variations would be created in any material above Ga droplets.” PO Resp. 53 (emphases omitted) (citing Ex. 2053 ¶ 330). Patent Owner contends that Smith at most suggests that some compositional variations might be created in the nitride semiconductor layer on which the Ga droplets are deposited (i.e., the etched

droplet region underneath the droplets). *Id.* at 54 (citing Ex. 1008, 30; Ex. 2053 ¶¶ 320–330). Patent Owner argues that applied to Ozaki, the variations would occur in the bottom gallium nitride semiconductor instead of the active layer. *Id.* at 54.

4. Discussion

Petitioner asserts that Ozaki discloses all the limitations of claims 1 and 8 for the same reasons discussed above. *See* Pet. 40 (“Ozaki discloses this element for the same reasons discussed in relation to Ground 1.”). Alternatively, Petitioner argues that if Ozaki is found not to disclose the limitations recited in step (c) of claim 1 (i.e., “spatial fluctuation”), then the limitations are disclosed by Ozaki in view of Smith and Stringfellow because Smith discloses that Ga droplets (“composition material”) formed on the surface of a GaN based semiconductor will cause unevenness and compositional variation in an AlGaN layer (“second gallium nitride based semiconductor”) formed in contact with and above the Ga droplets. Pet. 41 (citing Ex. 1029 ¶ 147). Petitioner relies on the same arguments for claim 8. Pet. 50–51.

Petitioner also presents similar arguments for dependent claims 2 and 9, which require that the “first gallium nitride based semiconductor” and the “second gallium nitride based semiconductor” are AlGaN and the “composition material” is Ga or Al. Pet. 49, 51; Ex. 1001, 5:45–48; 6:33–36. Below, we discuss claim 1, which is representative of the subject matter recited in claim 8 and dependent claims 2 and 9.

Based on the complete record, we determine that Petitioner has not explained sufficiently why a POSA would have combined Ozaki, Smith, and Stringfellow. Initially, we agree that Smith does teach, as Petitioner argues, “the basic physics and material science showing that Ga droplets will cause

compositional and thickness variations in the AlGa_N layer formed in contact with and above it.” Pet. 42. Particularly, Smith teaches that a “MBE grown sample shows *significant variations across the sample surface related to Ga droplets that formed during growth in the Ga-rich regime and were subsequently etched*. The region between Ga droplets (normal region) has atomic step structure correlated with high quality growth.” Ex. 1008, 27 (emphasis added). Smith further teaches that

[t]he MBE grown Al_xGa_{1-x}GaN HFET structure exhibits regions with significant variations in 2DEG density and regions of relatively little contrast. *The Ga droplet etch pits discussed earlier differentiate these regions*. The normal region exhibits little variation in the local electronic structure compared to the etched droplet region *Substantial variations are apparent in the etched droplet region and are attributed to both layer thickness variations and inhomogeneities in Al composition in Al_xGa_{1-x} epitaxial barrier layer*.

Ex. 1008, 30 (emphases added); see *id.* at 130 (“These results are not unexpected, as the Ga droplet on the surface may reduce the local Al incorporation during the growth.”).

Nonetheless, even assuming that there is some overlapping understanding of the effect of compositional or thickness variation on band gap in both Ozaki and Smith, Petitioner does not explain sufficiently why a POSA would have substituted Smith’s Ga droplets and AlGa_N layer for the In thin film layer and InGa_N active layer taught in Ozaki. Ozaki teaches

when a thin-film layer is grown that is very thin, there are spots in the film where metal atoms are present and spots in the film where metal atoms are absent from a microscopic viewpoint, and the presence or absence of these atoms in the film cause the film thickness to be uneven. *When the thickness of the thin-film layer is uneven, that is, when the thin-film layer is thick in places and thin in other places, the properties of the crystals will be different*. When an active layer is grown on top of this thin-film

layer, the active layer grows selectively. When the active layer grows selectively, the active layer itself forms quantum boxes or quantum dots, and the output improves significantly. In other words, because the thickness of the well layer is uneven on the plane and there is a band gap difference with the cladding layer in the in-plane direction, the carriers injected into the well layer are confined in a structure similar to a quantum box, quantum disk, or quantum dot structure.

Ex. 1041 ¶ 16 (emphasis added). Here, Ozaki explains that it is the unevenness of thickness in the thin film layer that can cause the active layer, grown on top, to be grown selectively (i.e., uneven thickness) as well. *Id.* However, Ozaki further explains that the unevenness of the thin film layer affects the properties of the *crystals*. As such, Ozaki presumes that the thin film layer has a crystalline form. This makes sense as Ozaki also discusses the importance of a lattice mismatch between the thin film layer and the nitride layer. Ex. 1041 ¶ 7. Ozaki teaches that

by providing a thin film layer with a lattice constant irregularity difference of $\pm 3\%$ or more and forming an active layer in contact with this thin-film layer, the active layer assumes a quantum well structure, quantum disk structure, quantum wire structure, or quantum dot structure, and output is improved significantly. The details of how the active layer assumes a quantum well structure, quantum disk structure, quantum wire structure, or quantum dot structure is unclear, but it is believed that because the lattice constant of the thin-film layer is shifted by $\pm 3\%$ or more relative to the lattice constant of the nitride layer, the lattice mismatch of the thin-film layer formed in contact with the nitride layer causes the film thickness to become uneven, and that forming an active layer in contact with an uneven thin-film layer causes uneven growth of the active layer.

Id. (emphases added).

Petitioner does not, however, explain persuasively how the substitution of Ga droplets and an AlGaIn active layer is compatible or viable with Ozaki's described semiconductor structures. For example,

Petitioner relies on Ozaki's Figure 3 to show that the active layer and thin film layer together form a quantum dot that exhibits spatial fluctuation. See Pet. Reply 22 ("In Ozaki, 'quantum dots' are the island growths shown in Figure 3 that include both the thin-film layer and active layer."). Yet, Petitioner does not explain sufficiently how the substitution of Ga and AlGaIn would result, predictably, in the same quantum dot structure shown in Figure 3 of Ozaki.

First, Ozaki teaches explicitly that in the active layer, shown in Figure 3, some of the thin well layer and/or barrier layer experiences *phase separation*, forming indium-rich regions with a larger amount of indium and indium-poor regions with a smaller amount of indium. Ex. 1041 ¶ 14. Ozaki teaches further that "[t]he indium-rich regions and indium-poor regions are arranged in a regular pattern on the plane and this includes the formation of quantum boxes." *Id.*; see *id.* ¶ 18 ("When InGaIn is grown, In compositional separation occurs in addition to dot formation and *quantum dots are formed by both effects.*") (emphasis added). We understand Ozaki to teach here that phase separation can cause the formation of quantum dots. However, Petitioner concedes that AlGaIn does not phase separate. Pet. Reply 28. Petitioner states "[w]hile AlGaIn does not phase separate, Smith teaches that Ga droplets causes decreased Al incorporation leading to the same compositional variation and thickness variation that Ozaki achieved with InGaIn." *Id.* (citing Ex. 1041, Fig. 3, ¶¶ 11, 14, 18; Ex. 1008, 27, 127, 140; Ex. 1029 ¶ 138).

Second, we observe that Ozaki teaches quantum dots may be formed by the strain energy from the lattice mismatch between layers. For example, Ozaki teaches that

[t]he active layer of the present invention is such that providing a thin-film layer having a lattice constant irregularity difference of $\pm 3\%$ or more relative to the nitride semiconductor layer and in contact with both the nitride semiconductor layer and the active layer causes the formation of a quantum well structure, a quantum disk structure, a quantum wire structure, or a quantum dot structure.”

Ex. 1041 ¶ 14. Additionally, Ozaki teaches that

[t]he details of how the active layer assumes a quantum well structure, quantum disk structure, quantum wire structure, or quantum dot structure is unclear, but *it is believed that because the lattice constant of the thin-film layer is shifted by $\pm 3\%$ or more relative to the lattice constant of the nitride layer, the lattice mismatch of the thin-film layer formed in contact with the nitride layer causes the film thickness to become uneven, and that forming an active layer in contact with an uneven thin-film layer causes uneven growth of the active layer.*

Ex. 1041 ¶ 7 (emphasis added). We understand from, at least, this disclosure that Ozaki teaches quantum dots, such as those shown in Figure 3, may also be formed by the lattice mismatch between a thin film layer and the active layer. However, Petitioner’s expert, Dr. Fitzgerald has acknowledged that metals may have crystalline and liquid forms depending on temperature. Ex. 2037, 22:11–23:11. In the case of gallium, Dr. Fitzgerald testified that “[a]t growth temperature, they’re liquid, so there’s no lattice mismatch.” Ex. 2037, 129:15–19. Thus, given that generally AlGa_N does not phase separate and Ga does not have a lattice at growth temperature, it is unclear why a POSA would have considered the use of Ga and AlGa_N to be a simple substitution into Ozaki’s quantum dot semiconductor structure (i.e., thin film layer and active layer) with predictable and dependable results.

Additionally, we are not persuaded by Petitioner's reliance on Ozaki's teaching that "[t]he thin-film layer may be a layer with *only metal atoms* (sometimes referred to below as a metallic layer)." Ex. 1041 ¶ 11 (emphasis added). Petitioner argues that because Ozaki expressly describes the use of a metallic layer, the lattice mismatch is not necessarily required for all embodiments. However, we disagree that that is what Ozaki teaches. This is because, even when describing a thin film layer with metal atoms, Ozaki still indicates that the uneven thickness is due to differences in the *properties of the crystals*. Ex. 1041 ¶ 16 ("[W]hen a thin-film layer is grown that is very thin, *there are spots in the film where metal atoms are present and spots in the film where metal atoms are absent from a microscopic viewpoint*, and the presence or absence of these atoms in the film cause the film thickness to be uneven. When the thickness of the thin-film layer is uneven, that is, when the thin-film layer is thick in places and thin in other places, the *properties of the crystals* will be different.") (emphases added). Further, as discussed above, Dr. Fitzgerald acknowledges that metals may have both a crystalline and liquid form. Ex. 2037, 22:11–23:11. Thus, even in the context of a metallic layer, Dr. Fitzgerald's testimony acknowledges that a crystalline metal may be used as a thin film layer, which we determine is more consistent with Ozaki's teaching of that quantum dots can form from strain energy.

Furthermore, we are not persuaded by Petitioner that Ozaki's quantum dots are irrelevant to our review. Pet. Reply 21–22. Petitioner expressly relies on the semiconductor structure shown in Ozaki's Figure 3 for these and other limitations recited in claim 1. In doing so, Petitioner acknowledges expressly that Ozaki teaches that the active layer forms quantum dots. Pet. 21 ("Ozaki specifically teaches that the active layer

(“*second gallium nitride based semiconductor*”) forms “quantum dots or quantum boxes.” *Id.* at ¶¶1416; Ex. 1002, ¶105. Ozaki depicts these “quantum dots or quantum boxes” in Figure 3, showing that the $\text{In}_x\text{Ga}_{1-x}\text{N}$ active layer (“*second gallium nitride based semiconductor*”) is in contact with and above the nitride semiconductor layer (“*first gallium nitride based semiconductor*”) on which the thin-film layer (“*composition material*”) has already been formed. *Id.* at Fig. 3, ¶¶14-16.”). Thus, in seeking to modify Ozaki’s disclosure with Smith’s teachings, there must be some explanation on Petitioner’s part for why or how a POSA would make the “simple” substitution into Ozaki’s specific quantum dot structure.

Alternatively, if Petitioner seeks to argue that a POSA would have modified Ozaki to obtain similarly improved output without the quantum dot structure, then that theory must also be fully explained and supported. *See* Pet. 39 (“[A] PHOSITA would have understood that substituting the metal droplet (*e.g.*, Ga)/InGaN quantum dot in Ozaki with Ga droplet/AlGaN based on the physical science teachings of Smith would yield predictable and dependable results of light emission in the UV spectrum.”). However, Petitioner has not explained how a POSITA would have made this modification, especially in light of Smith’s teaching that the Ga droplet is etched away from the semiconductor structure.¹¹ In any case, the quantum dot structure, shown in Ozaki’s Figure 3, and relied upon throughout the Petition cannot be set aside without some explanation. *See In re Nuvasive*,

¹¹ We recognize that it is axiomatic that bodily incorporation is not required. *See, e.g., In re Mouttet*, 686 F.3d 1322, 1332 (Fed. Cir. 2012) (“It is well-established that a determination of obviousness based on teachings from multiple references does not require an actual, physical substitution of the elements.”). Rather, here, we find Petitioner’s explanation to be incomplete.

842 F.3d 1376, 1383 (Fed. Cir. 2016) (holding conclusory statements insufficient if not supported by a reasoned explanation (citing *In re Lee*, 277 F.3d 1338, 1342 (Fed. Cir. 2002) (“The factual inquiry whether to combine references must be thorough and searching.”)); *InTouch Techs., Inc. v. VGO Commc’ns, Inc.*, 751 F.3d 1327, 1347 (Fed. Cir. 2014) (“While an analysis of any teaching, suggestion, or motivation to combine elements from different prior art references is useful in an obviousness analysis, the overall inquiry must be expansive and flexible.”)).

Accordingly, Petitioner has not demonstrated, by a preponderance of the evidence, that claim 1 would have been obvious over Ozaki, Stringfellow, and Smith. Further, as discussed, Petitioner relies on the same arguments for claim 8. For the same reasons, Petitioner has also not demonstrated by a preponderance of the evidence that claim 8 would have been obvious over Ozaki, Stringfellow, and Smith. The same applies to claims 2 and 9, which depend from claims 1 and 8, respectively.

F. Obviousness based on Tanaka and Ozaki – Claims 1, 2, 8, and 9

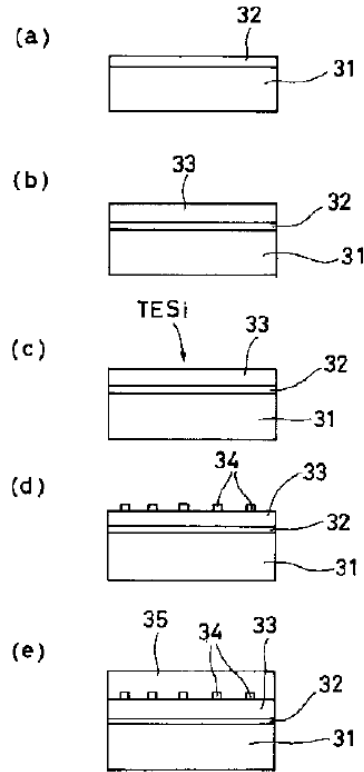
1. Summary of Tanaka (Ex. 1013)

Tanaka teaches that gallium nitride and other group III nitrides can be used for “high-quality short-wavelength light-emitting diodes and laser diodes.” Ex. 1013 ¶¶ 1–2. Tanaka notes that in this context, when quantum dots are used, the quantum dots “have to be formed in such a way as to be confined inside another semiconductor layer.” Ex. 1013 ¶ 6. Tanaka further provides a method to form quantum dots in material systems that currently cannot support the formation of quantum dots using metalorganic vapour-phase epitaxy (MOCVD) and molecular-beam epitaxy (MBE) methods. *Id.* ¶ 8. This method includes using a surfactant on a first compound semiconductor layer to change surface conditions before a second compound

semiconductor film is grown directly on top of the first compound semiconductor layer. *Id.* ¶ 10.

Figures 2(a)–(e) are reproduced below.

[FIG. 2]



These figures provide cross-sectional views of the film-forming process described in Tanaka. Ex. 1013, 14. In Figure 2(a), AlN buffer layer 32 is formed on substrate 31. Ex. 1013 ¶ 23. Then, as shown in Figure 2(b), $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cladding layer 33 is formed on top of AlN buffer layer 32. Ex. 1013 ¶ 24. In Figure 2(c), tetraethylsilane (TESi), a surfactant, is supplied to the surface of $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cladding layer 33. Ex. 1013 ¶ 26. In Figure 2(d), GaN quantum dots 34 are grown on the surface of $\text{Al}_x\text{Ga}_{1-x}\text{N}$ layer 33. *Id.* ¶ 27. Figure 2(e) shows $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cap layer 35 formed on top of $\text{Al}_x\text{Ga}_{1-x}\text{N}$

cladding layer 33 with GaN quantum dots 34 formed on the surface to bury the GaN quantum dots 34 in the cap layer 35. *Id.* ¶ 28.

2. Discussion

For this obviousness challenge based on Tanaki and Ozaki, Petitioner presents two theories. First, Petitioner contends that Tanaka teaches “a spatial fluctuation is created in the band gap” of the $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cap layer 35 due to variation in the compositional ratio in the $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cap layer 35 (“second gallium nitride based semiconductor”). Pet. 70 (citing Ex. 1029 ¶ 206). Petitioner contends that Tanaka teaches the GaN quantum dots are confined in a layer with a band gap greater than that of GaN such as an AlGaN layer. *Id.* (citing Ex. 1013 ¶ 5). According to Petitioner, “[b]ecause the $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cap layer 35 must have a higher band gap than the GaN quantum dots, there will be a spatial fluctuation in the band gap [*i.e.*, widening and narrowing of the band gap] laterally within $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cap layer 35 that is created by the GaN quantum dots 34, which have a narrower band gap than the surrounding $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cap layer 35.” Pet. 70.

These arguments are not persuasive. Initially, we observe that Tanaka teaches that

[w]hen applying quantum dots to an electronic device, quantum dots have to be formed in such a way as to be confined inside another semiconductor layer. For example, when GaN quantum dots are used in an electronic device, *GaN quantum dots have to be formed in such a way that the GaN quantum dots are confined in a layer with a band gap greater than that of GaN such as an AlGaN layer.*

Ex. 1013 ¶ 5 (emphasis added). We agree with Petitioner that Tanaka teaches there is a band gap difference between the GaN quantum dots and the cap layer. However, Tanaka does not explicitly teach that there is a “spatial fluctuation . . . in the band gap” or that any “spatial fluctuation is

created in the band gap by *variation in the compositional ratio in the second gallium nitride based semiconductor created by the composition material.*”

Instead, Petitioner contends that because the GaN quantum dots are confined and buried in $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cap layer 35, the GaN quantum dots are now part of $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cap layer 35. Pet. 68. Dr. Fitzgerald provides an annotated version of Tanaka’s Figure 2(e) (reproduced below) to illustrate the compositional variations in Tanaka’s structure.

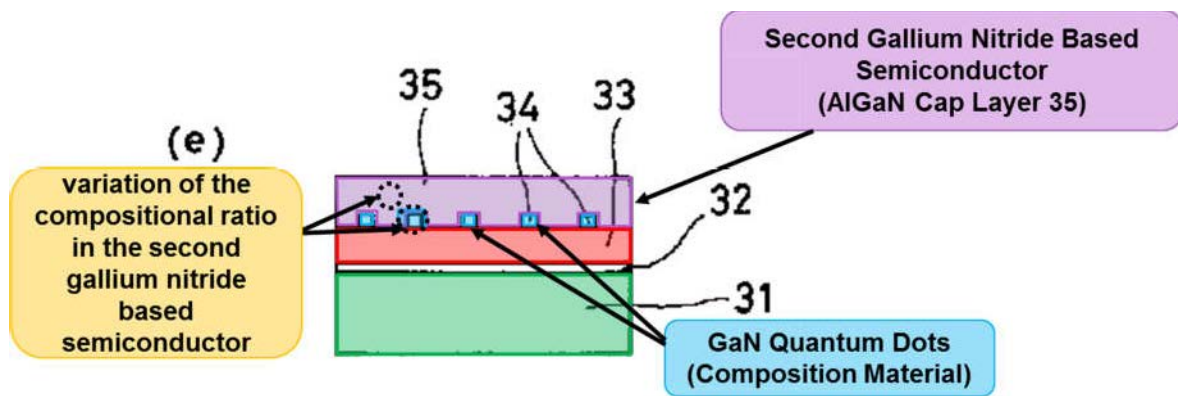


Figure 2e above depicts a semiconductor formation, as annotated by Dr. Fitzgerald. Ex. 1029

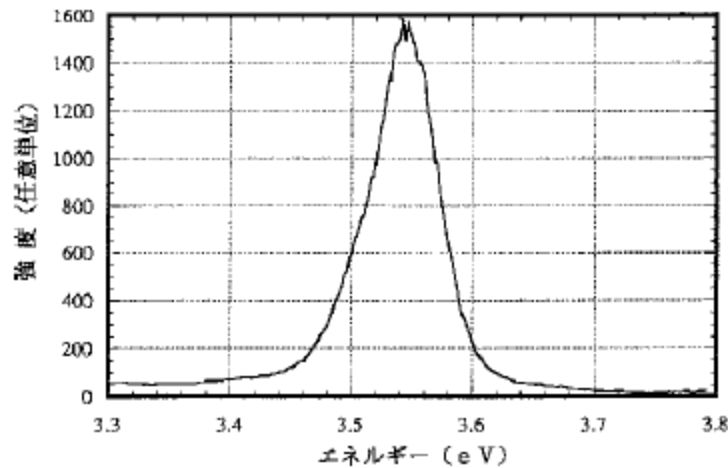
¶ 205. However, claim 1 requires that the variation in the compositional ratio is *created by the composition material*. Petitioner does not explain how the upper left area circled, which may exhibit differing concentrations of Al in that region of the cap layer, is *created by the alleged composition material of GaN* that is further away.

Additionally, Tanaka teaches explicitly that the “quantum dots have to be formed in such a way as to be confined inside another semiconductor layer.” Ex. 1013 ¶ 5. Dr. Fitzgerald agrees that GaN quantum dots 34 must be confined and buried in $\text{Al}_x\text{Ga}_{1-x}\text{N}$ cap layer 35. Ex. 1029 ¶ 205. But, neither Dr. Fitzgerald nor Petitioner persuasively explains how the

“confined” quantum dots can create compositional variation in the cap layer. In other words, as Patent Owner observes, there may be compositional variation between the quantum dot (GaN) and the AlGa_xN cap layer because the quantum dot does not contain any Al. See PO Resp. 67 (“Tanaka’s use of GaN quantum dots cannot result in spatial *fluctuation* in the band gap because there is an abrupt transition in Al concentration from the Al_xGa_{1-x}N cap layer 35 to zero upon entering GaN quantum dots 34.”). However, the GaN quantum dot (e.g., composition material) does not create the compositional variation. Rather, it is the confinement and burial of the GaN within the cap layer that arguably creates any variation.

Additionally, claim 1 requires that the second gallium nitride based semiconductor is a light emitting layer. We find that Petitioner has not sufficiently explained why a POSITA would have understood Al_xGa_{1-x}N cap layer 35 to be a light-emitting layer. See Pet. 70–71. Petitioner contends that the combination of the cap layer with the embedded GaN quantum dots emits light. But, Tanaka does not teach that the two structures are one and the same. Tanaka expressly teaches that the quantum dots are formed separately on the first compound semiconductor via a surfactant, and then, the cap layer is formed over the GaN quantum dots to confine and bury the dots. See Ex. 1013 ¶ 16. Tanaka does not teach that the quantum dots are a part of or merge with the cap layer. Rather, the cap layer is described as distinct layer that serves to *confine* the quantum dots. See *id.* Moreover, we are not persuaded that Tanaka’s Figure 5 supports Petitioner’s position. Figure 5 of Tanaka is reproduced below.

[FIG. 5]

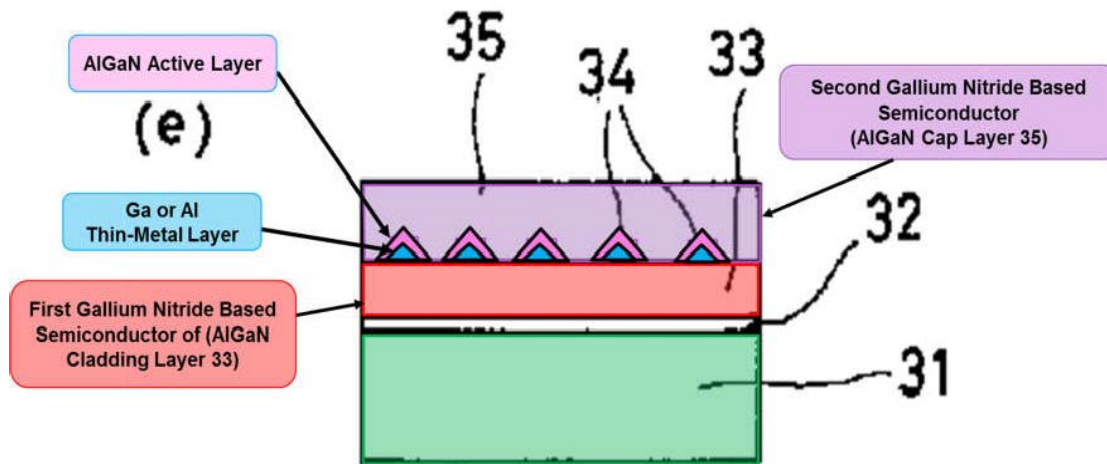


[Horizontal axis] Energy (eV)
[Vertical axis] Strength (arbitrary unit)

Figure 5 is a graph showing the photoluminescence spectrum of a sample with the GaN quantum dots shown in the AFM micrograph in Figure 3. Ex. 1013 ¶ 35. Both Dr. Fitzgerald and Dr. Doolittle agree that the single peak shown around 3.55 eV energy is from the GaN quantum dots. Ex. 2037, 106:22–107:5, Ex. 2053 ¶¶ 165–168, 384–385. Further, Tanaka expressly teaches that “[t]he luminescence from the AlGaIn layer was on the high-energy side and could not be observed.” Ex. 1013 ¶ 35. In other words, as far as Tanaka’s disclosure goes, light emission from AlGaIn could not be observed. Thus, we find Tanaka’s overall disclosure to be more consistent with Patent Owner’s arguments and evidence that a POSITA would not have considered the cap layer to be light emitting.

As a second theory of obviousness, Petitioner contends that a POSITA would have substituted Ozaki’s quantum dots for Tanaka’s. Pet. 71–74. Petitioner argues that “it would have been obvious to a PHOSITA to replace the GaN quantum dots in Tanaka with a quantum dot comprised of a Ga droplet thin-film layer as disclosed in Ozaki and an AlGaIn active layer.” *Id.*

at 72. Dr. Fitzgerald provides a figure (reproduced below) in his Declaration illustrating the proposed modification.



The Figure above was provided in paragraph 213 of Dr. Fitzgerald's Declaration and depicts a semiconductor formation annotated to show Dr. Fitzgerald's depiction of the combination of Tanaka and Ozaki. Ex. 1029 ¶ 213. Dr. Fitzgerald testifies that

[a] PHOSITA would know that combining the quantum dots of Tanaka and Ozaki would yield predictable results. Both Tanaka and Ozaki disclose quantum dots composed of Group III and Group V materials, and a PHOSITA would understand that these materials can be used interchangeably given the similar properties of III-V semiconductors.

Ex. 1029 ¶ 213.

We observe first that Petitioner argues that the materials between the references are interchangeable and easily substituted. Pet. 71–72. However, the semiconductor formation processes described in each reference are not the same. As discussed in detail above, Ozaki teaches the use of phase separation and/or strain energy to form quantum dots. See Ex. 1041 ¶ 16. Tanaka, on the other hand, applies a surfactant to a first compound semiconductor in order to form a quantum dot on the first compound semiconductor. Ex. 1013 ¶ 10. Then, a cap layer confines the quantum

dots. *Id.* ¶ 5. But, Petitioner does not explain how the materials taught in Ozaki, i.e., Ga or Al, would or could be substituted into process and structure described in Tanaka. *See* PO Resp. 69. For example, substituting Ozaki's quantum dot into Tanaka's structure presumes that there is a process for forming Ozaki's quantum dot, which Petitioner asserts includes both the active layer and an underlying thin film layer. *See* Ex. 1029 ¶ 213; *see* Pet. Reply 22 ("In Ozaki, 'quantum dots' are the island growths shown in Figure 3 that include both the thin-film layer and active layer."). However, Petitioner does not explain persuasively why a POSITA would have considered the formation a GaN quantum dot to be interchangeable with a quantum dot that includes Ozaki's two layers of different materials.

Moreover, even if the substitution could be made as Petitioner contends, we note that Petitioner identifies cap layer 35 as the second gallium nitride based semiconductor. *See* Ex. 1029 ¶ 213, Figure. Again, we are not persuaded that the confinement of the quantum dots by the cap layer teaches that the quantum dots are part of the cap layer. Further, we are not persuaded that the cap layer emits light. As discussed, even considering Petitioner's modification, the light emission occurs from the quantum dots that are confined and buried by the cap layer. Ex. 1013, Fig. 5. However, Tanaka expressly teaches that light emission from AlGa_N could not be observed. Ex. 1013 ¶ 35. Petitioner's proposed modification retains the same AlGa_N as the cap layer.

Accordingly, Petitioner has not demonstrated, by a preponderance of the evidence, that claim 1 would have been obvious over Tanaka and Ozaki. Petitioner relies on the same arguments for claim 8. Pet. 76–77. For the same reasons, Petitioner has also not demonstrated by a preponderance of the evidence that claim 8 would have been obvious over Tanaka and

Ozaki.¹² The same applies to claims 2 and 9, which depend from claims 1 and 8, respectively.

G. Remaining Ground

The remaining instituted ground of unpatentability relies on Ozaki as the primary reference for anticipation. Pet. 14–30.

Having found that Petitioner has demonstrated that the subject matter of claims 1 and 8 would have been obvious over Ozaki and Stringfellow, we need not reach whether claims 1 and 8 are anticipated by Ozaki. *See In re Gleave*, 560 F.3d 1331, 1338 (Fed. Cir. 2009) (“Therefore, we affirm the Board’s rejection of claims 1, 4, 15, and 18–21 of the ’493 application under § 102(b). We need not reach the § obviousness rejection.”).

III. CONCLUSION¹³

We determine that Petitioner has shown, by a preponderance of the evidence, that claims 1 and 8 would have been obvious over Ozaki and Stringfellow. We further determine that Petitioner has not shown, by a preponderance of the evidence, that claims 2 and 9 are unpatentable.

¹² Although claim 8 does not recite a “spatial fluctuation,” the same deficiencies discussed above for claim 1 apply to claim 8. For example, claim 8 requires that the “the second gallium nitride based semiconductor is a light emitting layer.” Ex. 1001, 6:30–32.

¹³ Should Patent Owner wish to pursue amendment of the challenged claims in a reissue or reexamination proceeding subsequent to the issuance of this decision, we draw Patent Owner’s attention to the April 2019 *Notice Regarding Options for Amendments by Patent Owner Through Reissue or Reexamination During a Pending AIA Trial Proceeding*. See 84 Fed. Reg. 16,654 (Apr. 22, 2019). If Patent Owner chooses to file a reissue application or a request for reexamination of the challenged patent, we remind Patent Owner of its continuing obligation to notify the Board of any such related matters in updated mandatory notices. See 37 C.F.R. § 42.8(a)(3), (b)(2).

Claims	35 U.S.C §	Reference(s)	Claims Shown Unpatentable	Claims Not Shown Unpatentable
1, 8	103	Ozaki and Stringfellow	1, 8	
1, 2, 8, 9	103	Ozaki, Stringfellow, and Smith		1, 2, 8, 9
1, 2, 8, 9	103	Tanaka and Ozaki		1, 2, 8, 9
1, 8	102	Ozaki		
Overall Outcome			1, 8	2, 9

IV. ORDER

In consideration of the foregoing, it is hereby:

ORDERED that, pursuant to 35 U.S.C. § 314(a), an *inter partes* review of claims 1 and 8 of the '270 patent have been shown to be unpatentable;

FURTHER ORDERED that Petitioner has not shown by a preponderance of the evidence that claims 2 and 9 of the '270 patent are unpatentable; and

FURTHER ORDERED that parties to the proceeding seeking judicial review of this Final Written Decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

IPR2018-01139
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