UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SATCO PRODUCTS, INC.,
Petitioner,

v.

SEOUL SEMICONDUCTOR CO., LTD.,
Patent Owner

Case: IPR2020-00146
U.S. Patent No. 7,667,225

PETITION FOR *INTER PARTES* REVIEW OF CLAIMS 1, 4-7, 10-11, AND 16-19 OF U.S. PATENT NO. 7,667,225

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1011	Shih-Wei Feng, et al., *Cluster size and composition variations in yellow and red light-emitting InGaN thin films upon thermal annealing*, J. Appl. Phys. Vol. 95, No. 10, pp.5388-5395 (May 10, 2004)

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1053	S.C.P. Rodrigues, et al., *Luminescence studies on nitride quaternary alloys double quantum wells*, Applied Surface Science 254 (2008) 7790-7792.
1054	Declaration of Sylvia Hall-Ellis, Ph.D.
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Satco Products, Inc. requests *inter partes* review of claims 1, 4-7, 10-11, and 16-19 of U.S. Patent No. 7,667,225. The ’225 patent claims a light emitting device having a multi-quantum well structure that includes what the patent calls a “carrier trap portion.” Ex. 1001, cl.1. That “carrier trap portion” exhibits a bandgap energy that decreases from a periphery of the carrier trap portion to a center of the carrier trap portion. *Id.* This feature was the focus during the prosecution of the ’225 patent and led the examiner to allow the ’225 patent. Ex. 1003, p.39.

The Office made a mistake when it issued the ’225 patent. The ’225 patent describes and claims that the variation in bandgap energy is caused by a variation in the indium content within the carrier trap portions. Ex. 1001, 4:32-39, cl.7, 10. To get the ’225 patent, the applicant contended—and the Office agreed—that the prior art did not show a variation of indium or bandgap energy within carrier traps. But it was known that the indium content is not uniform within carrier traps. Because indium content changes within carrier traps, it was understood that the bandgap energy also changes in an inverse way. Ex. 1002, ¶¶ 33, 40; Ex. 1010, p.3668, Fig. 2; Ex. 1031, Fig. 7, 19:30-45 (“[I]ncreasing the indium composition ratio decreases the bandgap.”). The feature central to allowance was thus old news.

As foreshadowed, the ’225 patent inventors were not the first to notice indium content variation in carrier traps. The variation in indium content had been observed for nearly a decade and was widely reported well before the ’225 patent was filed. Ex. 1025, Fig. 2(d); Ex. 1026, p.1673 (Fig. 4); Ex. 1015, Fig. 2; Ex. 1012, Fig. 13, p.9; Ex. 1018, Figs. 1 & 2, pp.299-300; Ex. 1046, Figs. 2(b), 3(c). The prior art is littered with teachings of indium concentration variation—and thus bandgap energy variation—within carrier traps. The prior art presented in this petition was not before the Office when it decided to grant the ’225 patent. If it had been, the challenged claims would not have issued. That mistake should be corrected in this proceeding.

I. U.S. PATENT NO. 7,667,225

A. Background

The ’225 patent relates to alleged improvements in multi-quantum well light emitting devices in which at least one layer in a multiple quantum well structure includes a “carrier trap portion.” Ex. 1001, 1:16-21.

One goal of the ’225 patent was to “prevent a reduction in internal quantum efficiency which is caused by crystal defects such as dislocations in an active region.” *Id.*, 2:6-9. Another goal was to “improve crystal quality of a mutli-quantum well structure.” *Id.*, 2:10-12. A “carrier trap portion” that “serves to trap carriers by taking the place of dislocations” is included in the MQW structure. *Id.*, 4:11-16. “For this purpose, the carrier trap portion 27 is configured to have a band-gap energy that gradually decreases from a periphery of the carrier trap portion to the center thereof, as shown in FIGS. 3 and 4," which show the location of various energy bands in cross-sectional drawings. *Id.*, 4:16-21. A "carrier trap portion"

> refers to a structure capable of using carriers which can be trapped and lost by the dislocations. Such a structure is not limited to a physical shape. In other words, according to embodiments of the invention, the carrier trap portion may be a physical shape or a quantum-mechanical energy state capable of efficiently using the carriers which can be trapped and lost by the dislocations.

Id., 4:40-47. The '225 patent explains that the desired bandgap profile can be obtained "when the layer including the carrier trap portion 27 contains indium, . . . the indium content of the carrier trap portion 27 gradually increases from the periphery to the center thereof." *Id.*, 4:32-39. "[W]hen the indium content exceeds 5% and the growth temperature exceeds 600°C, indium is subjected to phase separation in the layer and exhibit and intensive tendency to form the carrier trap portion 27 according to embodiments of the invention." *Id.*, 5:3-10. The '225 patent also reports that variation in indium content within the carrier trap portion can lead to improvements with respect to lattice mismatch when GaN barriers and InGaN well layers are used. *Id.*, 5:25-33.

The sole independent claim recites a light-emitting device with (1) a substrate, (2) a semiconductor layer on the substrate, (3) a second semiconductor layer on the first semiconductor layer, a multi-quantum well [("MQW")] having "at least one well layer and at least one barrier layer between the first and second semiconductor layers," and a "carrier trap portion" formed in one of the layers of the MQW structure where the carrier trap has a band-gap energy that decreases from the periphery of the carrier trap to the center of the carrier trap portion. Ex. 1001, cl.1.

B. Prosecution History

The '749 application—which led to the '225 patent—was filed with an Accelerated Examination Support Document.[1] Ex. 1004, pp.86-87, 105-142. In that document, the applicants concluded that the limitation "the at least one carrier trap portion having a band-gap energy decreasing from a periphery of the carrier trap portion to a center of the carrier trap portion" distinguished the claims from the prior art. Ex. 1004, p.134.

Accelerated examination proceeded, *id.*, p.80-82, and the examiner rejected the claims for statutory double patenting, obviousness-type double patenting, and

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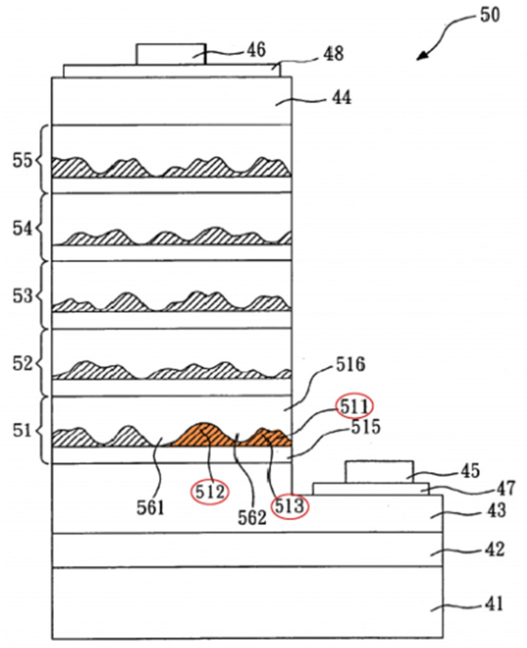
[1] The parent application—Application No. 12/486,267—had many identical claims to those in the '749 application resulting in a rejection for statutory double patenting. Ex. 1004, pp.64-68. The '267 application was expressly abandoned. *Id.*, p.5.

claims 1-9, 12-14, 17-18, and 20 as being obvious over U.S. Patent No. 7,271,417 to Chen (Ex. 1005). *Id.*, p.64-68. Chen issued from the application that published as U.S. Patent Application Publication No. 2006/0081832, which was discussed in the applicants' "Accelerated Examination Support Document."[2] The Examiner observed that Chen discloses indium carrier traps, which led the examiner to conclude that Chen's carrier trap portion "would provide the same characteristics" as those claimed. Ex. 1004, p.66.

The applicants disagreed and explained that "Chen does not teach carrier trap portions in a quantum well layer, but only discloses a carrier trap layer 31/511." *Id.*, p.38. "Further, Chen teaches the carrier trap layer 31/511 (or porous light emitting layers 51, 52, 53, 54, and 55) as having a lower band gap energy relative to barrier layers 32 (or 515, 516) . . . ." *Id.* Chen did not disclose "the band gap energy profile of the carrier trap layer 31/511." *Id.* Thus Chen did not expressly disclose the



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[2] The Office Action cited to the pre-grant publication, not the issued patent. Ex. 1004, p.37.

claimed subject matter. *Id.*, pp.38-39.

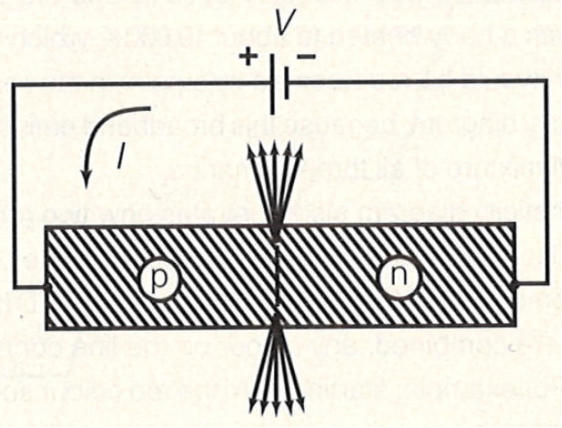
The applicants also disagreed with the Examiner's conclusion that the claimed behavior was inherent. *Id.*, p.39. The applicants contended that Chen does not disclose "adjusting the In concentration in the carrier trap layer 31/511." Ex. 1004, p.39. The applicants then faulted the Examiner for not providing a rationale for adjusting indium concentration in the carrier trap layer 31/511. *Id.*, p.40. The examiner allowed the claims and remarked that "Applicants' arguments solely place the claims in condition for allowance." *Id.*, p.18.

II. TECHNOLOGICAL BACKGROUND

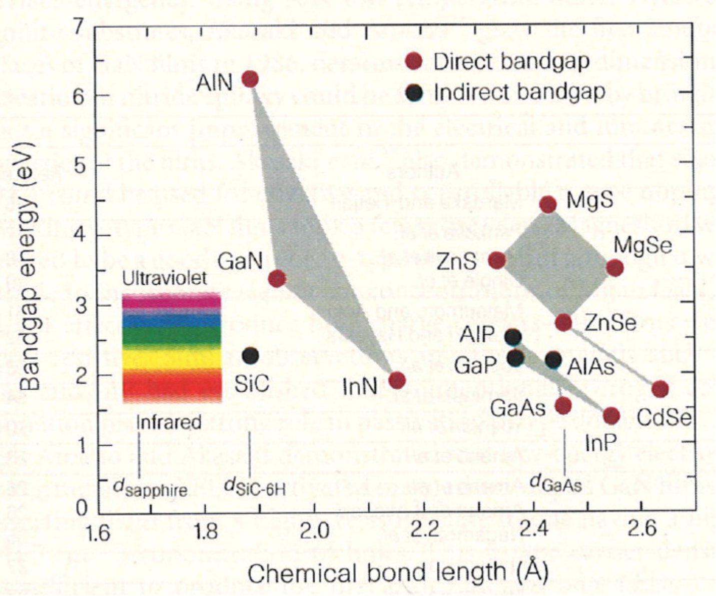
An understanding of some basic concepts associated with semiconductor light emitting devices reveals that there is nothing new and nonobvious found in the challenged '225 patent claims. This section is supported by declaration of Dr. Dupuis. *See* Ex. 1002, ¶¶ 30-46. The information provided herein is information that would have been understood by the person of ordinary skill in the art and would have informed how such a person would have understood the references relied upon in the grounds presented in this Petition. Ex. 1002, ¶ 31.

A. Semiconductor light emitters

A light emitting diode, or LED, is the combination of an n-type semiconductor material (high electron concentration) and a p-type semiconductor material (high hole concentration) which form a p-n junction. Ex. 1008, p.351. When a voltage is applied across the diode's terminals current can flow through the LED. This causes electrons (negative charge carriers) and holes (positive charge carriers) to recombine near the p-n junction ideally producing light. *Id.*



The LED may be characterized by a bandgap energy—i.e., the "minimum energy required to excite an electron from the valence band to the conduction band . . . ." Ex. 1008, pp.352-353. The bandgap also determines the energy of a photon produced when an electron and hole recombine. *Id.*, p.353. Different semiconductor materials have different bandgaps as illustrated in the Figure at



right. *Id.*, p.353 (Fig. 3). The wavelength of light produced by an LED may be tuned by adjusting its composition. Ex. 1002, ¶ 33; Ex. 1021, p.3976 (AlGaInN bandgap composition and temperature dependent); Ex. 1024, 1:40-42 (relationship between bandgap and wavelength), 3:16-18 (changing indium concentration changes bandgap), 3:22-23 ("The bandgap of a gallium nitride based semiconductor is inversely related to the amount of In in the material."); Ex. 1032, p.415 ("The bandgap energy of AlInGaN varies from 1.95 eV to 6.2 eV, depending on its composition ratio.").

When the LED is biased, "electrons in the conduction band flow across the junction from the n-doped side, and holes in the valance band flow from the p-doped side" and this results in electrons and holes recombining at the junction between the p-doped and n-doped materials. Ex. 1008, p.353. Ideally, this recombination will produce a photon and thus light in a desired wavelength range.

B. Radiative and Non-Radiative Recombination

Electrons and holes don't always recombine to emit light in LEDs. Instead, they recombine in one of two ways. Ex. 1034, p.35. Radiative recombination produces a photon at a wavelength corresponding to the bandgap energy. Electrons and holes can recombine non-radiatively in which case the energy released by the recombination is converted to vibrational energy of lattice atoms thus producing heat. *Id.* Though undesirable, these recombinations can "never be reduced to zero," *id.*, pp.27, 35, 44. Defects in the semiconductor crystal structure resulting in the formation of energy levels that would otherwise be forbidden by the band gap and thus cause increases in non-radiative recombination. Ex. 1034, pp.35-36. One such defect is called a "dislocation." *See* Ex. 1002, ¶ 34.

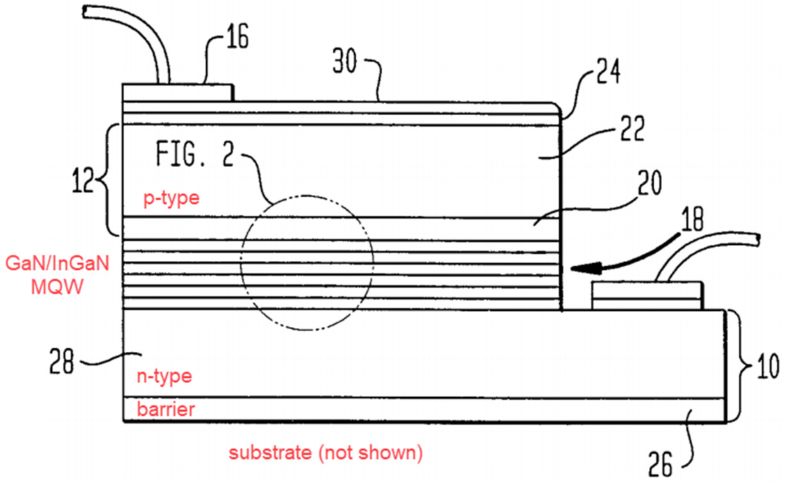
C. Nitride-Based LEDs

By the mid-1990's efficient blue light LEDs had been developed and commercialized. Ex. 1009, p.237 ("Nichia Chemical Industries have recently commercialized blue and green light-emitting diodes (LEDs) based upon InGaN quantum wells . . . ."); Ex. 1020, p.569 ("InGaN-based diodes are highly-efficient sources of visible light."); Ex. 1021, p.3976. These LEDs included a quantum well structure—either a single quantum well (SQW) or a multiple-quantum well (MQW). Ex. 1028, 1:24-2:15.

Blue LEDs are made from certain "III-V" semiconductor materials. This refers to the groups of elements found on the periodic table. Ex. 1028, 3:8-12. Group III elements include gallium (Ga), aluminum (Al), and indium (In); Group V elements include nitrogen (N), phosphorous (P), and arsenic (As). *Id.* Gallium nitride-based semiconductors exhibited excellent properties and had become widely adopted by the mid-2000's. Ex. 1010, p.3666 ("Group-III nitride semiconductors have led to high efficient quantum well (QW) structure light emitting diodes (LEDs) operating in the blue-green region of the spectrum . . . .");

Ex. 1012, p.1 (“InGaN/GaN multiple quantum wells are the key components of these commercial devices . . . .”); Ex. 1014, p.4300 (“InGaN is currently the primary material used as the active layer in high brightness optoelectronic devices such as light emitting diodes . . . .”); Ex. 1015, p.1 (“In the last decade, GaN has become one of the most important materials for optoelectronic devices.”); Ex. 1018, p.298; Ex. 1021, p.3976.

An exemplary nitride-based LED is shown in Figure 1 of WO 00/30178. The various parts of this LED are labeled in the diagram below consistent with the teachings of that reference. Ex. 1028, 9:15-11:5, Fig. 1 (right, annotated). The multiple quantum well structure (18) can include barrier layers formed of “pure GaN” and can include well layers that “have an average or overall composition according to the formula $In_yGa_{1-y}N$ such that y is greater than x and hence y is greater than 0,” and typically “between about 0.05 and 0.9.” Ex. 1028, 10:23-11:5.



D. Dislocations and Quantum Dots

When a III-V semiconductor is formed with an InGaN material in the active layer, there is a "large number of threading dislocations (TD) . . . that originate from the interface between GaN and the sapphire substrate due to a large lattice mismatch. . . ." Ex. 1013, p.957; *see also* Ex. 1010, p.1 ("InGaN heterostructures can exhibit intense photoluminescence (PL) and electroluminescence (EL) despite of a [sic] high dislocation and defects density . . . ."); Ex. 1021, p.3976. Because dislocations lead to deleterious non-radiative recombinations, one might think that these semiconductor materials would be a poor choice for a light emitting device. But, that was not the case for nitride-based semiconductors made of InGaN. Instead, these devices produced efficient light emitting devices notwithstanding the defects. Ex. 1002, ¶¶ 38-39. By the late 1990's researchers sought to discover why.

The general conclusion involved the presence of indium-rich regions within the InGaN layer, which were often referred to as "quantum dots." Ex. 1009, p.238 ("These quantum dots provide highly efficient centers for radiative recombination of excitons, free from the deleterious effects of the numerous dislocations present."); Ex. 1014, p.4300 ("Carrier localization has been widely observed in InGaN quantum wells . . . [E]xcitions are confined to potential minima, such as InGaN quantum discs [6] or dots [7, 8], formed by indium fluctuation resulting from solid phase immiscibility in InGaN QWs, before being captured by nonradiative recombination centres."); Ex. 1015, p.1 ("The high efficiency of these devices has been attributed to the localization of charge carriers in potential traps due to compositional inhomogeneities of the InGaN layers."); Ex. 1016, p.2988 ("In many articles it was proposed that nanoscale indium composition fluctuations, due to indium aggregation of phase separation, acted as quantum dots (QDs) in optical characteristics.[] In the QDs carriers are deeply localized and their migration toward nonradiative defects (dislocations) is hindered."); Ex. 1023, 12:34-39 (discussing formation of "indium-rich" and "indium-poor" regions that can localize electron and hole carriers). As one 1998 article explained:

> The localization induced by the In composition fluctuations seem to be a key role of the high efficiency of the InGaN-based LEDs. When the electrons and holes are injected into the InGaN active layer of the LEDs, these carriers are captured by the localized energy states before they are captured by the nonradiative recombination centers caused by the large number of dislocations.
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> *****
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> [H]igh-power UV LEDs can be obtained only when using the InGaN active layer instead of the GaN active layer. Tis difference is probably related to the deep localized energy states caused by the In composition fluctuations of the InGaN active layer due to a phase separation during growth . . . . Without In in the active layer, there are no In composition fluctuations that form the deep localized energy state in the InGaN active layer.

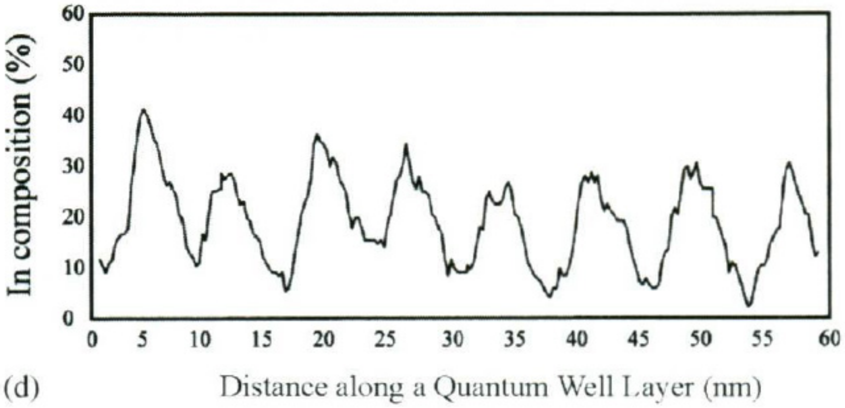
Ex. 1013, p.959; *see also* Ex. 1010, p.3666 (demonstrating that "the blue-green below-band-gap photoluminescence (PL) from the *c*-InGaN is directly related to In-rich separated phases in the alloy" and describing investigations that "are essential to clearly establishes the role of In-rich separated phases (QDs) in the luminescence emission mechanism").

Indium-rich clusters within the quantum well layer are believed to play an important role in the efficient emission of light from nitride-based LEDs. And, if the density of quantum dots was higher than the dislocation density, high luminescence efficiency is expected. Ex. 1016, p.2988; Ex. 1002, ¶ 39.

As a consequence of the advantages provided by InGaN and AlInGaN systems, these semiconductors have received extensive study by those skilled in the art. *See generally* Ex. 1010, p.3666, Ex. 1012, p.1; Ex. 1014, p.4300; Ex. 1015, p.1; Ex. 1016, p.7790; Ex. 1018, p.298; Ex. 1021, p.3976; Ex. 1033, p.183507-1 (discussing "progress in GaInN light-emitting diodes"); Ex. 1051, p.3881; *see also* Ex. 1002, ¶¶ 37-39.

E. Indium Composition And Bandgap Energy Within Quantum Dots

After these discoveries were made between the mid-1990s and early 2000s, those in the field continued to investigate the structures and quantum mechanical behaviors of InGaN-based light emitting devices. For example, in a paper to Lin et al. the authors observed that "[s]ize and distribution of indium-rich quantum dots (QDs) are important parameters for improving photon emission efficiency of InGaN/GaN quantum well (QW) structures." Ex. 1025, p.35. Lin then provides a plot showing the distribution of indium along an InGaN quantum well annealed at 900°C. As can be seen here, the indium concentration varies from the outer edges of the quantum dots to the centers. *Id.* (Fig. 2(d)) (at right); Ex. 1002, ¶ 40. The variation of indium along a quantum well strucutre was also reported in an article by Gerthsen, et al. Gerthsen provides "the



results of the analysis of an InGaN/GaN QW structure, which contains 5 InGaN layers separated by 5nm GaN spacers." Ex. 1035,[3] p.1673. The following "color-coded map" which shows "a strongly inhomogeneous In distribution in all QWs," along with "small In-rich clusters with lateral extensions below 4 nm, which are present at an extremely high density." *Id.*, pp.1673-1674. This map confirms what Lin showed—i.e., that within the quantum dots themselves, there is a variation in the indium content, with more indium being concentrated near the center of the quantum dot and decreasing outwardly from the center.

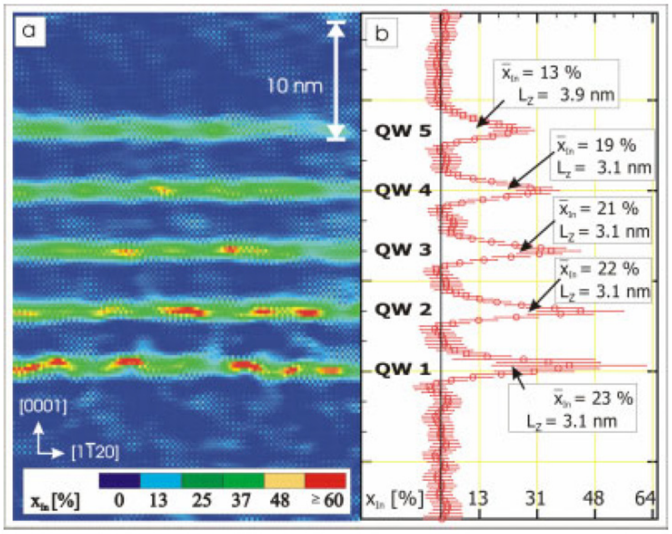


Fig. 4 a) Color-coded map of the In distribution of an InGaN/GaN multiple QW structure and b) averaged In concentration along the [11$\bar{2}$0] direction plotted as a function of the (0002)-plane. number.

The indium distribution within quantum dots was further discussed in Li,

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[3] The record includes two copies of Gerthsen: one which was obtained from a library, and one which was obtained from the Internet. *See* Exs. 1026 & 1035; *see also* Ex. 1054, ¶¶ 150-156. They are substantively the same, but the reproduction of the figures is slightly better in Ex. 1035 since it is not a photocopy. The citations to Exs. 1026 and 1035 are interchangeable throughout this petition.

which focused on developing a technique "for chemical analyses with atomic-scale spatial resolution," which was "particularly desirable for the study of InGaN epitaxial layers due to the small dimension of the clusters and quantum wells." Ex. 1015, p.1; Ex. 1043, p.1.[4] Li shows an image of an InGaN quantum-well and "a color-coded map of the local In concentration form the region imaged in Fig. 1(a)." *Id.*, p.2. The maximum indium concentration is plotted in Fig. 2(c). *Id.*, p.2.

Fig. 1 (Ex. 1015)

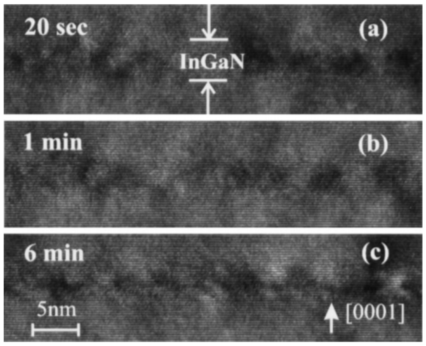
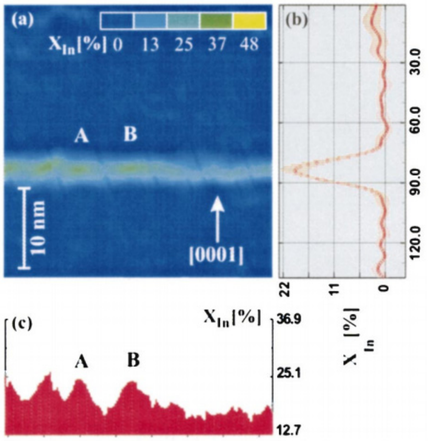


Fig. 2 (Ex. 1015)



As can be seen from the plot in Fig. 2(c), the indium concentration within the quantum dots exhibits a behavior that corresponds well to the distribution reported by Lin and Gerthsen. Ex. 1002, ¶¶ 41-42; Ex. 1015, Fig. 2(c); Ex. 1025, Fig. 2(d); Ex. 1026, Fig. 4(a); Ex. 1035 (same). A 2006 publication by Feng et al. confirms that the distribution of indium in quantum dots formed in InGaN layers is not

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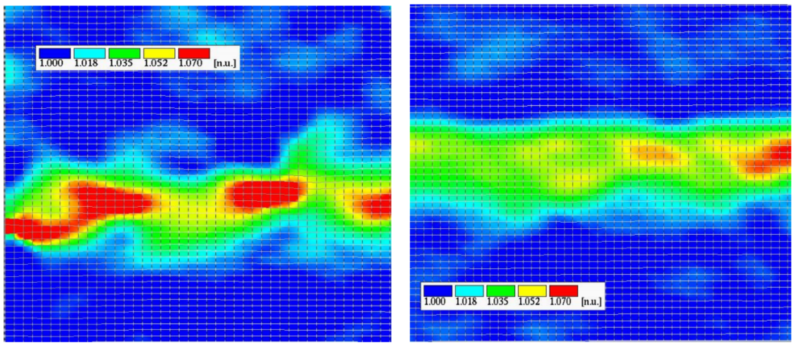
[4] Ex. 1015 is a paper copy retrieved from a library and Ex. 1043 is the digital version. Ex. 1054, ¶¶ 89, 93.

uniform:



(a) QW1

(b) QW5

Ex. 1012, Fig. 13, p.9 ("color-coded map of the local In concentration in this InGaN/GaN MQW structure containing 5 InGaN well layers" showing "quantum dot (QD)-like structures around the In-rich areas . . . which is the cause of strong luminescence from InGaN/GaN MQWs"). A 2002 publication from Gleize, et al. presented yet another effort to characterize the indium distribution within the indium rich regions of an InGaN quantum well. Ex. 1018, 299-300. As shown in Gleize, the concentration of indium rises from the edge to the center of the quantum dot. Ex. 1037,[5] Figs. 1 & 2 (annotated to add highlighting and

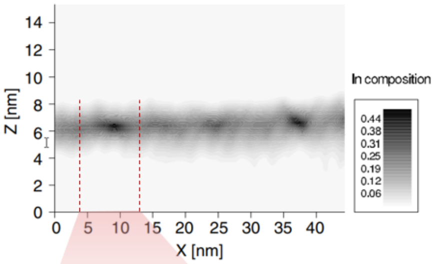


Fig. 1. Indium concentration profile in the InGaN quantum well. The nominal In concentration is about 15%

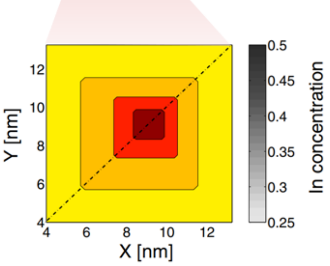


Fig. 2. (online colour). In concentration profile of the median (0001) plane of the QW (corresponding to the left indium rich region of Fig. 1). The concentration values obtained from HRTEM measurements (dot-dashed line) are projected onto primitive axes in the (0001) plane to recover the full concentration profile (an orthogonal set of axis is used here for convenience)

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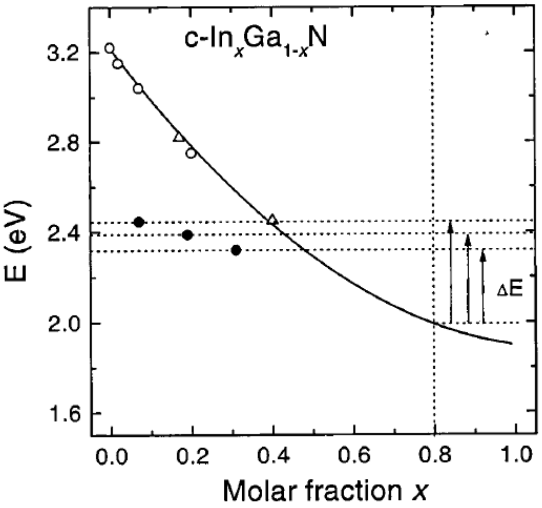
[5] The record includes two copies of Gleize: one which was obtained from a library,

dashed red lines).

Given the known impacts that changing the content of indium had on the bandgap, those skilled in the art knew that increasing indium content meant lowering bandgap energy, thus an increase of indium content in a quantum dot marked a corresponding decrease in bandgap energy as shown, for example, in Fig. 2 of Ex. 1010 (right). *See, e.g.*, Ex. 1002, ¶¶ 33, 40, 46; Ex. 1010, p.3668 & Fig. 2; Ex. 1031, Fig. 7 & 19:30-45. This observation had been made time and again before the earliest claimed effective filing date of the ’225 patent.



III. PERSON OF ORDINARY SKILL IN THE ART

A POSA as of the earliest claimed effective filing date of March 6, 2009 would have had at least a Master’s Degree in chemical engineering, materials engineering, or electrical engineering (with a focus on semiconductor materials), or similar advanced post-graduate education in this area, with roughly two years of

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and the other is the online version. *See* Exs. 1018 & 1037; *see also* Ex. 1054, ¶ 118. The online version included certain figures in color. Ex. 1018, p.300 (Fig. 2 (caption)); Ex. 1037, p.300 (same).

experience in researching nitride-based light emitting devices. *See, e.g.*, Ex. 1002, ¶ 27; Ex. 1001, 1:16-21 (describing the "field" of the invention as relating to "a light emitting device that include at least one carrier trap portion in at least one layer within a multi-quantum well structure"). A person with less education but more relevant practical experience, depending on the nature of that experience and degree of exposure to nitride-based light emitting semiconductor materials and their chemistry and physics, could also qualify as a person of ordinary skill in the field of the '225 patent. Ex. 1002, ¶ 27.

IV. CLAIM CONSTRUCTION

In this proceeding, claim terms are construed according to their ordinary and customary meaning as understood by a POSA in light of the specification and the prosecution history. 37 C.F.R. § 42.100(b); *Phillips v. AWH Corp.*, 415 F.3d 1303 (Fed. Cir. 2005). With the exception of the phrases construed below, which Petitioner addresses for the purposes of this proceeding, the claim language should be given its ordinary sand well-understood meaning as understood by those of skill in the art. Petitioner presents these constructions without waiver of its ability to present other terms for construction should they be germane to resolving other issues arising in district court proceedings.

A. "carrier trap portion[s]" (claims 1-12 and 15-19)

The term "carrier trap portion[s]" is found in clams 1-12 and 15-19 of the

’225 patent. The ’225 patent defines this term in the following passage:

> Herein, the carrier trap portion 27 refers to a structure capable of using carriers which can be trapped and lost by the dislocations. Such a structure is not limited to a physical shape. In other words, according to embodiments of the invention, a carrier trap portion 27 may be a physical shape or a quantum-mechanical energy state capable of efficiently using carriers which can be trapped and lost by the dislocations.

Ex. 1001, 4:40-47. This passage is a definition that governs the meaning of “carrier trap portion” in the claims of the ’225 patent. *See Martek Biosciences v. Nutrinova*, 579 F.3d 1363, 1379 (Fed. Cir. 2009) (“When a patentee explicitly defines a claim term in the patent specification, the patentee’s definition controls.”). A POSA would have understood that “quantum-mechanical energy state[s] capable of efficiently using carriers which can be trapped and lost by the dislocations” are often called “quantum dots” in the literature. *See, e.g.*, Ex. 1002, ¶ 67 (citing Ex. 1010, p.3668; Ex. 1016, p.2988; Ex. 1019, p.1); *supra* §II.D.

B. “multi-quantum well structure” (claim 1)

There are problems with the way that the “multi-quantum well structure” is recited in claim 1. According to the claim, a “multi-quantum well” only need comprise “at least one well layer and at least one barrier layer.” Ex. 1001, 6:48-48. There are two problems with the way that the claim is written. First, by its terms a *multi*-quantum well needs more than "one well layer," and thus the phrasing "at least one well layer" is ambiguous. Second, a multi-quantum well structure must have more than one barrier layer. This problem with the claim was noted by the European Patent Office, *see* Ex. 1029, p.2 ("[I]t is unclear whether the scope of said claim is intended to comprise single quantum well structures, multi- quantum well structures or both types of structures."); *see also* Ex. 1030, pp.2-3 ("[A] multi-quantum well structure by definition has a plurality of well and barrier layers."); Ex. 1002, ¶ 69.

Notwithstanding this problem with the claim language, the grounds for unpatentability presented herein all rely on multiple quantum well structures with multiple wells and multiple barriers and thus are clearly within the scope of the claims. Further resolution of the ambiguity discussed above is unnecessary for the purposes of this proceeding.

V. OVERVIEW OF THE CHALLENGE AND RELIEF REQUESTED

Pursuant to Rule 42.22(a)(1) and 42.104(b)(1)-(2), Petitioner challenges claims 1, 4-7, 10-11, and 16-19 of the '225 patent on the following grounds:

Ground	Claim(s)	Pre-AIA Statute	Prior Art Patents/Publications
1	1, 4-7, 10-11, 17-19	102(b)	Lin, *et al.*, *Effects of post-growth thermal annealing on the indium aggregated structures in InGaN/GaN quantum wells*, J. of Crystal Growth, Vol. 242, pp.35-40 (2002) ("Lin") (Ex. 1025).
2	4	103(a)	Lin in view of P. Schley, et al., *Dielectric function and Van Hove singularities for In-rich InxGa1-xN alloys: Comparison of N- and metal-face materials*, Physical Review Letters B, 205204 (2007) ("Schley") (Ex. 1055)
3	16	103(a)	Lin in view of Lin, et al., *Dependence of composition fluctuation on indium content in InGaN/GaN multiple quantum wells*, Appl. Phys. Lett., Vol. 77, No. 19 (Nov. 6, 2000) ("Lin II") (Ex. 1016).
4	1, 5-7, 10-11, 17-19	102(b)	Gerthsen, *Indium distribution in epitaxially grown InGaN layers analyzed by transmission electron microscopy*, phys. Stat. sol (c) Vol. 0, No. 6, pp.1668-1683 (2003) ("Gerthsen") (Ex. 1026).
5	16	103(a)	Gerthsen in view of Lin II

VI. THE GROUNDS FOR TRIAL ARE BASED ON PRIOR ART PRINTED PUBLICATIONS

A. Lin

Lin appeared in the 242nd volume of the *Journal of Crystal Growth*, dated

July 2002. Ex. 1025, p.35; Ex. 1054, ¶ 149. A POSA would have been aware of the *Journal of Crystal Growth*. Ex. 1002, ¶ 72. Lin bears a 2002 copyright date. Ex. 1025, p.35. A MARC record indicates that Linda Hall Library has received the *Journal of Crystal Growth* since 1967 and continues to do so to this day. Ex. 1054, ¶¶ 150, 152. Based a physical examination of a copy of the article retrieved from the Linda Hall Library shows it was received on July 16, 2002 and it would have been available at the Linda Hall Library "on or shortly after July 16, 2002." *Id.*, ¶ 152; Ex. 1025, cover, title page. MARC records also show a copy of this volume of the *Journal of Crystal Growth* was received at the University of Minnesota Library, Ex. 1054, ¶ 153, and was cataloged by subject matter, *id.*, ¶ 154. This journal was accessible to anyone with access to the OCLC bibliographic database or the online catalog that subscribed to the publication. *Id.* The *Journal of Crystal Growth* was also listed in "several well-known indices" pertaining to electronics, physics, and materials. *Id.*, ¶ 156. Lin is also cited in a number of publications showing that those skilled in the field had actually revived a copy of Lin. Ex. 1036, p.1373 (reference 10); Ex. 1041, p.23 (reference 23); Ex. 1042, p.985 (reference 7). Lin was both publicly accessible and distributed well before the critical date, making it prior art under pre-AIA 35 U.S.C. §§ 102(a), (b).

B. Lin II

Lin II appeared in the 77th volume of *Applied Physics Letters*, a journal published by the American Institute of Physics, a journal familiar to those skilled in the art. Ex. 1002, ¶ 76; Ex. 1016, p.2988; Ex. 1054, ¶ 101. Lin II bears a copyright date of 2000, and it appeared in the November 6, 2000 issue of *Applied Physics Letters*. Ex. 1016, p.2988; Ex. 1054, ¶ 101. MARC records show that the relevant issue and volume of *Applied Physics Letters* was received in the Physics Library at the University of Wisconsin—Madison "on or shortly after November 9, 2000," Ex. 1054, ¶¶ 103-104, and the Library of Congress "as early as July 6, 2005," *id.*, ¶ 106. A MARC record associated with the Library of Congress shows it was cataloged by subject matter. *Id.*, ¶ 106. And, this journal was included in *Chemical Abstracts*, a well-known index. *Id.*, ¶ 106. Lin II was cited by other authors many times before 2009, showing that it was distributed to and accessible by those skilled in the art. *See* Exs. 1044, p.217 (ref. 12); 1045, p.4447 (ref. 3); 1046, p.2573 (ref. 3); 1047, p.5451 (ref. 17). Lin II was therefore publicly accessible and distributed by May 31, 2003 and as such qualifies as prior art under pre-AIA 35 U.S.C. §§ 102(a), (b).

C. Gerthsen

Gerthsen appeared in the inaugural volume (0th) of *Physica Status Solidi c*, referred to herein as "PSSc." Ex. 1054, ¶¶ 157-159; Ex. 1026, p.1668; Ex. 1035, p.1668. PSSc would have been known to the POSA. Ex. 1002, ¶ 74. Gerthsen indicates that it was published online on April 23, 2003, and bears a copyright date of 2003. Ex. 1026, p.1668; Ex. 1035, p.1668. A copy of Gerthsen was located at the Physics Library at the University of Wisconsin—Madison. Ex. 1054, ¶ 158. MARC records show that the issue and volume of PSSc was received in the Linda Hall Library and entered into their catalog by April 11, 2003. Ex. 1054, ¶¶ 159-160. It was also entered into the catalog at the University of Texas Austin Libraries by January 15, 2004, and was cataloged by subject matter as of that date. *Id.*, ¶¶ 161-162. Gerthsen was thus "publicly available no later than April 11, 2003 . . . ." *Id.*, ¶ 163. Gerthsen was cited by an article published in IEEE Photonics Technology Letters in 2006. Ex. 1050, p.1602 (ref. 10). Gertnsen was therefore publicly accessible by at least April 2003 and was distributed by 2006; as such it qualifies as prior art under pre-AIA 35 U.S.C. §§ 102(a), (b).

D. Schley

Schley appeared in the May 2007 edition of the journal *Physical Review B*, *Condensed Matter*. Ex. 1055, cover page; Ex. 1054, ¶ 227. The copy submitted as Exhibit 1055 with this Petition was obtained from the Science Library at the University of Wisconsin—Madison. *Id.* This version of Schley was available to the public by June 26, 2007. Ex. 1054, ¶ 230. Furthermore, MARC records show that the issue and volume of *Physical Review B* in which Schley appeared was received by the library in which it was located since 1978 until publication ceased in 2015. Ex. 1054, ¶ 228, 230. Schley was also cataloged in MARC records by the University of Washington Libraries, and was cataloged there by subject matter. Ex. 1054, ¶¶ 231-232. This journal was also included in *Chemical Abstracts*, a well-known index. *Id.*, ¶ 234. Moreover, POSAs were familiar with *Physical Review B*. Ex. 1002, ¶ 78. As further evidence of actual distribution of Schley, Schley was cited by others in works from 2008. Ex. 1048, p.245207-6 (reference 4); Ex. 1049, p.115120-8 (reference 38). Therefore, Schley would have been publicly accessible more than one year before the earliest effective filing date of the '225 patent and it qualifies as prior art under pre-AIA 35 U.S.C. §§ 102(a), (b).

VII. DETAILED DISCUSSION SHOWING CLAIMS 1, 4-7, 10-11, AND 16-19 ARE UNPATENTABLE

A. Ground 1: Claims 1, 4-7, 10-11, and 17-19 Are Anticipated by Lin

1. Claim 1

a. [1P] "A light emitting device, comprising:"

Without regard to whether the preamble limits claim 1, Lin explains that "[s]ize and distribution of indium-rich quantum dots (QDs) are important parameters for improving *photon emission* efficiency of InGaN/GaN quantum well structures." Ex. 1025, p.35 (emphasis added). A POSA would have understood that this reference to "photon emission" refers to a device that emits light because photons are the fundamental unit of light. Ex. 1002, ¶ 82. Lin also refers to achieving "optimum performance of a practical device," Ex. 1025, p.35, which refers to Lin's light emitting device, Ex. 1002, ¶ 82.

b. [1A] "a substrate;" [1B] "a first semiconductor layer on the substrate," and [1C]"a second semiconductor layer on the first semiconductor layer,"

These three limitations—***the substrate***, the ***first semiconductor layer***, and the ***second semiconductor layer***—are all taught by Lin.

Lin explains that for the sample used in the described study, quantum well (QW) layers were "sandwiched between [1B] ***a 1.5 µm GaN buffer layer*** on [1A] ***a (0001) sapphire substrate*** and [1C] ***a 50 nm GaN cap layer***." Ex. 1025, p.36 (emphasis and color added). Lin, therefore, teaches each of these limitations as required by claim 1. Ex. 1002, ¶¶ 83-85. GaN is a semiconductor material, and the "cap" is on the barrier layer,[6] above the quantum well as required by claim 1. *Id.*, ¶¶ 84-85.

c. [1D] "a multi-quantum well structure comprising at least one well layer and at least one barrier layer between the first and second semiconductor layers . . . ."

Lin explains that "the QW layers were sandwiched" between the first and second semiconductor layers as explained with respect to the preceding limitations. These "QW layers" are further defined in Lin: "The InGaN/GaN QW sample consisted of ten periods of InGaN wells with 35 Å in thickness." Ex. 1025, p.36.

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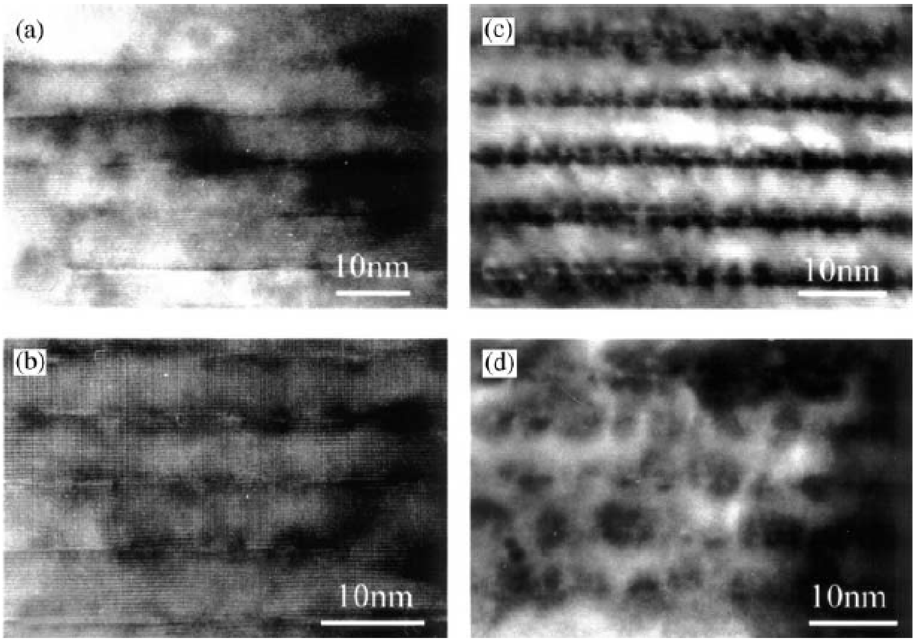
[6] As claim 1 makes clear by positioning the MQW structure between the first and second semiconductor layers, "on" does not mean "directly on." Ex. 1002, ¶ 85.

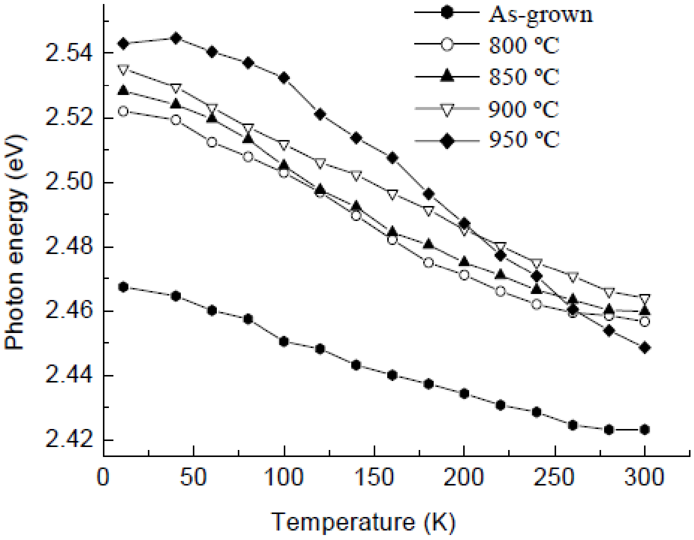
"Ten periods" of alternating InGaN/GaN "sandwiched" between the two semiconductor layers described above constitute a "multi-quantum well structure" that has "at least one well layer" (*i.e.*, the InGaN) and "at least one barrier layer" (*i.e.*, the GaN). Ex. 1002, ¶ 86.

d. [1E] "at least one layer within the multi-quantum well structure comprising at least one carrier trap portion formed therein . . ."

Lin teaches that "at least one layer within the multi-quantum well structure"—namely the InGaN well layers—comprise "at least one carrier trap portion formed therein," as required by claim 1. Specifically, Lin provides the following HRTEM images of the samples tested:



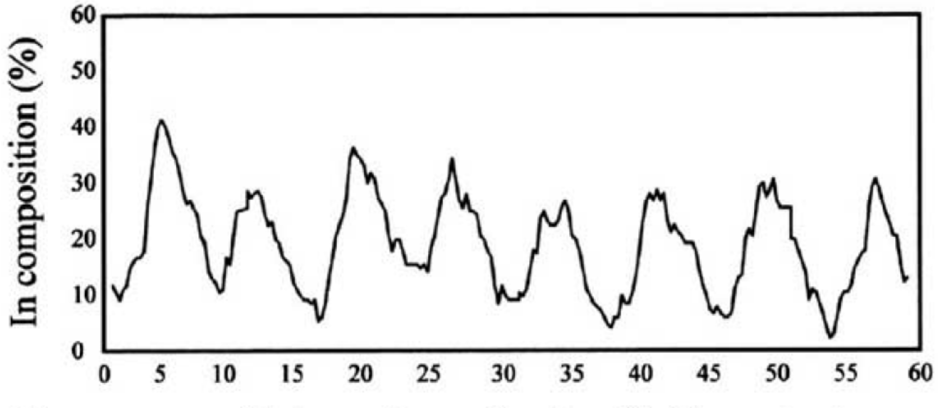
Ex. 1025, p.37. "The variations of the contrast in the pictures represent the fluctuations of indium composition." *Id.*, p.36. "The average size of the disk-like indium-rich clusters is larger than 10nm," and annealing led the clusters to "become sphere-like shaped" and to have a smaller size. *Id.*, p.37. For example, after annealing at 900°C (Fig. 1(c) in Lin, above), "one can observe that fine indium-rich QDs with size 2-5 nm were regularly distributed within the designated InGaN QW layers . . . ." *Id.*, p.37.



This regular distribution of quantum dots within the InGaN well layer describes a number of "carrier trap portions" within the layer. Ex. 1002, ¶¶ 89-90. This is further demonstrated by Lin's findings that thermal annealing results in a higher concentration in well-defined quantum dots, Ex. 1025, p.37, coupled with the observation that the thermal annealing led to an *increase* in the bandgap or photon energy (described as a "blue shift" in the resulting emission spectrum), *id.*, p.39. Lin's Figure 5 (at right) shows this. *Id.*, p.39. Lin explains that this "blue shift[] can be attributed to the stronger quantum confined effect with smaller sizes of QDs." Ex. 1025, p.39. Thus, Lin teaches that the quantum dots define quantum mechanical energy states that cause changes in the bandgap energy—and photon wavelength/energy—such that the quantum dots "can trap carriers for photon emission and reduce non-radiative recombination rate." Ex. 1025, pp.35, 39; Ex. 1002, ¶ 89. Thus, Lin teaches that the quantum dots in the well layer constiute "carrier trap portions" as that term is used in the '225 patent. Ex. 1002, ¶¶ 38-39 (explaining how disclocations cause "non-radiative recombination" and how quantum dots were known to suppress such non-radiative recombinations); *id.*, ¶ 90; *see also supra*, § II.D.

e. [1F] "the at least one carrier trap portion having a band-gap energy decreasing from a periphery of the carrier trap portion to a center of the carrier trap portion."

Lin's quantum dots have a band-gap energy that decreases from a periphery of the quantum dot (where the concentration of indium is lower) to the center of the quantum dot (where the concentration of indium is higher). Ex. 1002, ¶¶ 91-93. As explained above, Lin's quantum dots are "carrier trap portion[s]." *Supra* § VII.A.1.d. The distribution of indium within the indium-rich quantum dots for the sample annealed at 900°C is shown in the graph below:



Ex. 1025, p.38 (Fig. 2(d)). As can be seen from this graph, the indium concentration increases from one minima to a maxima and then returns to an adjacent minima periodically. A POSA reviewing this graph would have understood that the center of each of the quantum dots is defined by the point with a maximum indium composition. Ex. 1002, ¶ 92. On either side of each maxima, the concentration of indium decreases until it hits a local minima. *Id.*, ¶ 91. Therefore, regardless of where the precise bounds of carrier trap portion are defined—something that the ’225 patent says need not have “a physical shape,” Ex. 1001, 4:42-47—a POSA would have recognized that the indium concentration *increases* from the outer periphery of the carrier trap portion to the maxima for each quantum dot. Ex. 1002, ¶ 92; Ex. 1025, p.38 (Fig. 2(d)).

Because the concentration of indium *increases* from the outer periphery of the carrier trap portion to the center, the bandgap energy *decreases* given the inverse relationship between indium concentration and bandgap energy. Ex. 1002, ¶¶ 33, 40, 46, 93. This principle is reflected in the fact that smaller quantum dots achieved by annealing at 900°C resulted in “blue shifts,” which shows that the distribution of indium reduces the bandgap energy. Ex. 1025, p.39 & Fig. 5; Ex. 1002, ¶ 89; *see also* Ex. 1010, p.3668 & Fig. 2; Ex. 1031, Fig. 7 & 19:30-45 (“[I]ncreasing the indium composition ratio decreases the bandgap.”); *supra* § II.D. Therefore, because Lin teaches that the indium concentration increases within the carrier trap portion, Lin teaches that the bandgap energy decreases from the periphery of the carrier trap portion to its center. Ex. 1002, ¶¶ 91-93.

2. *Claim 4*

Lin teaches that the light emitting device of claim 1 wherein the "carrier trap portion has a band-gap energy decreasing in a curved line shape from a periphery of the carrier trap portion to a center of a carrier trap portion," as required by claim 4. Ex. 1001, cl. 4. This would have been apparent to a POSA based on Figure 2(d) of Lin because the POSA knew of the inverse relationship between indium content and bandgap energy in InGaN. *See* Ex. 1002, ¶ 137. As shown in Fig. 2(d), the indium concentration varies periodically throughout the quantum well layer of the sample. But, this figure does not show the resulting bandgap energies of the different portions of the sample. Calculating these values would have been within the level of a POSA, as reflected by equation 8 disclosed in Schley.[7] That equation relates the bandgap energies of InN and GaN, the concentration of indium, and a bowing parameter, *b*. Ex. 1055, pp.205204-5 to 205204-6. Specifically, Schley discloses the following equation:

$$E_{CP} = xE_{CP,InN} + (1-x)E_{CP,GaN} - bx(1-x)$$

Ex. 1055, p.205204-5 (eqn. 8). Here, *b* is the bowing parameter, $E_{CP,InN}$ is the

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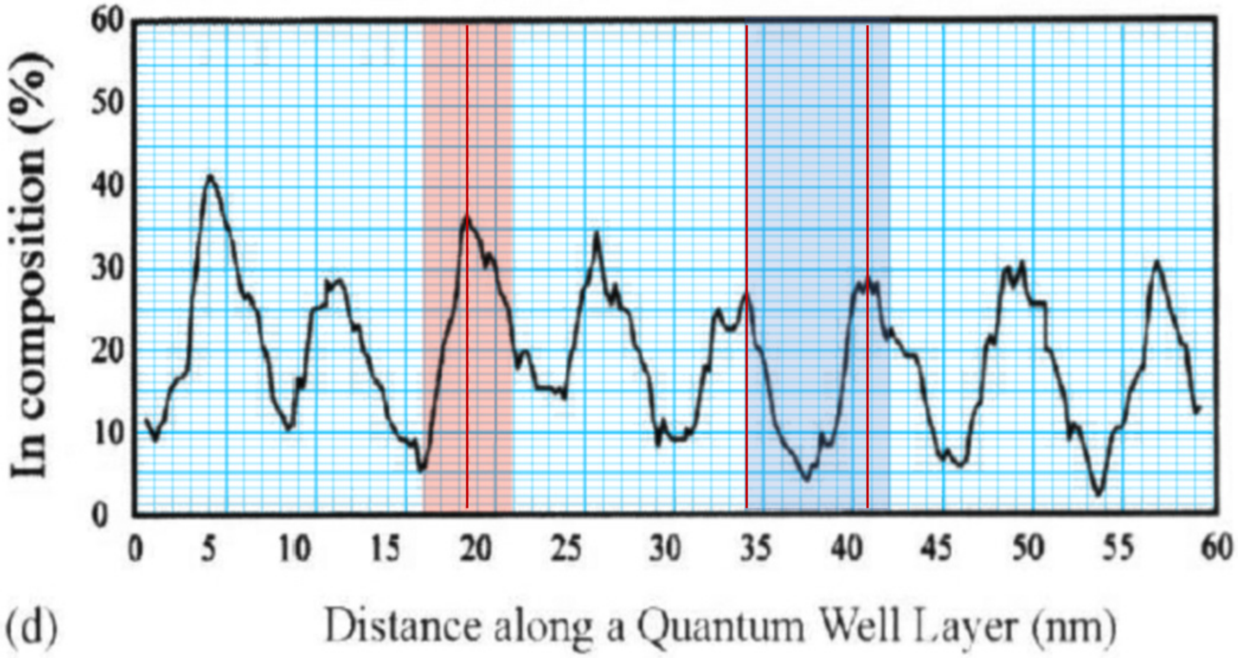
[7] Schley is provided to explain how a POSA would have understood the teachings of Lin.

bandgap energy for pure InN, $E_{CP,GaN}$ is the bandgap energy for pure GaN, and x is the indium concentration from the expression $In_xGa_{1-x}N$. *Id.*; *see also* Ex. 1002, ¶ 139, 141. Schley also provides the following values: (1) b = 1.72 eV, (2) $E_{CP,GaN}$=3.422 eV, and (3) $E_{CP,InN}$=0.68 eV. *See* Ex. 1055, p.205204-5 (providing a "free excitonic transition energy" of 3.422 eV for GaN at room temperature (300K)); *id.*, p.205204-6 (providing for a bowing parameter (b) of 1.72 eV and a value for the bandgap of pure InN of 0.68 eV); Ex. 1002, ¶ 141.

A POSA would have been able to derive the bandgap energies for the ranges shown below based on the teachings of Lin. Here, the red band corresponds to a first quantum dot or carrier trap portion having a size of 5 nm, and the blue band corresponds to an entire period for the variation of indium content and reflects at least parts of two carrier trap portions. Ex. 1002, ¶ 140. The red line indicates the location of maximum indium content of each carrier trap (and thus the location of bandgap minimum). *Id.*



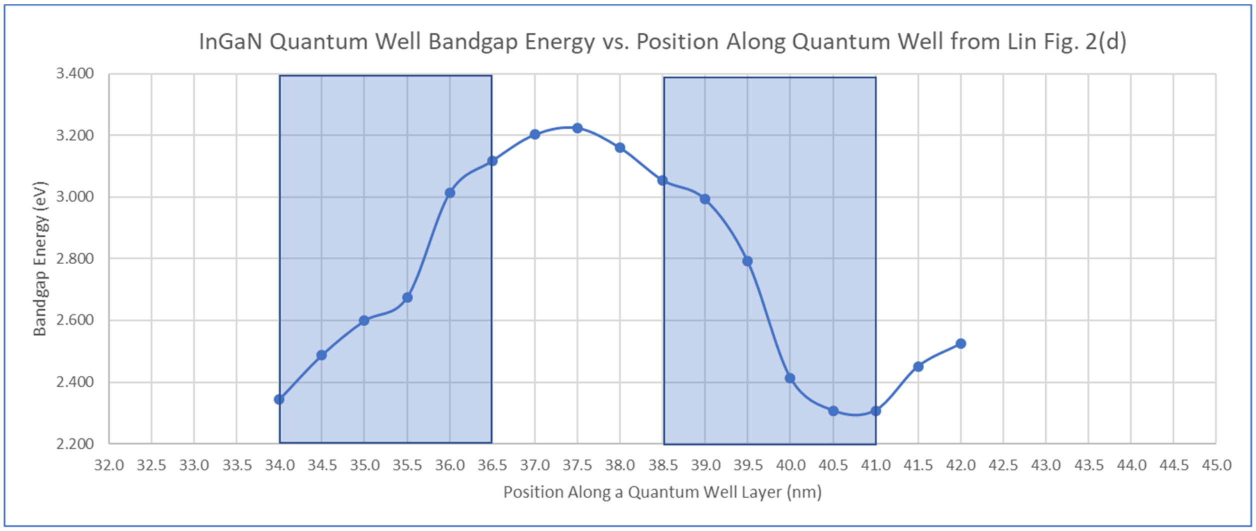
Ex. 1025, p.38 (annotated); Ex. 1002, ¶ 140.

Dr. Dupuis estimated the values of indium concentration along the quantum well distance for the red and blue bands and then calculated the values for expressions in Schley's equation 8. Ex. 1002, ¶ 141. He arrived at the following values.

Dist. (nm)	% In, x	$1-x$	$bx(1-x)$	xE_g(InN)	$(1-x)E_g$(GaN)	Bandgap (eV)
16.0	0.055	0.945	0.089	0.0374	3.232	3.1804
16.5	0.1	0.9	0.155	0.068	3.08	2.993
17.0	0.165	0.835	0.237	0.112	2.858	2.733
17.5	0.23	0.77	0.305	0.156	2.635	2.486
18.0	0.275	0.725	0.343	0.187	2.48095	2.32495
18.5	0.365	0.635	0.399	0.248	2.17297	2.02197
34.0	0.270	0.730	0.339	0.184	2.498	2.343
34.5	0.230	0.770	0.305	0.156	2.635	2.487
35.0	0.200	0.800	0.275	0.136	2.738	2.598
35.5	0.180	0.820	0.254	0.122	2.806	2.675
36.0	0.095	0.905	0.148	0.065	3.097	3.014

Dist. (nm)	% In, x	1-x	$bx(1-x)$	xE_g(InN)	$(1-x)E_g$(GaN)	Bandgap (eV)
36.5	0.070	0.930	0.112	0.048	3.182	3.118
37.0	0.050	0.950	0.082	0.034	3.251	3.203
37.5	0.045	0.955	0.074	0.031	3.268	3.225
38.0	0.060	0.940	0.097	0.041	3.217	3.160
38.5	0.085	0.915	0.134	0.058	3.131	3.055
39.0	0.100	0.900	0.155	0.068	3.080	2.993
39.5	0.150	0.850	0.219	0.102	2.909	2.791
40.0	0.250	0.750	0.323	0.170	2.567	2.414
40.5	0.280	0.720	0.347	0.190	2.464	2.307
41.0	0.280	0.720	0.347	0.190	2.464	2.307
41.5	0.240	0.760	0.314	0.163	2.601	2.450
42.0	0.220	0.780	0.295	0.150	2.669	2.524

Based on these values, a POSA would readily have seen that the profile of the bandgap energy from the center to the periphery of the carrier trap portions taught in Lin (and depicted in Figure 2(d)) declines in a "curved line shape" as recited in claim 4. For example, for the region between 34.0 nm and 42.0 nm, the plot of the bandgap energy is:



Ex. 1002, ¶ 143. Here, the blue bands represent 2.5 nm extending from the center of a carrier trap to the maximum potential periphery disclosed in Lin. *See* Ex. 1002, ¶ 144; Ex. 1025, p.37 ("one can observe that fine indium-rich QDs with size 2-5 nm were regularly distributed within the designated InGaN? QW layers"). As can be seen from this figure, a curved line shape extends from the point that is 34 nm along the quantum well (corresponding to a point of maximum indium concentration) to its periphery. And, a curved line shape can be seen extending from 41 nm, a point that corresponds to a maximum indium concentration for another carrier trap portion to its periphery. Therefore, a POSA would have understood Lin to teach claim 4. Ex. 1002, ¶ 144.

3. Claim 5

Lin teaches that the "carrier trap portion is formed in the well layer within the multi-quantum well structure," as required by claim 5. Ex. 1001, cl.5. Lin teaches that after annealing treatment at 900°C, "fine indium-rich QDs with size 2-5 nm" were "regularly distributed ***within the designated InGaN QW*** layers . . . ." Ex. 1025, p.37 (emphasis added). The InGaN layer is the well layer, whereas the barrier layers are formed of 100 Å GaN. *Id.*, p.36. Therefore, Lin teaches that the carrier traps—i.e., QDs in Lin—are formed within the InGaN well layer of the MQW structure. Ex. 1002, ¶ 108.

4. Claim 6

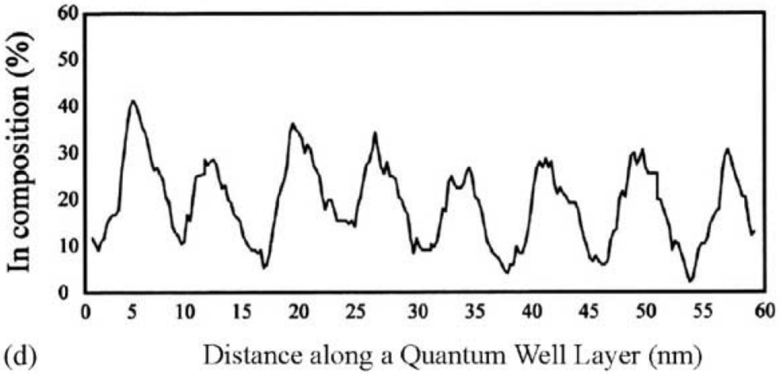
Lin teaches that for the sample annealed at 900°C, the carrier trap portions were embedded within the well layer. Ex. 1002, ¶ 111. As explained in Lin, the well layers are 35 Å thick (3.5 nm). Ex. 1025, p.35. The quantum dots were on the order of 2-5 nm and took on a "sphere-like" shape. *Id.*, p.37. These quantum dots are described as being "within the designated InGaN QW layers," whereas the larger clusters in other samples are described as "extend[ing] into GaN barrier layers." *Id.*, p.37. Because of this, a POSA would have understood that the carrier trap portions are embedded within the InGaN layer. Ex. 1002, ¶ 111.

5. *Claim 7*

Lin explains that the layer "comprising the carrier trap portion comprises indium," as required by claim 7. Ex. 1001, cl.7; Ex. 1002, ¶ 114. Specifically, the carrier trap portions are formed in the InGaN layer, and are "fine indium-rich QDs . . . ." Ex. 1025, p.37. The concentration of indium varies along the QW layer as shown in Fig. 2(d) for the sample that was annealed at 900°C. Ex. 1025, p.38.

6. *Claim 10*

Lin teaches that the "carrier trap portion comprises indium in an amount gradually increasing from the periphery of the carrier trap portion to the center thereof." Ex. 1001, cl.10; Ex. 1002, ¶ 117 Specifically, Lin shows the following graph indicating that the indium concentration decreases from the center to the periphery of each carrier trap portion:

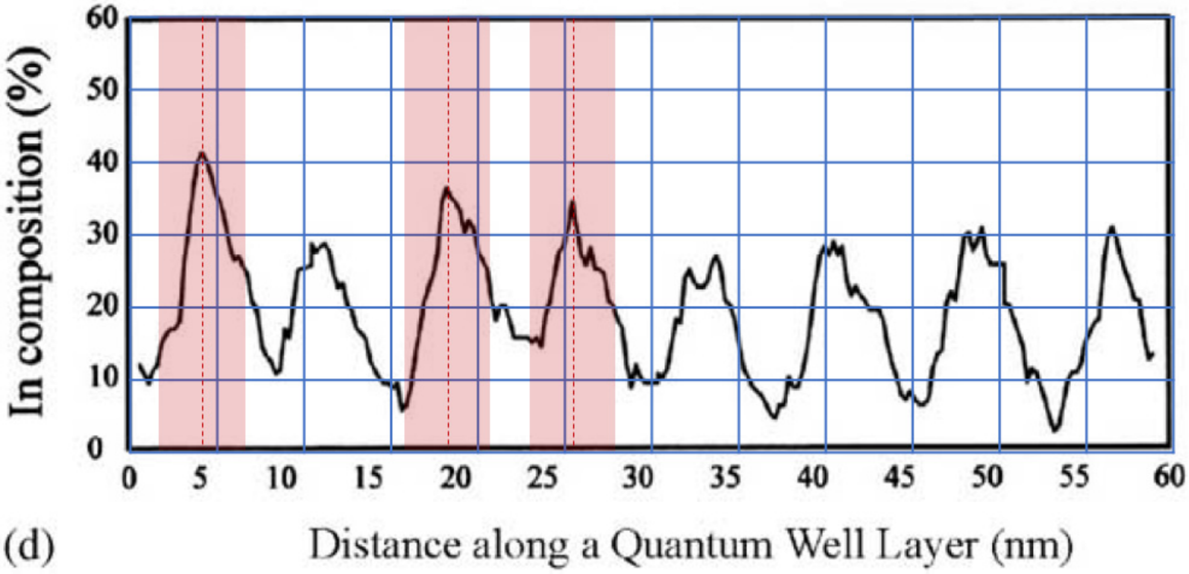


Ex. 1025, p.38 (Fig. 2(d)). This shows that the indium concentration increases from the outer periphery of each carrier trap portion to the center of the carrier trap portion.

7. *Claim 11*

Lin teaches the requirement of claim 11, which depends from claim 10. Specifically, Lin shows an indium concentration that increases from approximately 10% to about 40%—a transition of approximately 30%—from the minima to maxima. Even if the edge of a carrier trap portion was defined as having an indium concentration of 30% the difference in indium concentration from that point to the center would reflect an increase of roughly 10% for the sample at 5nm along the QW layer. Ex. 1002, ¶¶ 121-122. Therefore, Lin teaches that the carrier trap portion comprises at least 2% or more indium than an outermost region of the carrier trap portion." Ex. 1001, cl.11; Ex. 1002, ¶ 122.

Additionally, a POSA would have understood that because Lin teaches that the carrier trap portions are between 2-5nm, the changes in indium content can be seen as being significantly larger than 2%.



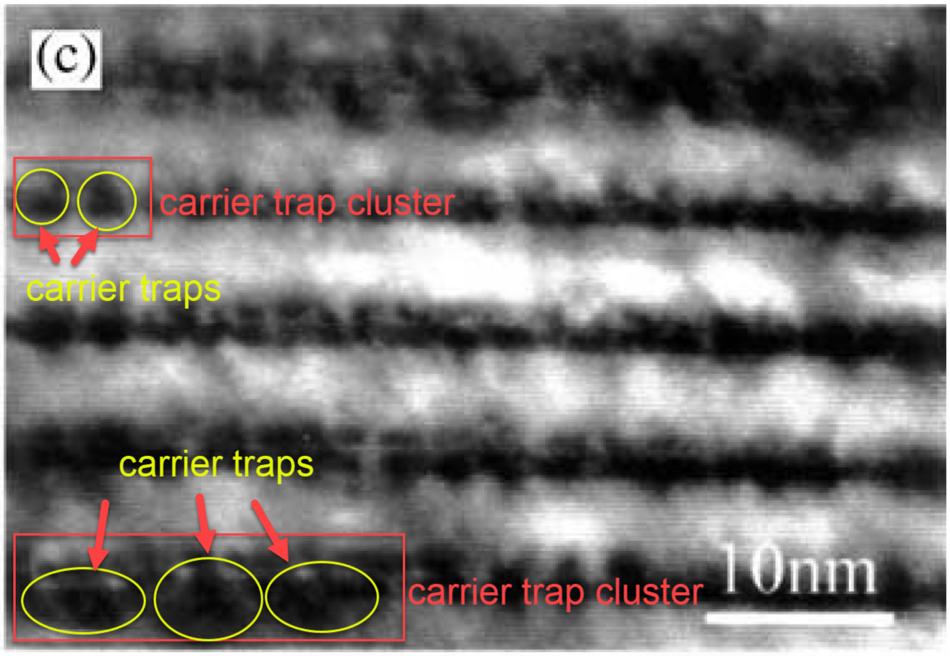
Ex. 1025, Fig. 2(d) (annotated); Ex. 1002, ¶¶ 121-122. Here, a blue grid was overlaid on top of the x and y axis shown on the graph and was scaled accordingly such that each block represents 5 nm along the x-axis and 10% on the y-axis. Ex. 1002, ¶ 122. Then, a 5nm wide block indicated in red was made and red dashed lines were drawn corresponding to maximum indium concentrations of three of the carrier traps (quantum dots). *Id.* The boxes were then centered on the red-dashed lines to show the composition variation across a 5nm quantum dot. As can be seen, in each instance the difference in indium concentration was far greater than 2%. *Id.*. Even if these bars were cut in half, thus reflecting a 2.5nm quantum dot, a variation of greater than 2% is evident. *Id.* Therefore, even if physical dimensions are ascribed to the carrier trap portions, Lin teaches the requirements of claim 11. Ex. 1002, ¶¶ 121-122.

8. Claims 17 and 18

Lin teaches that the carrier trap portions are between 1 and 10 nm—and specifically for the sample subjected to thermal annealing at 900°C—between 2 and 5 nm. Ex. 1025, p.37 ("Interestingly, one can observe that fine indium-rich QDs with size 2-5 nm were regularly distributed within the designated InGaN QW layers after annealing treatment at 900°C (Fig. 1(c))."). These carrier trap portions are thus in the ranges defined by claim 17 (1~10nm) and claim 18 (2~5nm). Ex. 1001, cls. 17-18; Ex. 1002, ¶¶ 128, 130.

9. Claim 19

Lin teaches carrier trap clusters. Ex. 1002, ¶ 133. As shown in Fig. 1(c), which depicts the sample annealed at 900°C, carrier trap clusters are formed in the well layer.



Ex. 1025, p.37 (Fig. 1(c) (annotated)). Defined clustering of the carrier trap portions can be seen as reflected in the annotated HRTEM image. Ex. 1002, ¶ 133. The phrase "formed by clustering at least two carrier trap portions," Ex. 1001, cl.19, recites the process by which the structure of claim 19 is formed—i.e., "formed by clustering." As such, the patentability determination must be made based on the resulting product—and not on the method of producing the product. Thus, "[i]f the product in the product-by-process claim is the same as or obvious from a product of the prior art, the claim is unpatentable even through the prior product was made by a different process." *In re Thorpe*, 777 F.2d 695, 698 (Fed. Cir. 1985). Since the product described by Lin is the same as recited in claim 19, it is unpatentable even without a showing that the clusters are "formed by clustering" as recited by claim 19.

B. Ground 2: Obviousness Of Claim 4 Over Lin in View of Schley

Because "anticipation is the epitome of obviousness," *Realtime Data, LLC v. Iancu*, 912, F.3d 1368, 1373 (Fed. Cir. 2019), Lin's teachings as understood in light of the relationship between bandgap energy to indium content render claim 4 obvious too.

A POSA would have found the creation of a decreasing bandgap profile that takes on a "curved line profile" obvious based on the combined teachings of Lin and Schley. With respect to the "scope and content of the prior art," *Graham v. John Deere Co.*, 383 U.S. 1, 17 (1966), Lin provides a plot of indium composition in terms of a percentage along the length of quantum well and plots that against the distance as measured in nanometers. Ex. 1025, p.38 (Fig. 2(d)). A POSA would also have been aware of Schley, which teaches the mathematical relationship between indium concentration, gallium concentration and the bandgap energy in $In_xGa_{1-x}N$. Ex. 1055, p.205204-5 (eqn. 8). Schley also defines the variables for that equation. *Id.*, pp.205204-5 to 205204-6. Therefore, everything a POSA would have needed to investigate the profile of bandgap energy along the quantum well layer taught in Lin was in the prior art. Ex. 1002, ¶ 145.

A POSA would have been readily able to perform the calculations set forth in Dr. Dupuis's declaration to ascertain the bandgap energy along the quantum well layer using the estimated values of indium content and distance. *Id.*, ¶¶ 141-

144. Indeed, once the values are estimated from Lin's Fig. 2(d), it is a simple matter of algebra to plug in values for the variables and calculate the bandgap energy of the $In_xGa_{1-x}N$ described by Fig. 2(d) of Lin. Ex. 1002, ¶ 141-144. Thus, reliance on Schley's characterization of $In_xGa_{1-x}N$ to obtain bandgap energies was within the level of skill of a POSA. Moreover, as explained above, there are no differences between Lin and the claimed subject matter. *See supra*, § VII.A.2. Any arguable difference arises from the fact that Lin's plot is presented as distance vs. indium concentration, but the claim is cast in terms of distance vs. bandgap energy.

But, considering Lin's and Schley's teachings, a POSA would have obviously and readily seen that bandgap profiles of Lin's example shown in Fig. 2(d) met the claimed requirement of having a decreasing and curved line shape. Ex. 1002, ¶¶ 141-144. Indeed, a POSA would have been naturally led to perform this routine arithmetic based on Schley's equations to characterize the bandgap profile of Lin's examples because "those skilled in the art were aware that research into InGaN and the mechanisms of radiative recombination of holes and electrons in such material was an area of intense study at the time of the alleged invention." Ex. 1002, ¶ 146 (citing Ex. 1002, ¶¶ 28, 37). This is evident from the discussion of the large amount of literature in the field studying the physical and quantum mechanical properties of InGaN for use in LEDs. *See generally supra* §§ V.D, V.E. Based on the intense research into this material, a POSA "would have found it obvious to examine not just the indium composition along the quantum well, but also examine the bandgap energies at various locations along the well layer" because "it is the bandgap energies that influence the wavelength of light radiated from the devices, and variations in the bandgap would not only impact the carrier confinement (e.g., due to the depth of the quantum well), but would also have an impact in spectral broadening and blueshift based on variations in the overall bandgap energies along the quantum well layer." Ex. 1002, ¶ 146. Therefore, even if claim 4 was not anticipated by Lin, it would have been obvious to apply the equations and values set forth in Schley to recast the graph shown by Lin to reveal the bandgap profiles rather than the indium concentration as such a calculation can reveal additional information about the spectral and quantum mechanical properties of the resulting material.

C. Ground 3: Obviousness of Claim 16 Over Lin In View of Lin II

Claim 16 would have been obvious over Lin in view of Lin II. Claim 16 requires "the carrier trap portions are distributed at a higher density than a dislocation density of the layer comprising the carrier trap portion." Ex. 1001, cl.16. Lin explains that indium-rich clusters "can trap carriers for photon emission and reduce non-radiative recombination rate." Ex. 1025, p.35. This trapping of carriers "is particularly important in such a normally high defect density material."

Id. Yet, other than observing that InGaN/GaN QWs have a "high defect density," *id.*, Lin does not discuss the density of the carrier traps with respect to the defects.

Lin II does. Like Lin, Lin II discusses quantum dots defined by indium-rich regions formed in InGaN/GaN quantum wells. Ex. 1016, p.2988. Like Lin, Lin II also explains that "[i]n the QDs, carriers are deeply localized and their migration toward nonradiative defects (dislocations) is hindered." *Id.* Lin II then explains that "[H]igh-luminescence efficiency is expected if the density of QDs is much higher than that of dislocations." *Id.* A POSA would have been motivated to arrive at a device that exhibited "[h]igh-luminescence efficiency." Ex. 1016, p.2988; Ex. 1002, ¶ 149. Indeed, increasing the efficiency of radiative recombinations to make brighter light emitters that use less power was a long-standing goal of those skilled in the art. Ex. 1002, ¶ 147, 149. Moreover, a POSA would have realized from Lin II that one way to improve the efficiency of the light emitter, such as that disclosed by Lin was to ensure that "the density of QDs is much higher than that of the dislocations." *Id.*; Ex. 1016, p.2988. Therefore, to obtain higher device efficiency, the POSA would have been motivated to arrive at the claimed subject matter based on the disclosure of Lin II that a "much higher" density of quantum dots (carrier trap portions) should be present when compared to the density of dislocations in the layer in which the electrons and holes recombine—namely the InGaN well layer of the MQW structure. Ex. 1002, ¶ 149.

D. Ground 4: Claims 1, 5-7, 10-11, 15, and 17-18 Are Anticipated by Gerthsen

1. Claim 1

a. [1P] "A light emitting device, comprising:"

Gerthsen explains that indium fluctuations in InGaN group-III nitride heterostructures "the defects and In distribution strongly affect the performance of light-emitting and electronic devices." Ex. 1026, p.1668. To the extent the preamble is a limitation Gerthsen teaches a "light emitting device." Ex. 1002, ¶ 95.

b. [1A] "a substrate;" [1B] "a first semiconductor layer on the substrate," and [1C]"a second semiconductor layer on the first semiconductor layer,"

These three limitations—***the substrate***, the ***first semiconductor layer***, and the ***second semiconductor layer***—are all taught by Gerthsen. Gerthsen explains that the structure analyzed for the purposes of Fig. 4 "was grown on ***a SiC (0001) substrate*** on ***Si-doped 380 nm AlGaN*** and 75 nm GaN buffer layers. It was capped by 75 nm GaN and ***240 nm AlGaN doped with Mg***." Ex. 1026, p.1673 (emphasis and color added). Gerthsen, therefore, teaches each of these limitations as required by claim 1. Ex. 1002, ¶¶ 96-99. GaN and AlGaN are semiconductor materials. Ex. 1002, ¶¶ 97, 99. And, the quantum well structure is grown on, *inter alia*, a "75 nm GaN buffer layer," which is on the substrate. Ex. 1026, p.1673; Ex. 1002, ¶ 97. Moreover, by indicating that the quantum wells were "capped" by 240 nm AlGaN doped with Mg, Gerthsen teaches that the second semiconductor layer is on the first semiconductor layer. Ex. 1026, p.1673; Ex. 1002, ¶¶ 98-99.

c. [1D] "a multi-quantum well structure comprising at least one well layer and at least one barrier layer between the first and second semiconductor layers . . . ."

Gerthsen teaches a multi-quantum well structure that is described as being "an InGaN/GaN QW structure." Ex. 1026, p.1673; Ex. 1002, ¶ 100. This multi-quantum well structure "contains 5 InGaN layers," Ex. 1026, p.1673, which a POSA would have understood to be well layers, Ex. 1002, ¶ 100. Those InGaN layers are "separated by 5nm GaN spacers," which a POSA would have understood to be barrier layers, Ex. 1002, ¶ 100. These QW layers are described as being "between the first and second semiconductor layers," as required by claim 1. Ex. 1001, cl.1; Ex. 1026, p.1673; Ex. 1002, ¶ 100.

d. [1E] "at least one layer within the multi-quantum well structure comprising at least one carrier trap portion formed therein . . ."

Gerthsen teaches that "at least one layer within the multi-quantum well structure" includes a "carrier trap portion formed therein," as required by claim 1. Ex. 1001, cl.1; Ex. 1002, ¶ 102. For example, Gerthsen studied a number of samples of QWs made of InGaN. Ex. 1026, p.1669. Based on these studies, Gerthsen concluded that "composition fluctuations are always present in InGaN. In particular, In-rich agglomerates with sizes of only a few nm are a characteristic feature, which are often suggested to act optically as quantum dots." *Id.*

A POSA would have recognized that indium-rich quantum dots are carrier traps because an increase in indium reduces the bandgap energy to create localized states. Ex. 1002, ¶¶ 33, 40, 46, 103; *see also* Ex. 1016, p.2988 ("[I]t was proposed that nanoscale indium composition fluctuations, due to indium aggregation . . . acted as quantum dots (QDs) in optical characteristics.[] In the QDs, carriers are deeply localized and their migration toward nonradiative defects (dislocations) is hindered."); Ex. 1019, p.1 ("[T]he indium concentration in quantum wells is assumed to fluctuate spatially, thus forming deep cusps or 'quantum dots' in the energy gap . . . . Exciton pairs are confined in the local minima, and the cusps operate as excellent radiative recombination centers."). Indeed, the '225 patent itself discloses and claims that increases to the concentration of indium gives rise to carrier traps within the layers of a MQW structure. *See, e.g.*, Ex. 1001, 2:40-44, 4:32-39, 7:19-25. Therefore, the quantum dots studied by Gerthsen are carrier trap portions.

e. <u>[1F] "the at least one carrier trap portion having a band-gap energy decreasing from a periphery of the carrier trap portion to a center of the carrier trap portion."</u>

The carrier trap portions described and taught by Gerthsen have "a band-gap energy decreasing from a periphery of the carrier trap portion to a center of the carrier trap portion," as required by claim 1. Ex. 1001, cl.1. As explained above, Gerthsen's quantum dots are "carrier trap portion[s]." *Supra* § VII.G.1.d. The distribution of indium within the indium-rich quantum dots for a MQW sample disclosed by Gerthsen is shown below:

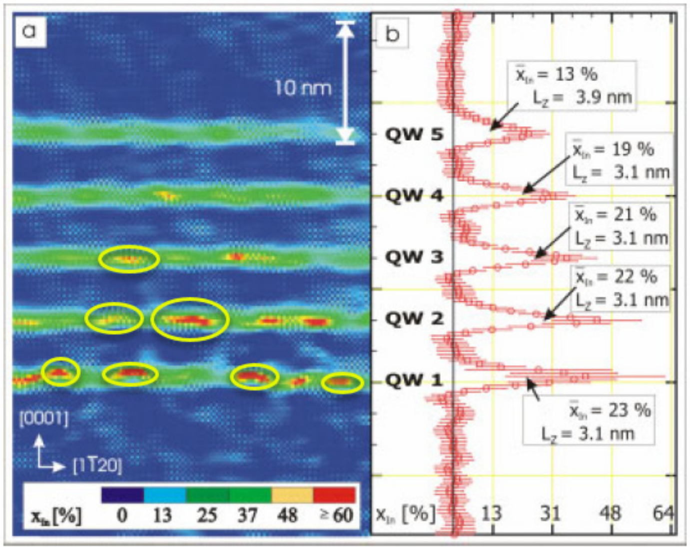


Fig. 4 a) Color-coded map of the In distribution of an InGaN/GaN multiple QW structure and b) averaged In concentration along the [11$\bar{2}$0] direction plotted as a function of the (0002)-plane. number.

Ex. 1026, p.1673 (Fig. 4(a) (annotated to identify some carrier trap portions)). As can be seen from this figure, the indium concentration (X_{In}[%]) in, for example, the bottom most well-layer of the MQW structure is nominally at 37% and increases in regions of the quantum dots from 48% to a concentration of greater than 60%.[8]

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[8] As taught by Gerthsen, these numbers are scaled and Gerthsen notes that the "evaluated composition of the clusters is only an apparent In concentration" and "[t]he real In concentration inside the clusters will be higher because they are embedded in an InGaN QW with a lower In concentration." Ex. 1026, p.1673-74.

Ex. 1002, ¶ 104. Therefore, regardless of where the precise bounds of carrier trap portion are defined—something that the ’225 patent says need not have “a physical shape,” Ex. 1001, 4:42-47—a POSA would have recognized that the indium concentration *increases* from the outer periphery of the carrier trap portion to the maxima for each quantum dot. Ex. 1002, ¶ 105; Ex. 1026, p.1673 (Fig. 4(a)). Moreover, as is evident from the graph to the right of Figure 4a) (reproduced above), the concentration of indium varies both along the well layer itself as well as vertically through the well layer.

Because the concentration of indium *increases* from the outer periphery of the carrier trap portion to the center as is evident in the color-coded map and indium concentration plot above, the bandgap energy *decreases* given the inverse relationship between indium concentration and bandgap energy. Ex. 1002, ¶ 106 (discussing Ex. 1010, p.3668 & Fig. 2; Ex. 1031, Fig. 7 & 19:30-45 (“[I]ncreasing the indium composition ratio decreases the bandgap.”); *supra* § II.D. Therefore, because Gerthsen teaches that the indium concentration increases within the carrier trap portion, Gerthsen also teaches that the bandgap energy decreases from the periphery of the carrier trap portion to its center. Ex. 1002, ¶ 106.

2. Claim 5

Gerthsen teaches that “the carrier trap portion is formed in the well layer within the multi-quantum well structure,” as required by claim 5. Ex. 1001, cl.5.

Gerthsen explains that the paper is to give an overview of the "microstructure and composition analyses of InGaN quantum wells embedded in Ga(Al)N barriers . . . ." Ex. 1026, p.1668. Gerthsen shows an "InGaN/GaN QW structure, which contains 5 InGaN layers . . . ." Ex. 1026, p.1673. These InGaN layers include the carrier trap portions. *Id.*, p.1674 (noting that the In clusters "are embedded in an InGaN QW with lower indium concentration"). Based on the foregoing, a POSA would have understood that Gerthsen is describing the carrier trap portions to be disposed in the well layers. Ex. 1002, ¶ 109.

3. Claim 6

Gerthsen teaches that the "carrier trap portion is embedded in the well layer," as required by claim 6. Ex. 1001, cl.6. For example, Gerthsen teaches that "[t]he real In concentration within the clusters [i.e., the carrier trap portions] will be higher because they are ***embedded*** in an InGaN QW with a lower In concentration." Ex. 1026, p.1674. This teaches that the carrier trap portions are embedded within the well layer since the well layers are made of InGaN, *see* Ex. 1026, p.1673 (referring to "5 InGaN layers separated by GAN spacers"); *see also* Ex. 1002, ¶ 112.

4. Claim 7

In Gerthsen, "the layer comprising the carrier trap portion comprises indium" as required by claim 7. Specifically, Gerthsen teaches an "InGaN/GaN

QW structure, which contains 5 InGaN layers separated by 5 nm GaN spacers." Ex. 1026, p.1673. "In" in "InGaN" is indium. Ex. 1002, ¶ 115. Gerthsen further discloses a "[c]olor coded map of the In distribution of an InGaN/GaN multiple QW structure," showing that the carrier trap portions were indium-rich clusters. Ex. 1026, pp.1669, 1673. Therefore, Gerthsen discloses that the layer having the carrier trap portion comprises indium. Ex. 1002, ¶ 115.

5. Claim 10

Claim 10 depends from claim 7 and claim 7 is disclosed by Gerthsen. *See supra* §VII.G.4. Gerthsen teaches that the "carrier trap portion comprises indium in an amount gradually increasing from the periphery of the carrier trap portion to the center thereof," as required by claim 10. This is seen in the following illustration:

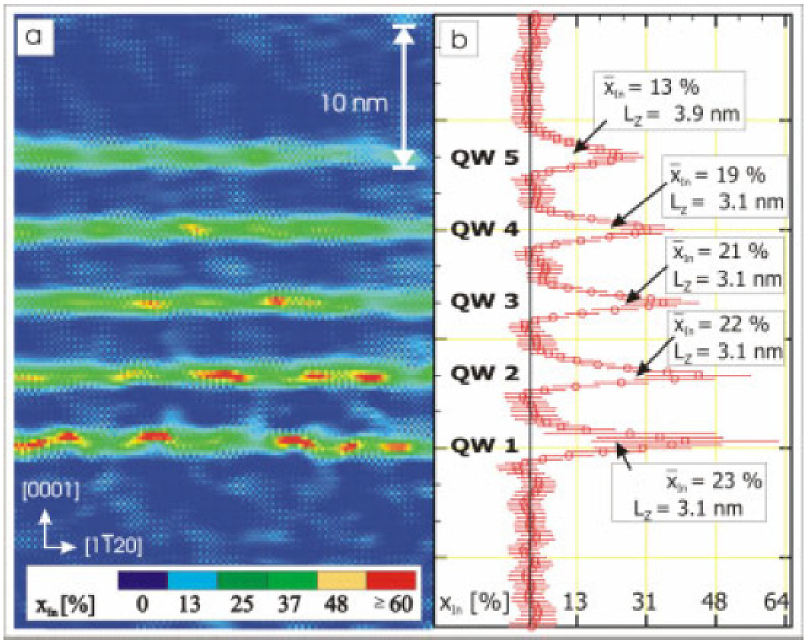


Fig. 4 a) Color-coded map of the In distribution of an InGaN/GaN multiple QW structure and b) averaged In concentration along the [11$\bar{2}$0] direction plotted as a function of the (0002)-plane. number.

In the plot to the right ("(b)"), the concentration of indium increases along the [11$\bar{2}$0] direction gradually increases from local minima to local maxima between approximately 31% In to 63% In, depending on the depth of the well layer in the MQW structure. This shows that as one moves from the periphery of the carrier trap portion in the [11$\bar{2}$0] direction, the indium concentration increases, and then decreases gradually, with the indium profile in the top-most well layer being the most gradual. Ex. 1002, ¶ 119. Additionally, as indicated by the profile gradients in the "color map," the profiles in the horizontal direction would also increase gradually between roughly 13% and more than 60%, passing from one color to the next until the amount of indium reaches a maxima, and then decreases, e.g., moving left to right across a well layer in the color map. Ex. 1002, ¶ 119. Therefore, Gerthsen discloses the requirements of claim 10.

6. Claim 11

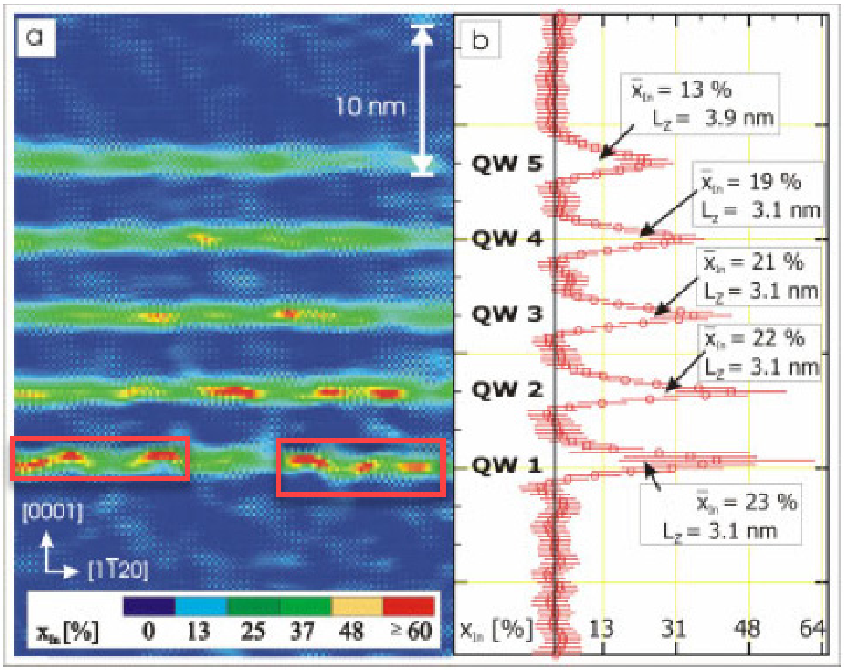
Claim 11 depends from claim 10, which is taught by Gerthsen as discussed above. Gerthsen also discloses the requirements of claim 11, i.e., that "the carrier trap portion comprises at least 2% or more indium than an outermost region of the carrier trap portion." Ex. 1001, cl.11. This can be seen in Fig. 4 from Gerthsen, where indium concentrations range from either 37% or 13% (depending on which "cluster" or "carrier trap portion" is being examined) to more than 60%. In either case, the increase of indium concentration is greater than 2%. This is further evident in the $[11\bar{2}0]$ direction, where the indium concentration increases from a minimum to a maximum and the differential is well above 2%. Ex. 1002, ¶ 124; Ex. 1026, p.1673. Indeed, Gerthsen explains that the clusters or dots are "only a few nm". Ex. 1026, p.1669; *see also id.*, p.1677 ("The size of the In-rich agglomerates is—as usual—in the order of a few nm and the In concentration in the clusters reaches almost 60 %."). Looking at Fig. 4, since the clusters have a size of "a few nm," and the average width of the well layers is between about 3 and 4 nm, *see* Ex. 1026, p.1673 (Fig. 4(b)) & p.1674 (Table 1), the outermost portion of the carrier trap portion approximately corresponds to the edge of the well layer--thus yielding gradients between for example, 13% indium to 64% indium (for the bottom QW) or 13% indium to 31% indium (for the top QW). Ex. 1002, ¶ 135. Thus, this claim is disclosed by Gerthsen.

7. *Claims 17 and 18*

Claims 17 and 18 recite certain dimensions for the carrier trap portions. For example, claim 17 requires that the carrier trap portions to have dimensions between 1~10 nm, Ex. 1001, cl.17, and claim 18 narrows that range to be between 2~5 nm, *id.*, cl.18. A teaching of the narrower range is a teaching of the broader range in this context. Gerthsen teaches indium rich clusters having a diameter of "a few nm". *See, e.g.*, Ex. 1026, p.1669 (referring to studies showing indium concentration fluctuations "on a scale of only a few nm"), p.1679 ("small In-rich clusters with lateral extensions of a few nm and high In concentrations"). The POSA would have realized that "a few nm" was in the range of about 2-4 nm based on Gerthsen's Figure 4(a), based on the scale provided in that figure because the carrier trap portions are less than half of the 10 nm scale in the figure. Ex. 1002, ¶¶ 128, 131. Therefore, claims 17 and 18 are disclosed by Gerthsen. *Id.*

8. *Claim 19*

Gerthsen teaches "carrier trap clusters that are formed by clustering at least two carrier trap potions," as required by claim 19. Ex. 1001, cl.19. This is shown, for example, in Figure 4(a), which shows various clusters of carrier traps in the well layers:



Ex. 1026, p.1673 (annotated to add red boxes). The red boxes added to this figure show clusters of carrier trap portions. Ex. 1002, ¶ 134.

The phrase "formed by clustering at least two carrier trap portions," Ex. 1001, cl.19, recites the process by which the structure of claim 19 is formed. As such, the patentability determination must be made based on the resulting product—and not on the method of producing the product. Thus, "[i]f the product in the product-by-process claim is the same as or obvious from a product of the prior art, the claim is unpatentable even through the prior product was made by a different process." *In re Thorpe*, 777 F.2d 695, 698 (Fed. Cir. 1985). Since the product described by Gerthsen is the same as recited in claim 19, it is unpatentable even without a showing that the clusters are "formed by clustering" as recited by claim 19.

E. Ground 5: Obviousness of Claim 16 Over Gerthsen In View of Lin II

Claim 16 would have been obvious over Gerthsen in view of Lin II. Claim 16 requires “the carrier trap portions are distributed at a higher density than a dislocation density of the layer comprising the carrier trap portion.” Ex. 1001, cl.16. Gerthsen recognized that “the effects and In distribution strongly affect the performance of light-emitting and electronic devices.” Ex. 1026, p.1668. Gerthsen further notes that “In-rich agglomerates with sizes of only a few nm are a characteristic feature” of the studied samples, and they are “often suggested to act optically as quantum dots.” *Id.*, p.1669. Yet, Gerthsen does not describe the density of carrier traps vis-à-vis the density of dislocations in the samples.

Lin II does. Like Gerthsen, Lin II discusses quantum dots defined by indium-rich regions formed in InGaN/GaN quantum wells. Ex. 1016, p.2988. Lin II explains that “[i]n the QDs, carriers are deeply localized and their migration toward nonradiative defects (dislocations) is hindered.” *Id.* Lin II then explains that “high-luminescence efficiency is expected if the density of QDs is much higher than that of dislocations.” *Id.* A POSA would have been motivated to arrive at a device that exhibited “[h]igh-luminescence efficiency,” Ex. 1016, p.2988; Ex. 1002, ¶ 151. Increasing the efficiency of radiative recombinations to make brighter light emitters that use less power was a long-standing goal of those skilled in the art. Ex. 1002, ¶ 147, 151. Moreover, a POSA would have realized from Lin II that one way to improve the efficiency of the light emitter, such as that disclosed by Gerthsen was to ensure that "the density of QDs is much higher than that of the dislocations." *Id.*; Ex. 1016, p.2988. Therefore, to obtain higher device efficiency, the POSA would have been motivated to arrive at the claimed subject matter by improving on the device disclosed by Gerthsen based on the disclosure of Lin II that a "much higher" density of quantum dots (carrier trap portions) should be present when compared to the density of dislocations in the layer in which the electrons and holes recombine—namely the InGaN well layer of the MQW structure. Ex. 1002, ¶ 151.

VIII. MANDATORY NOTICES

A. Real Party-In-Interest

The real party-in-interest in this petition is Satco Products, Inc., 110 Heartland Blvd., Brentwood, New York 11717.

B. Related Matters

The '225 patent is currently being asserted against Petitioner in the action captioned *Seoul Semiconductor Co., Ltd. v. Satco Products, Inc.*, No. 2:19-cv-04951 pending in the United States District Court for the Eastern District of New York. The '225 patent is also currently being asserted in the action captioned *Seoul Semiconductor Co., Ltd. v. The Factory Depot Advantages, Inc.*, No. 2:19-cv-05065 pending in the United States District Court for the Central District of

California. Petitioner is unaware of any other proceedings involving the ’225 patent that may impact or be impacted by this proceeding.

C. Lead and Back-Up Counsel

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D. Service

Service on Petitioner may be made by mail or hand delivery to: Greenberg Traurig, LLP, 1144 15th St., Suite 3300, Denver, CO, 80202. Petitioner also consents to and prefers electronic service by emailing satco-iprs@gtlaw.com and counsel of record (shown above).

IX. FEES

The required fee is being paid electronically through PTAB E2E.

X. CONCLUSION

For the reasons set forth herein, Petitioner requests that the Board institute trial and ultimately cancel claims 1 and 5-19 of the ’225 patent.

Dated: December 16, 2019	Respectfully Submitted,
	/Andrew R. Sommer/
	Andrew R. Sommer Reg. No. 53,932

CERTIFICATE OF COMPLIANCE

This petition complies with the word count limits set forth in 37 C.F.R. § 42.24(a)(i), effective May 2, 2016, because this Petition contains 11,890 words, excluding the parts of the petition exempted by 37 C.F.R. § 42.24(a), as determined using the word count provided by Microsoft Word, which was used to prepare this Petition.

Dated: December 16, 2019

Respectfully Submitted,

/Andrew R. Sommer/

Andrew R. Sommer
Reg. No. 53,932

CERTIFICATE OF SERVICE

Pursuant to 37 C.F.R. §§ 42.6(e) and 42.105(a), the undersigned certifies that on December 16, 2019, I caused a true and correct copy of the foregoing Petition for *Inter Partes* Review of Claims 1, 4-7, 10-11, and 16-19 of U.S. Patent No. 7,667,225, all exhibits, and the accompanying Power of Attorney to be served by EXPRESS MAIL on the Patent Owner at the correspondence address of record for U.S. Patent No. 7,667,225 as follows:

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Reston, VA 20191

I further certify that a courtesy copy of the above-identified materials were served on litigation counsel by electronic means upon the foregoing individuals:

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