

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

LITE-ON TECHNOLOGY CORPORATION,

Petitioner

v.

Sensor Electronic Technology, Inc.

Patent Owner

CASE: Unassigned

U.S. Patent No. 9,923,117

Title: SEMICONDUCTOR STRUCTURE WITH INHOMOGENEOUS
REGIONS

**DECLARATION OF DR. JAMES RICHARD SHEALY IN SUPPORT OF
PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 9,923,117**

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Exhibit List

Exhibit. No.	Description
Ex. 1001	U. S. Patent No. 9,923,117 (“the ’117 Patent”)
Ex. 1002	Declaration of Dr. James Richard Shealy
Ex. 1003	Curriculum Vitae of James Richard Shealy
Ex. 1004	U.S. Patent Application Publication No. 2007/0085093 to Ohmae et al. (“ Ohmae ”)
Ex. 1005	Japan Patent No. 2000-22283 to Ban et al. (“ Ban ”)
Ex. 1006	W.O. Publication No. 2013/023197 to Shur et al. (“ Shur ”)
Ex. 1007	U.S. Patent Application Publication No. 2004/0031956 to Saxler (“ Saxler ”)
Ex. 1008	U.S. Patent No. 6,478,871 “Single step process for epitaxial lateral overgrowth of nitride based materials”
Ex. 1009	Phase separation and ordering in InGaN alloys grown by molecular beam epitaxy
Ex. 1010	Growth kinetics of AlGaN films by plasma-assisted molecular-beam epitaxy
Ex. 1011	Phase Separation and Atomic Ordering in AlGaInN Alloys
Ex. 1012	Nitride-based semiconductors for blue and green light-emitting devices
Ex. 1013	Photoconductive detectors based on partially ordered AlGaN alloys grown by molecular beam epitaxy
Ex. 1014	Alloy scattering in ternary III-V compounds
Ex. 1015	Epitaxial Lateral Overgrowth Techniques Used In Group III Nitride Epitaxy
Ex. 1016	U.S. Patent No. 8,114,691 (“ Lee ”)

Exhibit. No.	Description
Ex. 1017	Electrical and structure properties of AlGaN: a comparison with CVD diamond by Stutzmann (“ Stutzmann ”)
Ex. 1018	File History for the ’117 Patent
Ex. 1019	U.S. Patent No. 6,201,262

I. INTRODUCTION

1. My name is James Richard Shealy, and I am currently a Professor at Cornell University. I am over 21 years of age and otherwise competent to make this declaration.

2. I make this declaration in support of Petitioner Lite-On Technology Corporation's ("Lite-On") petition for *inter partes* review of U. S. Patent No. 9,923,117 ("the '117 Patent"; **Ex. 1001**). I have no financial interest in Lite-On or the '117 Patent.

3. I understand that Sensor Electronic Technology, Inc. ("SETi") is listed as the owner of the '117 Patent. I have no financial interest in SETi, nor to my recollection have I ever had any contact with SETi or the listed inventors on the '117 Patent.

4. Although I am being compensated for my time in preparing this declaration, the opinions herein are my own, and I have no stake in the outcome of the *inter partes* review proceeding.

5. This declaration summarizes the opinions I have formed to date and is based on information currently available to me. I reserve the right to modify my opinions, if necessary, based on further review and analysis of information that I receive subsequent to the filing of this report, including in response to positions

that parties to the *inter partes* review proceeding, or their experts, may take that I have not yet seen.

II. QUALIFICATIONS AND EXPERIENCE

6. I have been involved in the science and engineering of light emitting diodes (“LEDs”) and high-power compound semiconductor transistors for over 40 years. My education, research, and experience in this field is detailed in my curriculum vitae, attached as **Ex. 1003**.

7. I am currently a Professor at Cornell University, School of Electrical and Computer Engineering, and have been teaching and conducting research at Cornell since 1987.

8. I received a B.S. degree from North Carolina State in 1978, an M.S. from Rensselaer Polytechnic in 1980, and a Ph.D. in 1983 from Cornell. I joined the Cornell faculty in 1987 and am currently a Full Professor in the School of Electrical and Computer Engineering. I have been deeply involved in the research and design of III-V compound semiconductor devices over the course of my career. In 1978, I joined the technical staff of General Electric's Corporate Research and Development Center under an Edison Fellowship. While there, among other work, I developed GaAs epitaxial materials for high voltage electronics. I was the inventor of two patents on Vertical Field Effect Transistors. I

also researched device fabrication by organometallic vapor phase epitaxy (“OMVPE”).

9. In 1980, I transferred to General Electric's Advanced Electronics Laboratory where I developed materials and processes for the fabrication of AlGaAs LEDs as well as developing an OMVPE reactor and related processes for the fabrication of AlGaAs quantum well laser diodes. These lasers were the highest power, lowest threshold devices at the time. The AlGaAs LEDs were developed in my group: from materials to device fabrication to a variety of packaging solutions. The packages included lead frame packages, hermetically sealed metal and ceramic packages, and packages which combined the LED with a silicon photo transistor (commonly referred to as an opto-coupler). These packages included wire bonds to pads on the LED and on the package, silver epoxy die mounts, eutectic pre-form die mounts, LED passivation, reflectors, and focusing lenses integrated into the package assembly. In 1985, I was designated Principal Staff Scientist at General Electric in recognition of my research contributions.

10. For a portion of my time at General Electric I was also concurrently working at Cornell. In 1984, my group at Cornell developed the first single quantum well red laser and LEDs by OMVPE with AlGaInP materials. The fabrication of these devices involved multi-level metallization and dielectric passivation.

11. I joined the Cornell faculty in 1987 as a Professor of Electrical and Computer Engineering (ECE) and Materials Science and Engineering (MSE).

While at Cornell I have continued my research in OMVPE, particularly as it relates to LEDs, laser diodes, and high frequency transistors. I have also researched GaN and related materials for both LEDs and high-power transistors.

12. In 1997, I was named the Director of Cornell's Optoelectronics Technology Center. In 1998, I was promoted to full professor at Cornell. I have published over 120 articles and I am the inventor of over 19 patents, many of which deal with GaN-based materials and devices. Over the years, I have received numerous teaching awards for delivering quality instruction to undergraduates in Materials Science and Electrical Engineering.

13. In 1998-99, the research group that I led invented and patented a single temperature method for nucleation and growth of GaN materials on sapphire, SiC, and Si substrates. This nucleation method was used to produce a single step epitaxial lateral overgrowth technology (also patented). This nucleation technique has become the preferred method for growing GaN-based LEDs and transistors today. This nucleation method was also used to grow AlN/GaN layers on silicon. By mid-1999, my research group had produced the first gallium nitride-on-silicon (GaN-Si) RF transistor, a technology currently used by several GaN companies for high efficiency power convertors and RF amplifiers.

14. By the early 2000s, my research group produced the first RF integrated circuits with gallium nitride-on-silicon carbide (GaN on SiC) transistors including X Band VCOs, TR switches, frequency doublers, and internally matched power amplifiers. By 2008, my group discovered a new passivation technology (LPCVD of AlSiN, patented) for GaN-based FETs which, when applied to GaN-SiC HEMTs, produced the largest power density operation (over 18 Watts/mm at 10 GHz) ever observed on submicron gated devices. These devices also delivered record power-added-efficiencies and linear gain during 10 GHz operation (PAE > 65 %, Gain > 36 dB at 60 V bias). This same GaN-SiC HEMT technology when scaled for high voltage operation using micron size gates and field plates produced high voltage devices (exceeding 440 volts) with a 40 GHz bandwidth. Each of these benchmarks remain unchallenged today.

15. I have remained current in the field, as evidenced by my publications listed in my CV.

16. I also have provided expert consulting relating to LEDs and GaN transistors, including materials growth, device fabrication, and packaging.

17. In 2015, I cofounded Akoustis Technology (AKTS on the NASDAQ), a company which manufactures AlN bulk acoustic wave filters which are required for 5G communications. In 2019, I cofounded Odyssey Semiconductor, a company which is developing GaN Vertical field effect transistors for the emerging power

convertor market. Odyssey Semiconductor also recently developed the fabrication techniques and built micro-LED Arrays in both AlGaInP and AlGaInN materials.

18. I have used my education and experience teaching, researching, publishing, and working in the LED and compound semiconductor transistor fields, and my understanding of the knowledge, creativity, and experience of a person having ordinary skill in the art in forming the opinions expressed in this report, as well as any other materials discussed or cited herein.

III. MATERIALS CONSIDERED

19. In forming my opinions, I read and considered the '117 patent and its prosecution history, the exhibits listed in the Exhibit List filed with the petition for *inter partes* review of the '117 patent, as well as any other material referenced herein.

20. Additionally, in performing my analysis, I have relied upon my own personal knowledge and experience, as well as information generally available to, and relied upon by, persons of ordinary skill in the art at the time of the alleged invention, including technical dictionaries, technical standards, technical reference materials, catalogues, and well-known engineering principles practiced in the industry.

21. For any future testimony I may give in this matter, I may use some or all of the documents and information cited to, referred to, and identified in this

declaration, as well as any additional materials that are entered into evidence in this matter.

IV. STATEMENT OF LEGAL PRINCIPLES

A. Claim Construction

22. I have been instructed by Lite-On's counsel on the law regarding claim construction and patent claims and understand that a patent may include two types of claims, independent claims and dependent claims. An independent claim stands alone and includes only the limitations it recites. A dependent claim can depend from an independent claim or another dependent claim. I understand that a dependent claim includes all the limitations that it recites in addition to all of the limitations recited in the claim from which it depends.

23. I understand that the United States Patent and Trademark Office interprets claim terms in an *inter partes* review proceeding under the same claim construction standard that is used in a United States federal court. I understand that under this standard, the meaning of claim terms is considered from the viewpoint of one of ordinary skill in the art at the time of the alleged invention.

24. I have been informed that claim terms are generally given their ordinary and customary meaning as understood by one of ordinary skill in the art in light of the specification and the prosecution history pertaining to the patent. I

understand, however, that claim terms are generally not limited by the embodiments described in the specification.

25. I understand that in addition to the claims, specification, and prosecution history, other evidence may be considered to ascertain the meaning of claim terms, including textbooks, encyclopedias, articles, and dictionaries. I have been informed that this other evidence is often less significant and less reliable than the claims, specification, and prosecution history.

B. Anticipation

26. Lite-On's counsel has advised that in order for a patent claim to be valid, what is claimed must be novel. They have further advised that if each and every element of a claim is disclosed in a single prior art reference, then the claimed invention is anticipated under 35 U.S.C. § 102, and the claimed invention is not valid. In order for the invention to be anticipated, each element of the claimed invention must be described or embodied, either expressly or inherently, in the single prior art reference. In order for a reference to inherently disclose a claim limitation, that limitation must necessarily be present in the reference. Lite-On's counsel has also advised that a prior art reference must, in order to anticipate, provide sufficient disclosure to enable a person of ordinary skill in the art to practice what is described.

C. Obviousness

27. In addition to being novel, Lite-On's counsel has advised that in order for a patent claim to be valid, what is claimed must be non-obvious. Lite-On's counsel has advised that obviousness under 35 U.S.C. § 103 is a basis for unpatentability as follows: where a prior art reference discloses less than all limitations of a given patent claim, that patent claim is unpatentable if the differences between the claimed subject matter and the prior art reference are such that the claimed subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the relevant art. In other words, I understand that a single prior art reference, even though not anticipating, could still render a claim obvious to a person of ordinary skill in art, given that person's knowledge and experience in the field, and understanding of the state of the art at the time the prior art reference was disclosed. Obviousness can also be based on a combination of references that discloses all limitations of the claimed invention, either expressly or inherently.

28. In evaluating whether a claimed combination would have been obvious, I understand that I may consider whether there was a reason that would have prompted a person of ordinary skill to combine the elements or concepts from the prior art in the same manner as claimed. I understand that, among other things, I can consider whether market forces or other design incentives might have

prompted the particular combination claimed in the patent. I understand that I may also consider whether the combination simply achieved a predictable result by using prior art elements according to their known functions. I understand that I may consider whether there is some teaching or suggestion in the prior art to make the claimed combination, although identifying such a teaching, motivation, or suggestion is not required to prove obviousness. I understand that teachings, suggestions, and motivations may also be found within the knowledge of a person of ordinary skill, including inferences and creative steps that such a person would employ.

29. I also understand that obviousness should not be analyzed using the benefit of hindsight. Instead, it must be analyzed from the standpoint of what a person of ordinary skill in the art would have known and understood at the time of the claimed invention.

V. LEVEL OF ORDINARY SKILL IN THE ART

30. It is my understanding that the claims and specification of a patent must be read and construed through the eyes of a person of ordinary skill in the art (“POSITA”) at the time of the alleged invention. This reference point prevents one from using his or her own insight or hindsight in deciding whether a claim is obvious.

31. Counsel has also advised me that to determine the appropriate level of a person having ordinary skill in the art, the following factors may be considered:

a) the types of problems encountered by those working in the field and prior art solutions thereto; b) the sophistication of the technology in question, and the rapidity with which innovations occur in the field; c) the educational level of active workers in the field; and d) the educational level of the inventor(s).

32. The relevant technologies to the '117 Patent are light emitting semiconductor devices, specifically deep ultraviolet light emitting devices.

33. The technical and human-centered problems encountered in these technologies require understanding and experience in emitting semiconductor devices, LEDs, and semiconductor manufacturing. Based on my extensive experience with these types of technologies, innovations occur rapidly in the field. For example, hundreds of research articles or other technical articles are published in these fields every year, and commercial improvements are frequent. As explained above, I have substantial experience in semiconductor devices and nitride-based deep-UV light emitting devices. I am also the named inventor on U.S. Patent No. 6,478,871, which was filed before the earliest filing date of February 25, 2013, for the '117 Patent. *See* **Ex. 1008**. Thus, I am well-aware of the state of the art relevant to the '117 Patent and with what characteristics would define an artisan in this field with ordinary or average skill.

34. Based on my experience and the above considerations, it is my opinion that a person having ordinary skill in the art at the time of the alleged invention would have a Bachelor's degree in physics, electrical engineering, materials science, or a related field, and three to five years of experience in semiconductor devices, with specific experience in nitride based LEDs.

35. I also recognize that a less skilled definition is possible for a POSITA relevant to the '117 Patent. However, my opinions expressed below are the same even if a significantly lower definition is adopted, especially as the prior art that I have considered discloses each limitation of the challenged claim of the '117 Patent.

VI. OVERVIEW OF THE '117 PATENT

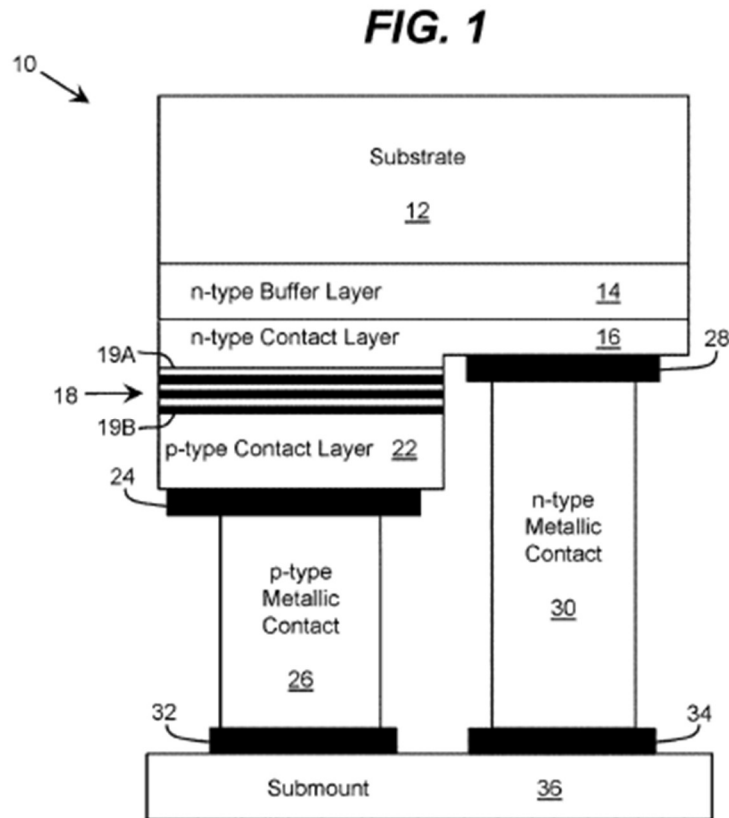
36. The '117 Patent concerns semiconductor structures with inhomogeneous regions. Ex. 1001, at Title.

37. According to the '117 Patent, conventional light emitting diodes (LEDs) are composed of semiconductor layers. *Id.*, 1:38. During operation of an LED, a voltage bias is applied across doped layers, which leads to injection of electrons and holes into an active layer where electron-hole recombination leads to light generation. *Id.*, 1:39-42. Each semiconductor layer has a particular combination of molar fractions for the various chemical elements, which influences the optical properties of the semiconductor layer. *Id.*, 1:44-48. In

particular, a refractive index and absorption characteristics of a semiconductor layer are sensitive to the molar fractions of the semiconductor alloy forming the layer. *Id.*, 1:48-51.

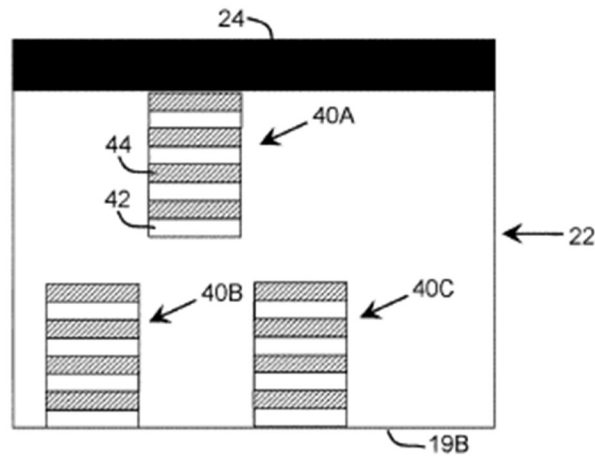
38. The '117 Patent asserts that conventional deep ultraviolet LEDs “have a low efficiency due to light trapping within the device, light absorption in the semiconductor layers, as well as light absorption in the contact regions.” *Id.*, 1:52-55. The '117 Patent allegedly improves the prior art structure with “a design using ultraviolet transparent p-type cladding and contact layers, an ultraviolet reflecting ohmic contact, and chip encapsulation having an optimized shape and refractive index” so that the light extraction efficiency is improved. *Id.*, 1:55-60.

39. In the purportedly new LED structure described in the '117 Patent, the semiconductor layer includes a plurality of inhomogeneous regions. *Id.*, 2:4-5. This LED structure is depicted in Figure 1 of the '117 Patent, where the emitting device 10 includes a semiconductor heterostructure having multiple semiconductor layers, including an active region 18 and a p-type contact layer 22:



40. The '117 Patent discloses that the p-type contact layer 22 is a group III nitride semiconductor layer. *Id.*, 5:11-18. The '117 Patent also teaches a p-type metallic contact 26. Figure 1 above shows that the p-type contact layer 22 (“group III nitride semiconductor layer”) is located between the active region 18 and the p-type metallic contact 26. Further, the p-type contact layer 22 has one or more inhomogeneous regions located therein. *Id.*, 5:36-39. These inhomogeneous regions are arranged at different levels along a height of the semiconductor structure. *Id.*, 6:41-45. This can be seen by the inhomogeneous regions 40A-C in Figure 3A:

FIG. 3A



41. Further, Figure 3A shows that inhomogeneous regions 40A in a first level are vertically offset from inhomogeneous regions 40B, 40C in a second level. The inhomogeneous regions can include one or more of: a set of transparent regions, a set of reflective regions, and/or a set of conductive regions. *Id.*, 5:43-46. Additionally, each inhomogeneous region in the p-type contact layer “can have a set of attributes that differ from the group III nitride material forming the semiconductor layer.” *Id.*, 13:14-17.

VII. SUMMARY OF THE PROSECUTION HISTORY

42. The '117 Patent was filed on December 30, 2015 and purports to claim priority to Provisional Application No. 61/768,581, filed on February 25, 2013. Ex. 1001, (22), (60). The '117 Patent is also a continuation-in-part of the application that issued as U.S. Patent No. 9,331,224 (the “224 Patent”). *Id.* at

(63). To overcome a double patenting rejection, the '117 Patent is terminally disclaimed to the '224 Patent. *Id.* at Notice.

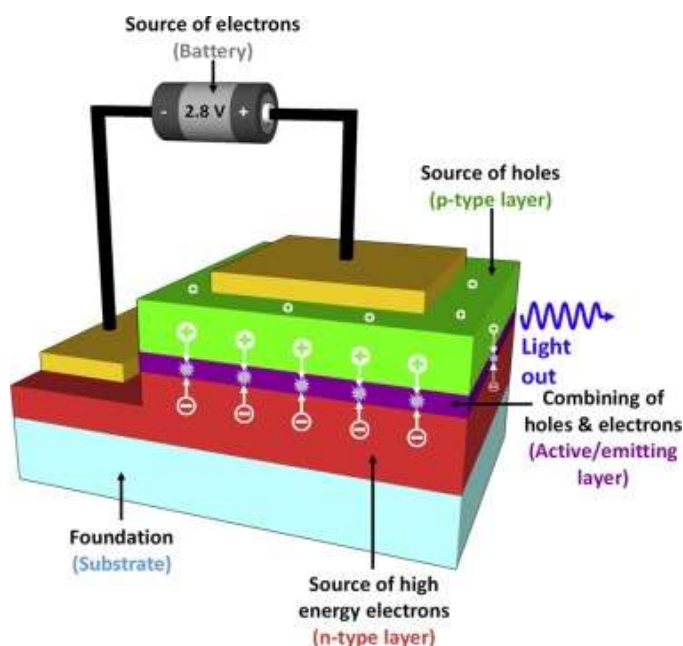
43. The prior art Ohmae (Ex. 1004) and Ban (Ex. 1005) references were not cited or discussed during prosecution of the '117 Patent. Ex. 1001; Ex. 1018. The Shur reference (Ex. 1006) was cited on an IDS but was not discussed during prosecution. *Id.* The prior art Saxler reference (Ex. 1007) was used as the basis for an obviousness rejection in combination with U.S. Patent Application Publication No. 2013/0270514 to Saxler ("Saxler '514") for claims not challenged here (claims 8-10). *See, e.g.*, Ex. 1018, 100-102. Applicant argued that the combination of Saxler '514 (the base reference) and Saxler "does not disclose or suggest a single semiconductor layer having a plurality of inhomogeneous regions arranged within multiple levels of the single semiconductor structure." Ex. 1008, 74. The Applicant was wrong, as I will explain in detail in Ground 4, below.

VIII. BACKGROUND TECHNOLOGY

A. Background of LED Technology

44. A light-emitting diode, or an LED, is a semiconductor light source that emits light when current flows through the device. The LED is comprised of a p-n junction diode having a p-type region (positive terminal) and an n-type region (negative terminal). A p-type semiconductor has a larger concentration of holes than electrons, whereas an n-type semiconductor has a larger concentration of

electrons than holes. When voltage is applied across the terminals of the LED, electrons (formed in the conduction band of the semiconductor) recombine with holes (formed in the valence band of the semiconductor) to release photons. This recombination process, often referred to as electroluminescence, is how an LED generates and emits light.



45. The '117 Patent was filed on February 25, 2013. Prior to the filing of the '117 Patent, alloy group III-Nitride or gallium nitride (GaN) based materials, such as GaN, InGaN, and AlGaN, were well known and have been used for years in the design and development of light emitting diodes (LEDs). *See, e.g.*, **Ex. 1009**, “Phase separation and ordering in InGaN alloys grown by molecular beam epitaxy,” at 1389-1395; **Ex. 1010**, “Growth kinetics of AlGaN films by plasma-assisted molecular-beam epitaxy,” at 295-297; **Ex. 1011**, “Phase Separation and

Atomic Ordering in AlGaInN Alloys,” at 193-204; **Ex. 1012**, “Nitride-based semiconductors for blue and green light-emitting devices,” at 351-359; **Ex. 1013**, “Photoconductive detectors based on partially ordered AlGaN alloys grown by molecular beam epitaxy,” at 2203-2205.

46. All semiconductor materials have a band gap, which relates to the difference in energy between the valence band and the conduction band of a semiconductor material. Accordingly, all GaN based semiconductors (*e.g.*, AlGaN, GaN) have a band gap as an inherent property of the material.

B. Inhomogeneous Regions

47. Compound semiconductor materials have been synthesized using a variety of methods as early as the 1960’s. It was known since the 1970’s that ternary and quaternary III-V compound semiconductor materials have lateral inhomogeneities caused by lateral changes in the material composition itself. The random distribution of the alloy’s components gives rise to an electron scattering mechanism caused by the local (and lateral) changes in the semiconductor bandgap.

48. In 1976, Harrison and Hauser produced a model which described the mean time between electron collisions caused by the random changes in the bandgap. *See, e.g.*, **Ex. 1014** (“Alloy scattering in ternary III-V compounds”) at 5347. It is well known that this collision time is proportional to the electron

mobility which relates the low field conductivity to the concentration of electrons. The random distribution of the alloy's components is native to the epitaxial processes used to form the semiconductor materials. Indeed, this is described in the '117 Patent as "Ternary and quaternary nitride semiconductor epitaxial layers inherently grow inhomogeneously due to contrasting optimum growth conditions needed for respective binary layers." Ex. 1001,18:15-18. It is clear to one skilled in the art that growth of compound semiconductor alloys will result in compositional fluctuations and inhomogeneous regions within the semiconductor layer. Accordingly, the concept of "inhomogeneous regions" have been known to a POSITA dating back to the 1960-1970 timeframe.

49. For GaN based semiconductor materials having at least three chemical elements (*e.g.*, InGaN or AlGaN), the distribution of metal atoms (*e.g.*, In, Al, Ga) within the crystal structure of the material during growth of the semiconductor layer can vary, including randomly, leading to compositional fluctuations, which are sometimes referred to as inhomogeneities, across the lateral dimension (the direction parallel to the surface of the substrate). *See, e.g.*, **Ex. 1009**, 1391. For example, inherently in a single layer of AlGaN, there may be more Ga atoms than Al atoms at one location and more Al atoms than Ga atoms at another location within the semiconductor layer due to random ordering. *See, e.g.*, **Ex. 1013**, 2203. This lateral inhomogeneity or composition fluctuation of AlGaN semiconductor

layer is an inherent property of AlGa_N. Similarly, InGa_N will have inherent compositional fluctuations where there are regions having more In atoms than Ga atoms. *See, e.g., Ex. 1009*, 1391. This inherent, compositional fluctuation of the Ga_N based semiconductor alloys can lead to inhomogeneous regions in the semiconductor layer, and the phenomenon was well known before the invention of the '117 Patent.

50. Therefore, the '117 Patent did not invent inhomogeneous regions in a Ga_N based semiconductor. Rather, the ability to include inhomogeneous regions in a group III nitride semiconductor layer was well known prior to the '117 Patent.

C. Epitaxial Lateral Overgrowth

51. Further, a POSITA would understand that epitaxial lateral overgrowth (“ELO”) techniques can also be used in group III nitrides to create inhomogeneous regions. ELO of Ga_N and AlGa_N materials dates to the early 2000’s. In a 2001 review article published by Hiramatsu (**Ex. 1015**, “Epitaxial Lateral Overgrowth Techniques Used In Group III Nitride Epitaxy”), lateral inhomogeneous regions are known to appear from the laterally patterned ELO mask (*e.g.*, silicon dioxide) itself and from the distribution of threading dislocations in the Ga_N above the mask which are often concentrated above the openings in the patterned masking layer.

52. Indeed, the '117 Patent recognizes that ELO can be used to form inhomogeneous regions: "Aspects of the invention provide a semiconductor structure The semiconductor structure can include inhomogeneous regions formed by one or more of patterning, masking, epitaxial growth, epitaxial overgrowth, deposition techniques, and/or the like." Ex. 1001, 4:4-14. Clearly, ELO predates the '117 Patent by over a decade and ELO produces the inhomogeneous regions. Moreover, I myself have several patents directed to the ELO technology, all prior to the filing of the '117 Patent. *See, e.g., Ex. 1008* ("Single Step Process For Epitaxial Lateral Overgrowth Of Nitride Based Materials").

IX. CLAIM CONSTRUCTION

53. In conducting my analysis of the claims of the '117 Patent, I have applied the claim language consistent with the customary and ordinary meaning standard described above.

54. The claim terms in the '117 Patent should be given their plain and ordinary meaning because they are commonly used terms in the English language and/or are common in the relevant fields of semiconductor devices and LEDs.

55. While it is my opinion that there are no claim terms that require a construction, for clarity, I do note that the '117 Patent describes "**inhomogeneous regions**" as follows: "Each inhomogeneous region has **one or more attributes**

that differ from a material forming the semiconductor layer. The inhomogeneous regions can include one or more regions configured based on radiation having a target wavelength. These regions can include **transparent and/or reflective regions**. The inhomogeneous regions also can include one or more regions having a **higher conductivity** than a conductivity of the radiation-based regions, e.g., at least ten percent higher” (Ex. 1001, 2:5-13; emphasis added) and “The semiconductor structure can include inhomogeneous regions formed by one or more of patterning, masking, epitaxial growth, epitaxial overgrowth, deposition techniques, and/or the like.” Ex. 1001, 4:11-14.

56. The ’117 Patent describes that “A **conductive region** can be configured to **promote conductivity** of carriers in the semiconductor structure. A conductive region can have a **higher concentration of carriers** due to, for example, a locally reduced band gap of the semiconductor layer, a local **high doping** of the semiconductor layer, and/or the like.” Ex. 1001, 5:60-65; emphasis added. The ’117 Patent went on to define “conductive region” and explains, “In an embodiment, a conductive region has a **conductivity at least ten percent higher** than a conductivity of a transparent region and a conductivity of a reflective region and a **higher conductivity than a base semiconductor material** for the layer.” *Id.*, 6:5-9; emphasis added. The ’117 Patent also defines “transparent region” and explains that “a region is a **transparent region** when the region **allows at least ten**

percent of radiation having a target wavelength, which is radiated at a normal incidence to an interface of the region, to pass there through.” *Id.*, 5:46-49; emphasis added.

57. The ’117 Patent likewise defines the “reflective region” and explains, “as used herein, a region is a **reflective region** when the region **reflects at least ten percent of radiation having a target wavelength**, which is radiated at a normal incidence to an interface of the region. In an embodiment, the target wavelength of the radiation corresponds to a wavelength of radiation emitted or sensed by the active region 18 during operation of the device 10.” *Id.*, 5:50-53; emphasis added. Further, “A reflective region can be formed of one or more composite mirrors. A composite mirror includes any structure having multiple sublayers of dielectric or metallic material.” *Id.*, 6:64-66.

58. The ’117 Patent further states, “As used herein, unless otherwise noted, the term “**set**” means **one or more (i.e., at least one)**” *Id.*, 3:67-4:1; emphasis added.

X. IDENTIFICATION OF THE PRIOR ART AND SUMMARY OF OPINIONS

59. I understand that the earliest priority date for the claims in the ’117 Patent is the filing of a provisional application on February 25, 2013.

60. As explained below, it is my opinion that the following prior art references disclose all technical features in the challenged claim of the ’117 Patent:

- U.S. Patent Application Publication No. 2007/0085093 to Ohmae et al. (“**Ohmae**”)
- Japan Patent No. 2000-22283 to Ban et al. (“**Ban**”)
- W.O. Publication No. 2013/023197 to Shur et al. (“**Shur**”)
- U.S. Patent Application Publication No. 2004/0031956 to Saxler (“**Saxler**”)

Specifically, it is my opinion that Claim 1 of the ’117 Patent is unpatentable as being anticipated and/or rendered obvious by the prior art.

A. Summary of Opinions under 35 U.S.C. § 102 and § 103

61. It is my opinion that Ohmae anticipates and/or renders obvious Claim 1 of the ’117 Patent, as further described below.

62. It is my opinion that Ban anticipates and/or renders obvious Claim 1 of the ’117 Patent, as further described below.

63. It is my opinion that Shur anticipates and/or renders obvious Claim 1 of the ’117 Patent, as further described below.

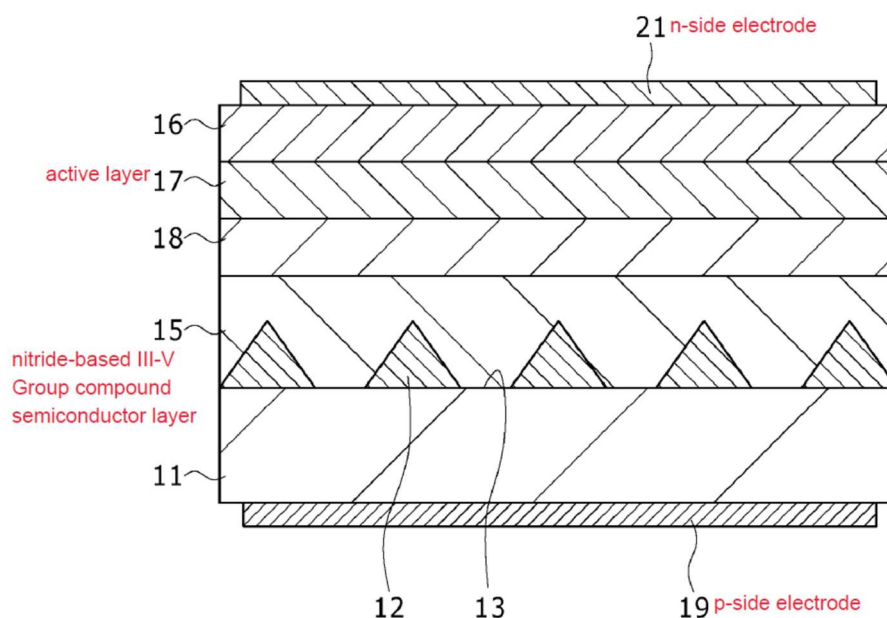
64. It is my opinion that Saxler anticipates and/or renders obvious Claim 1 of the ’117 Patent, as further described below.

XI. ANALYSIS OF THE CHALLENGED CLAIM

A. Ground 1: Ohmae Anticipates and/or Renders Obvious Claim 1

65. I will provide a brief overview of the Ohmae publication before explaining how it discloses each and every limitation of the challenged claim.

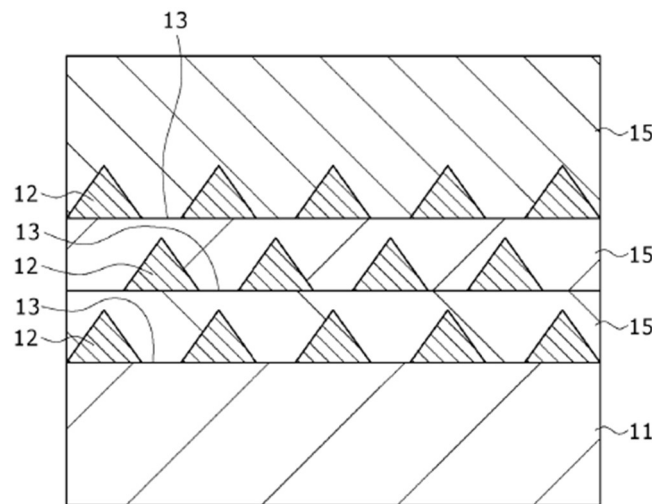
66. Ohmae is directed to a “method for manufacturing a light-emitting diode.” Ex. 1004 (“Ohmae”), Abstract. Ohmae’s light-emitting diode includes a “nitride-based III-V Group compound semiconductor layer 15,” “an active layer 17,” and “a p-side electrode 19.” *Id.*, [0231]. As shown in annotated Figure 35, below, the nitride-based III-V Group compound semiconductor layer 15 is located between the active layer 17 and the p-side electrode 19.



67. Further, Ohmae teaches “forming protruded portions 12 on the substrate 11, followed by repeating the step plural times. In this case, the

protruded portions in the respective layers are formed at positions that are mutually shifted by a half cycle within planes parallel to the main surface of the substrate 11.” *Id.*, [0247]. Figure 39, below, shows the result of a plurality of layers of protruded portions 12:

FIG. 39



1. Claim 1

68. Claim 1 of the '117 Patent recites the following limitations (I have added alphabetical labels to each limitation):

[1.preamble] A semiconductor heterostructure, comprising:

[1a] an active region;

[1b] a metallic contact;

[1c] a group III nitride semiconductor layer located between the active region and the metallic contact,

[1d] the semiconductor layer including a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction of the semiconductor layer,

[1e] wherein some of the inhomogeneous regions in a first level of the semiconductor layer are vertically offset from inhomogeneous regions in a second level of the semiconductor layer, and

[1f] wherein the plurality of inhomogeneous regions include one or more of a set of transparent regions, a set of reflective regions and/or a set of conductive regions,

[1g] each of the inhomogeneous regions having a set of attributes differing from a group III nitride material forming the semiconductor layer.

69. I will address each of these limitations in turn.

[1.preamble] “A semiconductor heterostructure, comprising:”

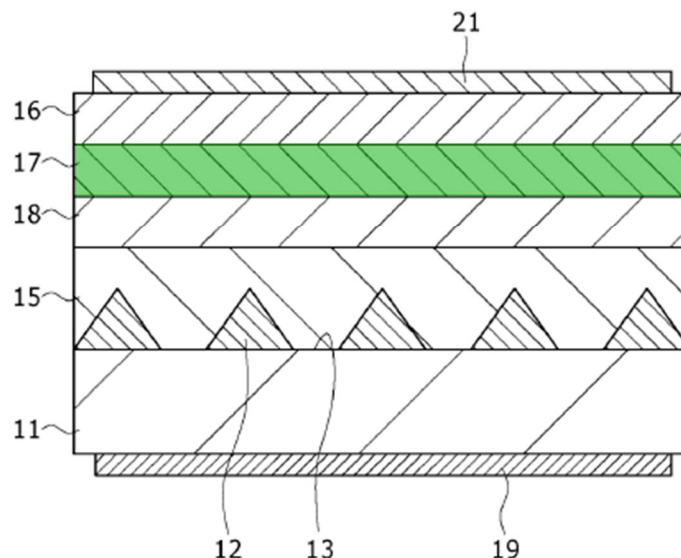
70. To the extent that the preamble is limiting, Ohmae discloses a semiconductor heterostructure. For example, Ohmae discloses that “FIG. 35 is a sectional view illustrating a method for manufacturing a light-emitting diode according to a further embodiment of the invention.” Ex. 1004, [0100]. Further, the ’117 Patent discloses, “In general, each emitting device 10 includes a semiconductor heterostructure having multiple semiconductor layers.” Ex. 1001 at

4:34-36. Accordingly, the light-emitting diode of Ohmae is a semiconductor heterostructure having multiple semiconductor layers.

[1a] “an active region;”

71. Ohmae discloses an active region. For example, Ohmae teaches “an active layer 17 using a nitride-based III-V Group compound semiconductor.” Ex. 1004, [0157]. The active region is shown in green in Figure 35:

FIG. 35



(Annotated FIG. 35)

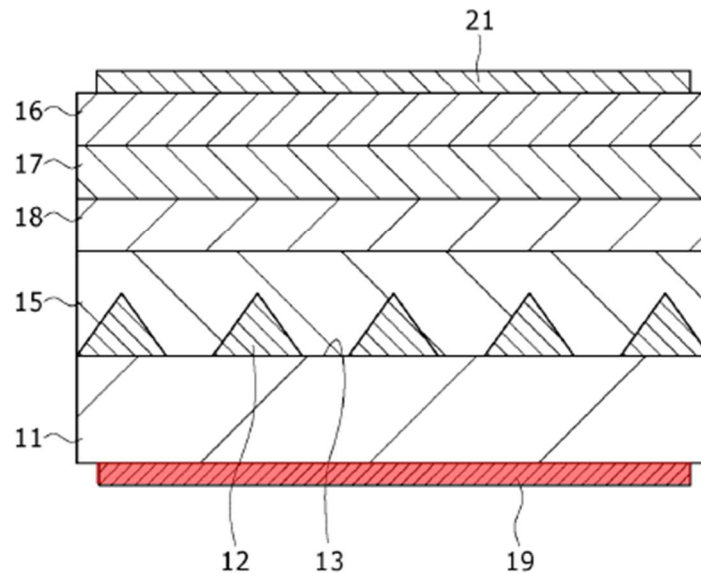
[1b] “a metallic contact;”

72. Ohmae discloses a metallic contact. For example, Ohmae teaches “a p-side electrode 19.” *Id.*, [0231]. Further, Ohmae discloses that [t]he material for the p-side electrode 19 includes, for example, Ag or Pd/Ag, or if necessary, barrier metals made of Ti, W, Cr, WN, CrN or the like.” *Id.*, [0167]. Further, the ’117

Patent discloses that metallic contacts “comprise highly conductive metal.” Ex. 1001, 5:34-35. Therefore, the p-side electrode 19 of Ohmae, which includes highly conductive metal, is a metallic contact.

73. The p-side electrode 19 is shown in red in Figure 35:

FIG. 35



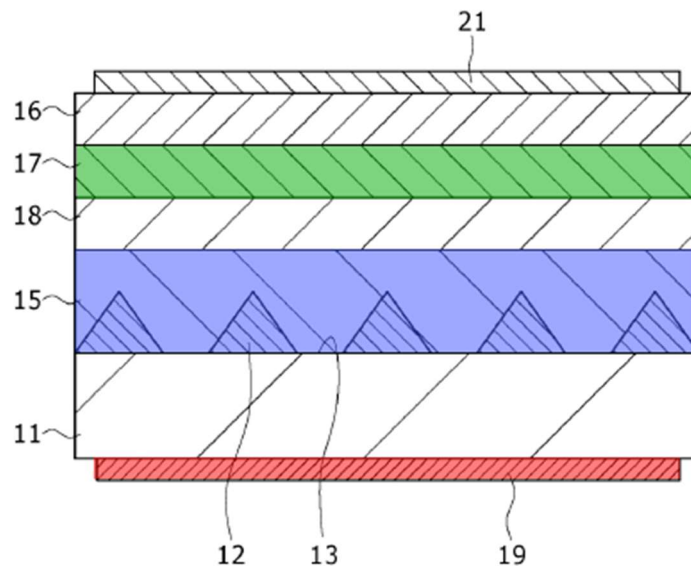
(Annotated FIG. 35)

[1c] “a group III nitride semiconductor layer located between the active region and the metallic contact,”

74. Ohmae discloses this limitation. For example, Ohmae teaches a “nitride-based III-V Group compound semiconductor layer 15” located between the active region (active layer 17) and the metallic contact (p-side electrode 19). Ex. 1004, [0231]. As shown in Figure 35 below, the blue nitride-based III-V

Group compound semiconductor layer 15 is located between the green active region 17 and the red p-side electrode 19 (“metallic contact”).

FIG. 35



(Annotated FIG. 35)

[1d] “the semiconductor layer including a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction of the semiconductor layer,”

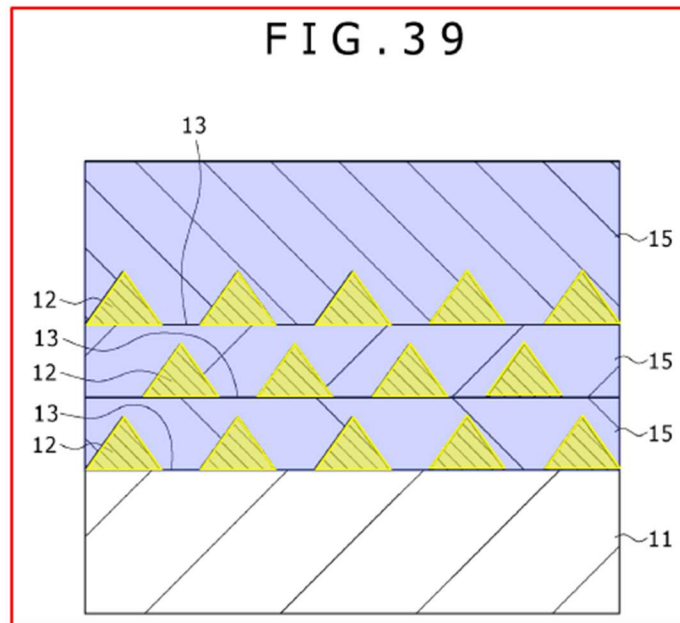
75. Ohmae discloses this limitation. For example, Ohmae teaches forming a plurality of protruded portions on the substrate and subsequently growing a nitride-based III-V Group semiconductor layer that embeds the protruded portions. *Id.*, [0021]. Specifically, “the step of forming protruded portions 12 and growing the nitride-based III-V Group compound semiconductor layer 15 like the first embodiment starts from forming protruded portions 12 on the

substrate 11, followed by repeating the step plural times.” *Id.*, [0247]. Further, Ohmae discloses, “The materials for the protruded portion may be of various types and may be electrically conductive or non-conductive. Mention is made, for example, dielectric materials such as oxides, nitrides, carbides and the like and conductors such as of metals, alloys and the like (including transparent conductors).” *Id.*, [0026].

76. In my opinion, protruded portions made of dielectric materials or conductors would constitute inhomogeneous regions within the semiconductor layer composed of nitride-based III-V Group compound semiconductor. In addition, in my opinion, the nitride-based semiconductor material grown on top of the protruded portions are also inhomogeneous regions. Indeed, the ’117 Patent includes examples for forming inhomogeneous regions: “Aspects of the invention provide a semiconductor structure The semiconductor structure can include inhomogeneous regions formed by one or more of patterning, masking, epitaxial growth, epitaxial overgrowth, deposition techniques, and/or the like.” Ex. 1001, 4:4-14.

77. Additionally, repeating the step of forming protruded portions and growing the semiconductor layer results in a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction of the semiconductor layer. Figure 39 shows a plurality of yellow protruded

portions 12 (“inhomogeneous regions”) arranged within multiple levels of the blue semiconductor layer 15 along a height direction of the semiconductor layer 15.



(Annotated FIG. 39)

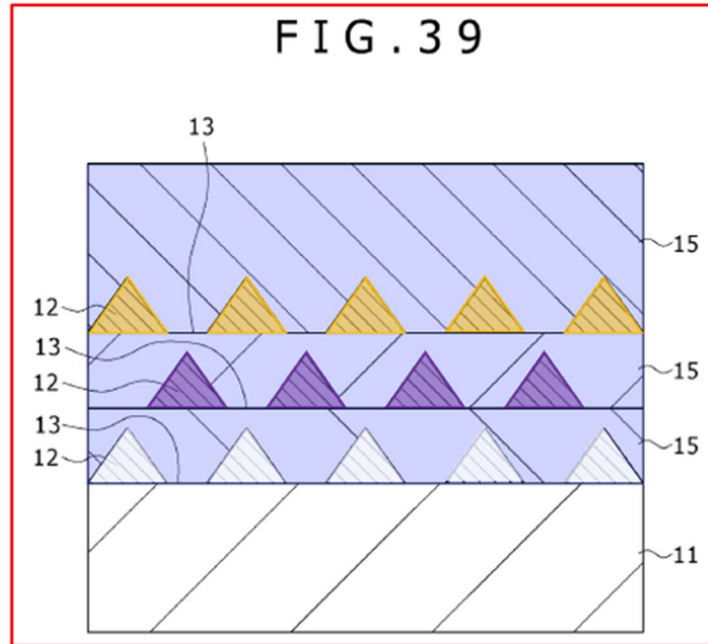
78. Based on the teachings of Figure 39 of Ohmae, in my opinion, the nitride-based III-V Group compound semiconductor layer 15 in Figure 35 of Ohmae can include multiple levels (i.e., multiple sub-layers 15) as shown in Figure 39 of Ohmae, and the protruded portions 12 are arranged within the multiple levels of the nitride-based III-V Group compound semiconductor layer 15 along the vertical direction. Thus, Ohmae discloses this limitation because multiple levels of the protruded portions (as well as semiconductor material grown on top of the protruded portions) form a plurality of inhomogeneous regions arranged within

multiple levels of the semiconductor layer along a height direction of the semiconductor layer.

[1e] “wherein some of the inhomogeneous regions in a first level of the semiconductor layer are vertically offset from inhomogeneous regions in a second level of the semiconductor layer, and”

79. Ohmae discloses this limitation. For example, Ohmae teaches, “the step of forming protruded portions 12 and growing the nitride-based III-V Group compound semiconductor layer 15 like the first embodiment starts from forming protruded portions 12 on the substrate 11, followed by repeating the step plural times. In this case, the protruded portions in the respective layers are formed at positions that are **mutually shifted by a half cycle** within planes parallel to the main surface of the substrate 11.” Ex. 1004, [0247]; emphasis added.

80. A POSITA would understand that as a result of the layers formed at positions that are **mutually shifted by a half cycle**, some of the inhomogeneous regions in a first level of the semiconductor layer are vertically offset (*e.g.*, vertically misaligned) from inhomogeneous regions in a second level of the semiconductor layer. Figure 39, below, shows that the inhomogeneous regions in a first level of the semiconductor layer (colored in orange) are vertically offset from inhomogeneous regions in a second level of the semiconductor layer (colored in purple).



(Annotated FIG. 39)

[1f] “wherein the plurality of inhomogeneous regions include one or more of a set of transparent regions, a set of reflective regions and/or a set of conductive regions,”

81. Ohmae discloses this limitation. For example, Ohmae teaches that “the materials for the protruded portion may be of various types and may be **conductive** or non-conductive. Mention is made, for example, dielectric materials such as **oxides, nitrides**, carbides and the like and **conductors** such as of metals, alloys and the like (including **transparent conductors**).” *Id.*, [0026]; emphasis added. In my opinion, Ohmae explicitly discloses that the protruded portions are made of “transparent” and “conductor” material; thus, the protruded portions of Ohmae formed of “oxides,” “conductors,” and “transparent conductors” constitute a set of transparent regions and a set of conductive regions. Further, metals are

reflective. The '117 Patent defines “reflective region” as “a region is a reflective region when the region reflects at least ten percent of radiation having a target wavelength.” Ex. 1001, 5:50-52. As a result, the “metal” protruded portion of Ohmae constitutes a set of reflective regions. Indeed, Ohmae describes that “the second portion 12b of the protruded portion 12 is made of a metal or an alloy, light emitted from the active layer 17 can be **reflected** to a side opposite to the substrate 11” Ex. 1004, [0210]; emphasis added.

82. Therefore, Ohmae discloses wherein the plurality of inhomogeneous regions include one or more of a set of transparent regions, a set of reflective regions and/or a set of conductive regions.

[1g] “each of the inhomogeneous regions having a set of attributes differing from a group III nitride material forming the semiconductor layer.”

83. Ohmae discloses this limitation. For example, Ohmae describes, “the materials for the protruded portion may be of various types and may be electrically conductive or non-conductive. Mention is made, for example, **dielectric materials** such as oxides, nitrides, carbides and the like and **conductors** such as of metals, alloys and the like (including transparent conductors).” *Id.*, [0026]; emphasis added. Dielectric materials and conductors have different material attributes than the group III nitride semiconductor material. For example, dielectric materials are electrically insulating; metals and conductors are electrical conducting; in contrast,

semiconductor materials have an electrical conductivity that falls between that of a metal and an insulator. Further, dielectric materials and conductors have different chemical composition than the group III nitride semiconductor material.

Accordingly, due to their different material attributes, the protruded portions made of dielectric materials or conductors have a set of attributes different from the nitride-based III-V Group compound semiconductor layer.

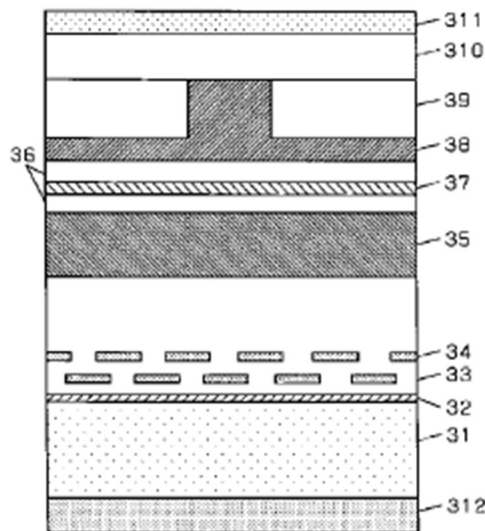
84. Accordingly, Ohmae discloses all the limitations of Claim 1.

B. Ground 2: Ban Anticipates and/or Renders Obvious Claim 1

85. I will provide a brief overview of the Ban before explaining how it discloses each and every limitation of the challenged claim.

86. Ban is directed to a “semiconductor device used in a light emitting element.” Ex. 1005, [0001]. The structure of the semiconductor laser device includes an n-type GaN layer 33, a SiO₂ mask layer 34, a GaInN quantum well active layer 37, and a Ni/Au layer 312 formed on the back surface of the substrate. *Id.*, [0042]. Further, multiple layers of the SiO₂ mask layer 34 are grown with the mask shifted between the first layer and the second layer. *Id.*, [0046]. The layout of the semiconductor device of Ban is shown in Figure 3:

【図3】



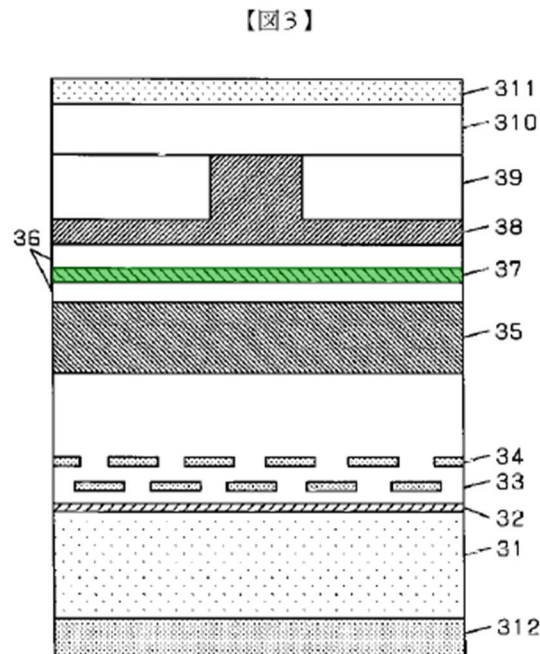
1. Claim 1

[1.Preamble] “A semiconductor heterostructure, comprising:”

87. To the extent the preamble is limiting, Ban discloses a semiconductor heterostructure. For example, Ban discloses “a manufacturing method of the semiconductor device used in a light emitting element.” *Id.*, [0001]. Further, the ’117 Patent discloses, “In general, each emitting device 10 includes a semiconductor heterostructure having multiple semiconductor layers.” Ex. 1001 at 4:34-36. As a result, a POSITA would have understood that the light emitting element of Ban is a semiconductor heterostructure having multiple semiconductor layers.

[1a] “an active region;”

88. Ban discloses an active region. For example, Ban teaches that “37 is a GaInN quantum well active layer.” Ex. 1005, [0042]. Figure 3 of Ban below shows the active region (colored in green):

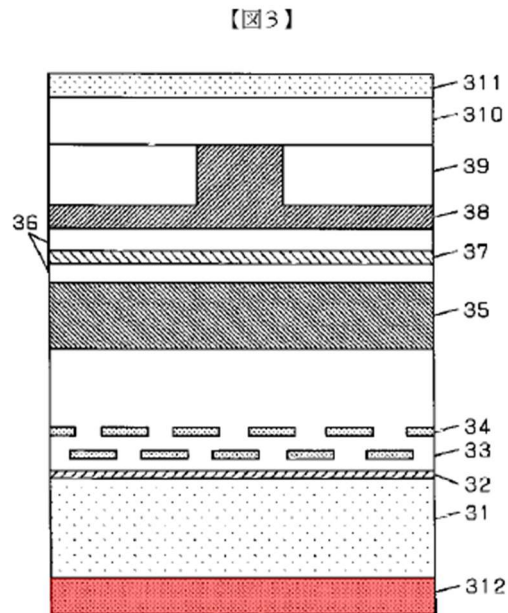


(Annotated FIG. 3)

[1b] “a metallic contact;”

89. Ban discloses a metallic contact. For example, Ban teaches “a Ni/Au layer 312 (with a film thickness of 500nm) is formed on the back surface of the substrate.” *Id.*, [0042]. Ban discloses that “a Ni/Au layer” can “serve as the metal layer.” *Id.*, [0034]. Further, the ’117 Patent discloses that metallic contacts “comprise highly conductive metal.” Ex. 1001, 5:34-35. The Ni/Au layer of Ban formed on the back surface of the substrate is a metal layer that constitutes the

metallic contact. Figure 3 of Ban, below, shows the metallic contact (colored in red):



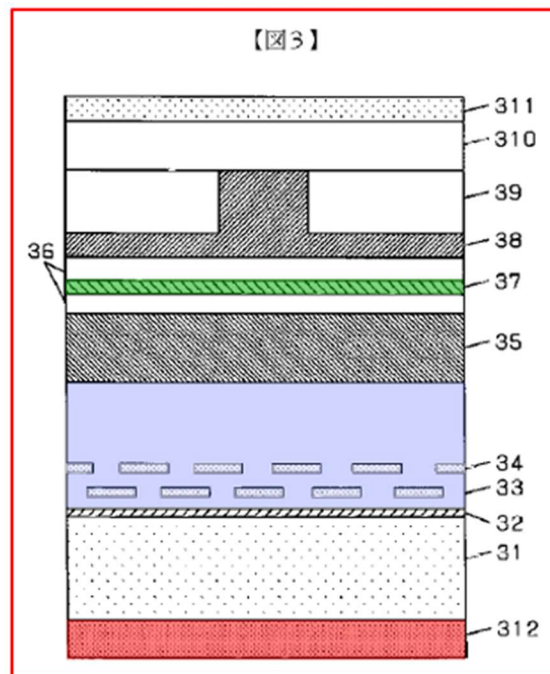
(Annotated FIG. 3)

[1c] “a group III nitride semiconductor layer located between the active region and the metallic contact,”

90. Ban discloses this limitation. For example, Ban teaches that “33 is an n-type GaN layer,” which is a “group III-V compound semiconductor layer.” Ex. 1005, [0042], [0043].

91. Ban further discloses the group III nitride semiconductor layer is located between the active region and the metallic contact. As shown in annotated Figure 3 of Ban, below, the blue-colored n-type GaN layer 33 (“group III nitride semiconductor layer”, excluding the SiO₂ mask layers 34) is located between the

green-colored active layer 37 (“active region”) and the red-colored Ni/Au layer 312 (“metallic contact”).



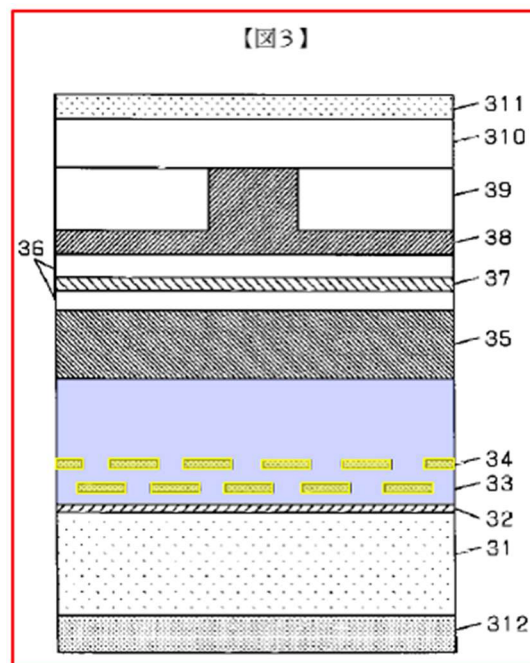
(Annotated FIG. 3)

[1d] “the semiconductor layer including a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction of the semiconductor layer,”

92. Ban discloses this limitation. For example, Ban uses a “SiO₂ mask layer,” which “is embedded in a stripe shape in the group III-V compound semiconductor layer on the substrate.” *Id.*, [0042], [0043]. In my opinion, the SiO₂ mask layer constitutes an inhomogeneous region. Indeed, the ’117 Patent includes examples for forming inhomogeneous regions: “Aspects of the invention provide a semiconductor structure The semiconductor structure can include inhomogeneous regions formed by one or more of patterning, masking, epitaxial

growth, epitaxial overgrowth, deposition techniques, and/or the like.” Ex. 1001, 4:4-14.

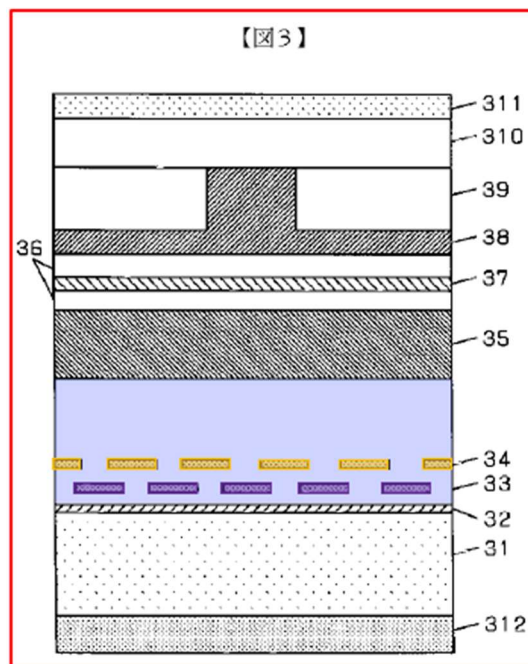
93. Ban further teaches that “a SiO_2 mask layer 34 ... is formed by plasma CVD or the like, and a striped opening with a pitch of $4\mu\text{m}$ and a width of $1.5\mu\text{m}$ is formed in the [1-100] direction of the GaN.” *Id.*, [0045]. Subsequently, “the stripe shaped SiO_2 mask layer 34 ... of the second layer is formed in the same direction as above by the plasma CVD method or the like.” *Id.*, [0046]. The result is the blue-colored n-type GaN layer 33 (“semiconductor layer”) including a plurality of yellow-colored SiO_2 mask layers 34 (“inhomogeneous regions”) arranged within multiple levels of the semiconductor layer along a height direction of the semiconductor layer, shown in annotated Figure 3 below.



(Annotated FIG. 3)

[1e] “wherein some of the inhomogeneous regions in a first level of the semiconductor layer are vertically offset from inhomogeneous regions in a second level of the semiconductor layer, and”

94. Ban discloses this limitation. For example, Ban teaches that for forming the second layer, “the opening of the mask is **shifted** to the mask of the first layer to form the mask of the second layer.” *Id.*, [0046]; emphasis added. A POSITA would understand that the **shifting** of the mask opening causes mask of the first layer to be vertically offset (*e.g.*, vertically misaligned) from the mask of the second layer. Further, annotated Figure 3, below, shows the inhomogeneous regions in a first level of the semiconductor layer (annotated in orange) are vertically offset from inhomogeneous regions in a second level of the semiconductor layer (annotated in purple).



(Annotated FIG. 3)

[1f] “wherein the plurality of inhomogeneous regions include one or more of a set of transparent regions, a set of reflective regions and/or a set of conductive regions,”

95. Ban discloses this limitation. Ban uses a “SiO₂ mask layer,” which “is embedded in a stripe shape in the group III-V compound semiconductor layer on the substrate.” *Id.*, [0042] and [0043].

96. The ’117 Patent defines “transparent region” and explains that “a region is a transparent region when the region allows at least ten percent of radiation having a target wavelength, which is radiated at a normal incidence to an interface of the region, to pass there through.” Ex. 1001, 5:46-49. A POSITA would understand that SiO₂ (which is similar to fused silica or quartz glass) is a transparent material because it allows at least 10% of radiation having a target wavelength of Ban (e.g., UV to blue light) to pass through. For example, Lee discloses, “The intermediate layer 36 may be formed of a **transparent** insulating material ... For example, the transparent insulating material can be **SiO₂**, SiN_x, Al₂O₃, HfO, TiO₂, or ZrO.” Ex. 1016, 4:65-5:2; emphasis added. Thus, the SiO₂ mask layer 34 of Ban forms a plurality of transparent inhomogeneous regions.

97. Therefore, Ban discloses wherein the plurality of inhomogeneous regions include one or more of a set of transparent regions, a set of reflective regions and/or a set of conductive regions.

[1g] “each of the inhomogeneous regions having a set of attributes differing from a group III nitride material forming the semiconductor layer.”

98. Ban discloses this limitation. For example, Ban describes, “SiO₂ is embedded in a stripe shape in the group III-V compound semiconductor layer on the substrate.” *Id.*, [0043]. A POSITA would understand that the SiO₂ mask layer is made of a dielectric material that has material attributes substantially different from the n-type GaN semiconductor layer. Additionally, the SiO₂ mask layer form a transparent region that has material attributes substantially different from the n-type GaN semiconductor layer.

99. Therefore, Ban teaches that each of the inhomogeneous regions having a set of attributes differing from a group III nitride material forming the semiconductor layer.

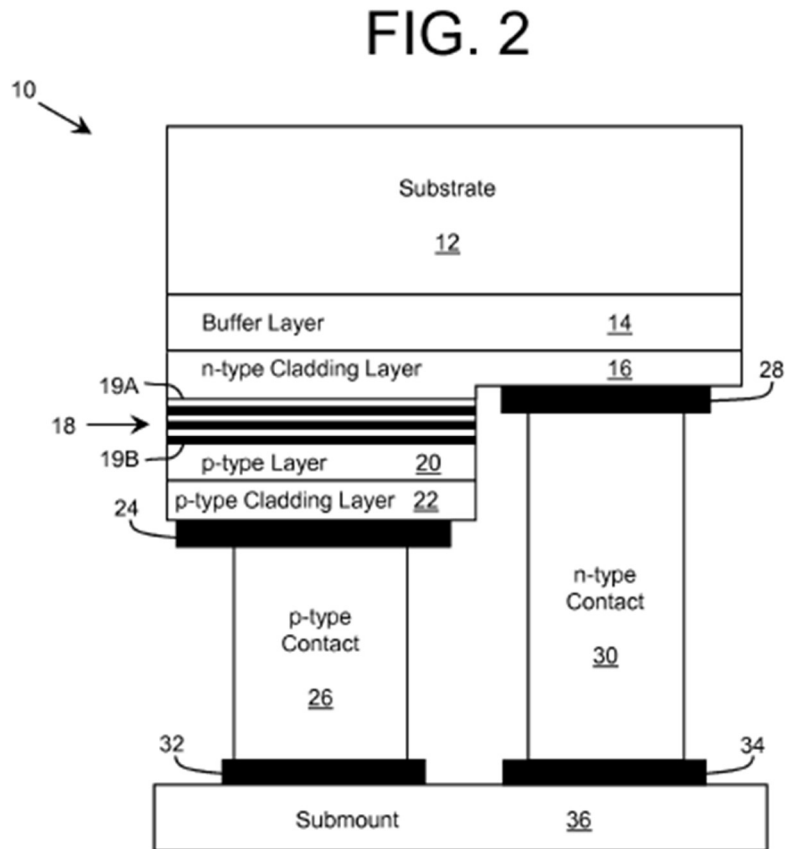
100. Accordingly, Ban discloses each and every limitation of Claim 1.

C. Ground 3: Shur Anticipates and/or Renders Obvious Claim 1

101. I will provide a brief overview of the Shur reference before explaining how it discloses each and every limitation of the challenged claim.

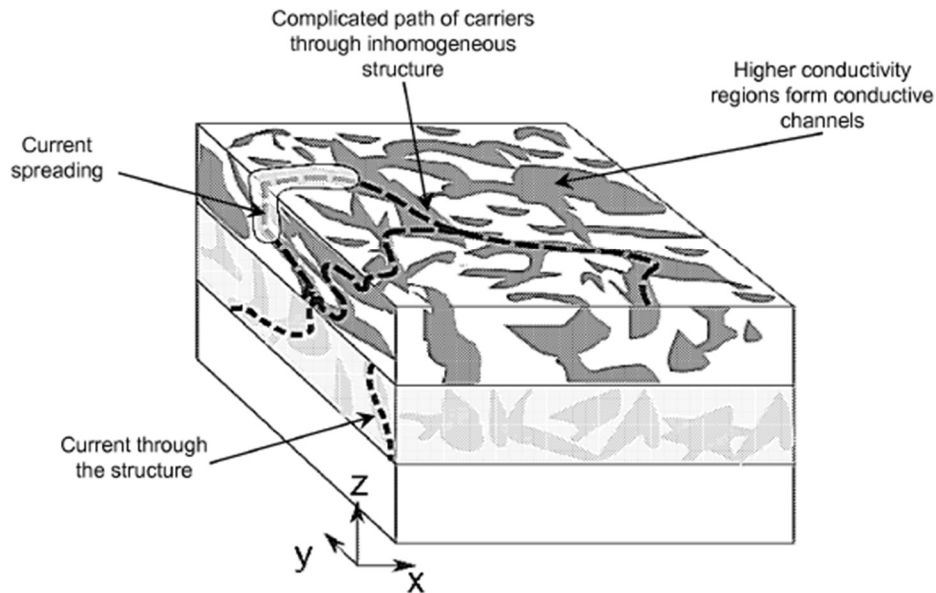
102. Shur discloses “an emitting device.” Ex. 1006, [0002]. The emitting device 10 of Shur includes a heterostructure comprising a substrate 12, an active region 18, a p-type cladding layer 22, and a p-side metal 24. *Id.*, [0033], [0036]. Further, the p-type cladding layer 22 comprises magnesium-doped AlGaIn/AlGaIn

short period superlattice structure (SPSL). *Id.*, [0036]. The emitting device configuration is shown in Figure 2 below:



103. Further, within the layer 22 of Shur comprises inhomogeneous regions. *Id.*, [0054]. Figure 5, below, shows a schematic representation of the inhomogeneous regions within the layer 22:

FIG. 5



1. Claim 1

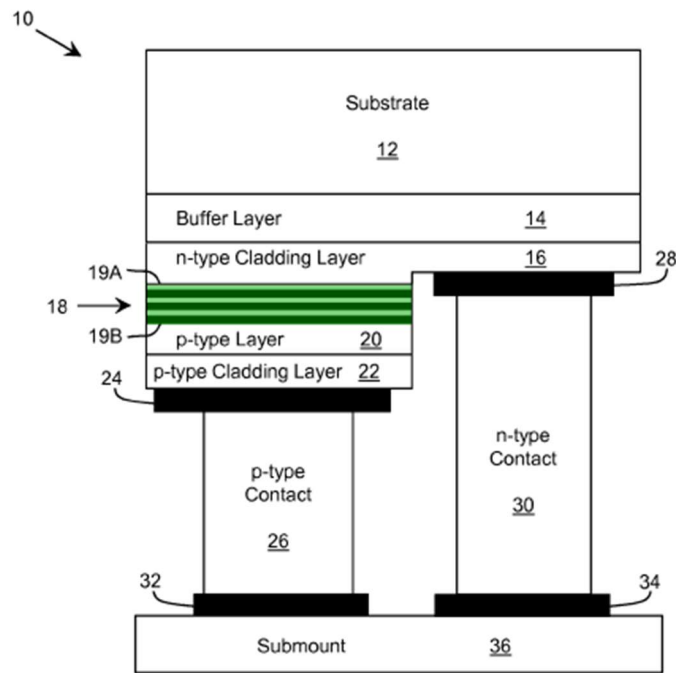
[1.Preamble] “A semiconductor heterostructure, comprising:”

104. To the extent that the preamble is limiting, Shur discloses a semiconductor heterostructure. For example, Shur discloses a semiconductor device (e.g., emitting device 10 of FIG. 2) that includes a heterostructure. *Id.*, [0033], FIG.2. Thus, Shur teaches a semiconductor heterostructure.

[1a] “an active region;”

105. Shur discloses an active region. For example, Shur teaches “an active region 18.” *Id.*, [0033]. This element is shown in green in annotated Figure 2:

FIG. 2



(Annotated FIG. 2)

106. Further, Shur teaches “an active region 18 (e.g., a series of alternating quantum wells and barriers) composed of $\text{In}_y\text{Al}_x\text{Ga}_{1-x-y}\text{N}$, $\text{Ga}_z\text{In}_y\text{Al}_xB_{1-x-y-z}\text{N}$, and $\text{Al}_x\text{Ga}_{1-x}\text{N}$ semiconductor alloy, or the like.” Thus, Shur discloses an active region.

[1b] “a metallic contact;”

107. Shur discloses a metallic contact. For example, Shur teaches a p-side “metal 24” that can form an “ohmic contact[.]” *Id.*, [0036]. A POSITA would understand that the p-side metal and the ohmic contact are metallic contacts of the semiconductor device. The p-side metal 24 is shown in red in annotated Figure 2:

10

Substrate 12

Buffer Layer 14

n-type Cladding Layer 16

18

19A

19B

p-type Layer 20

p-type Cladding Layer 22

24

p-type Contact 26

n-type Contact 30

32

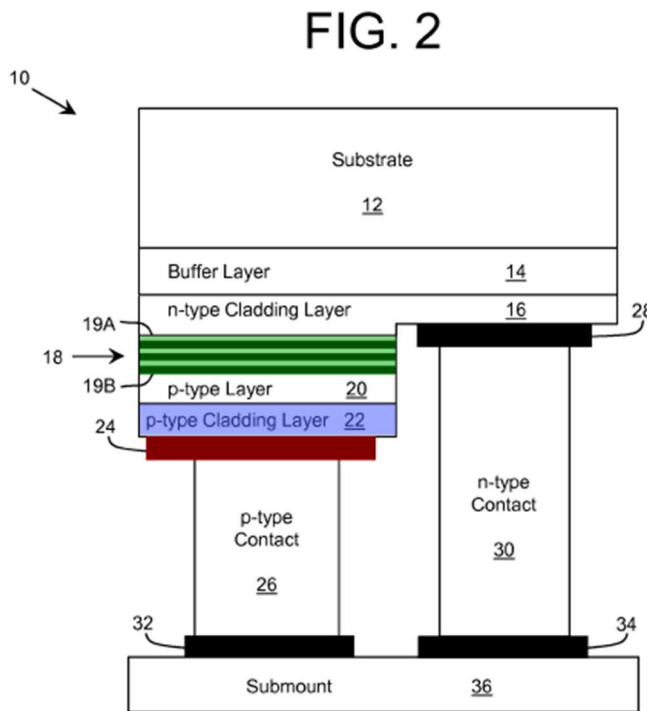
34

Submount 36

108. Thus, the p-side metal 24 of Shur constitutes the claimed metallic contact.

109. Shur discloses this limitation. For example, Shur teaches that “the p-type cladding layer 22 ... can comprise a short period superlattice lattice structure, such as an at least partially transparent magnesium (Mg)-doped AlGa_N/AlGa_N short period superlattice structure (SPSL).” *Id.* at [0036]. A POSITA would understand that AlGa_N is a group III nitride semiconductor layer because aluminum (Al) and gallium (Ga) are both group III elements and combined with nitride (N) form AlGa_N, which is a group III nitride. As a result, the p-type cladding layer 22 constitutes a group III nitride semiconductor layer.

110. Shur further discloses the group III nitride semiconductor layer located between the active region and the metallic contact. As shown in annotated Figure 2, below, the blue p-type cladding layer 22 (“group III nitride semiconductor layer”) is located between the green active region 18 and the red p-side metal 24 (“metallic contact”).



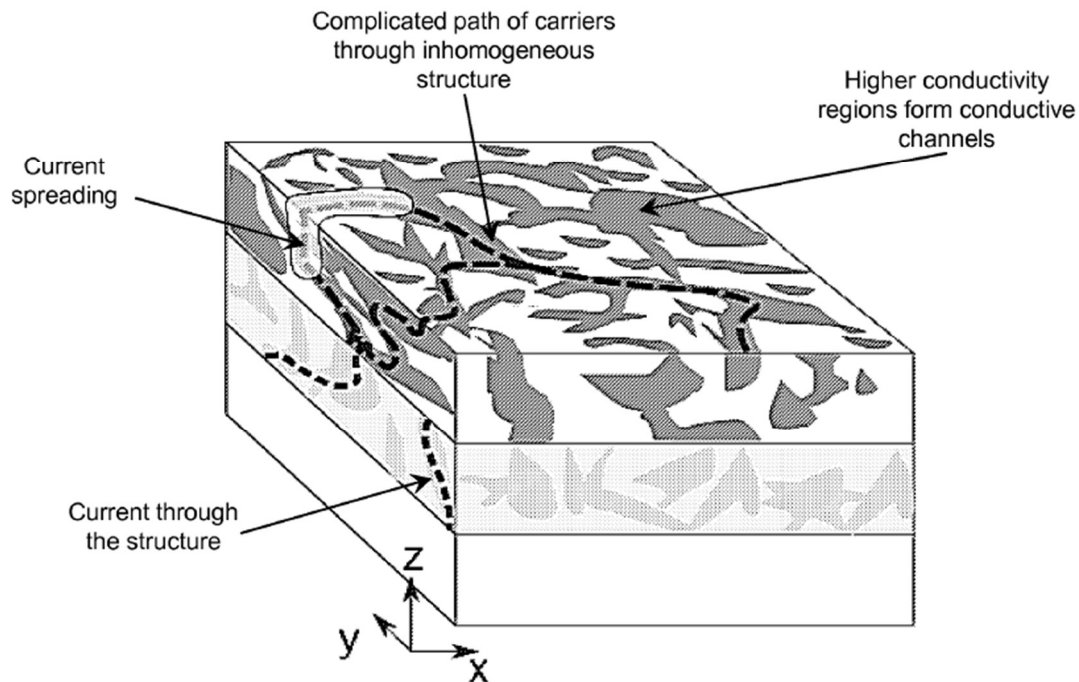
[1d] “the semiconductor layer including a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction of the semiconductor layer,”

111. Shur discloses this limitation. For example, Shur teaches that “one or more of the semiconductor layers of the device 10 can comprise nano-scale and/or micron-scale localized compositional and/or doping inhomogeneities along the lateral dimensions of the device die.” *Id.*, [0042]. “In an illustrative embodiment

described further herein, the inhomogeneities are incorporated into a layer formed using a p-type superlattice, such as the p-type cladding layer 22.” *Id.*, [0044].

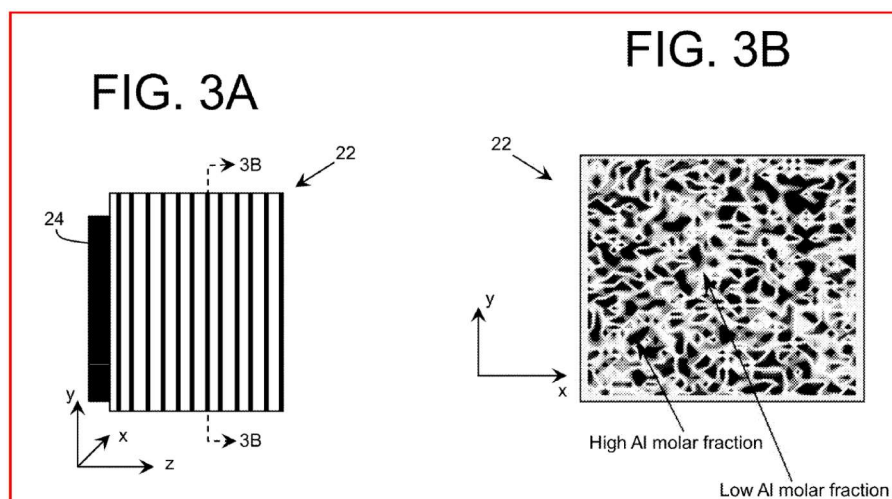
112. Further, “FIG. 5 shows a schematic representation of an illustrative carrier path in a complicated energy landscape caused by the inhomogeneities according to an embodiment.” *Id.*, [0054].

FIG. 5



113. Shur also discloses the semiconductor layer including a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction of the semiconductor layer. For example, “FIGS. 3A and 3B show illustrative schematic representations of the p-type cladding layer 22 formed using a p-type superlattice” and “FIG. 3A illustrates variation in aluminum

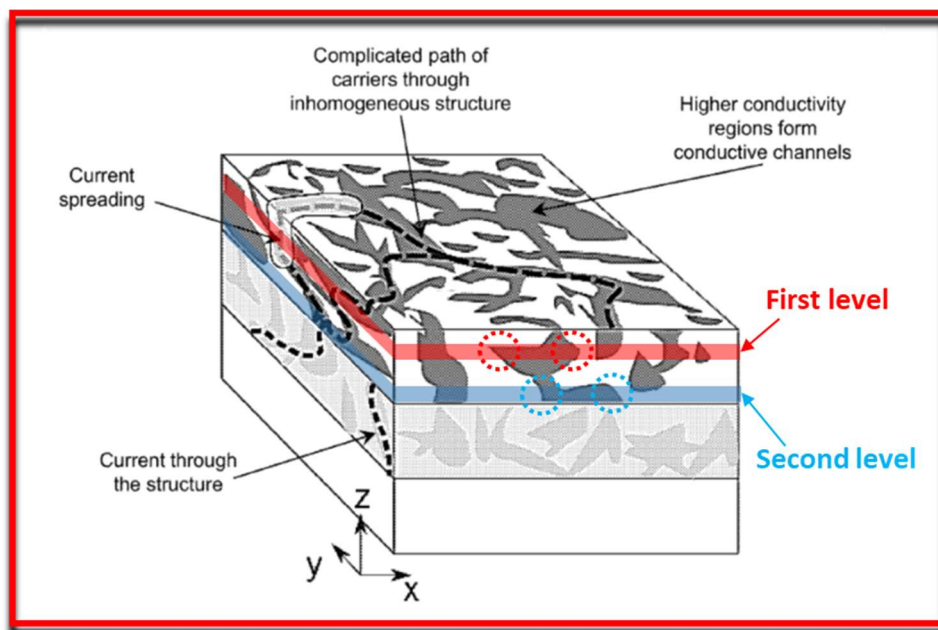
composition within the layer 22 along the height of the layer (e.g., indicated by direction z) in a direction normal to a surface of the layer 22 adjacent to the p-type metal 24”; “FIG. 3B illustrates variation in the aluminum composition of the p-type cladding layer 22 in the lateral directions (e.g., indicated by directions x and y) of the layer 22.” *Id.*, [0045-46].



114. A POSITA would understand that each layer of the multi-layer superlattice (as shown in FIG. 3A) includes a plurality of inhomogeneous regions within such layer (as shown in FIG. 3B). Thus, Shur discloses the semiconductor layer (e.g., p-type cladding layer 22) including a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction of the semiconductor layer.

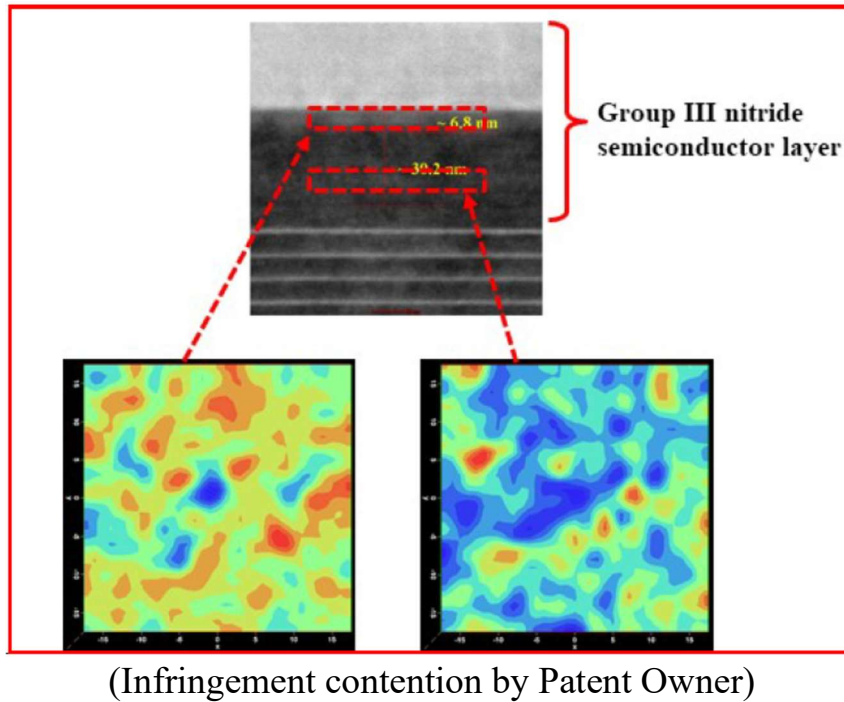
115. In addition, annotated Figure 5, below, shows a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction z of the semiconductor layer. For example, a first level of

the semiconductor layer is shaded in red and a second level of the semiconductor layer is shaded in blue. Additionally, the inhomogeneous regions within the first level (within red circles) are vertically offset from the inhomogeneous regions within the second level (within blue circles). Accordingly, a POSITA would understand that FIG. 5 of Shur teaches a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction z of the semiconductor layer.



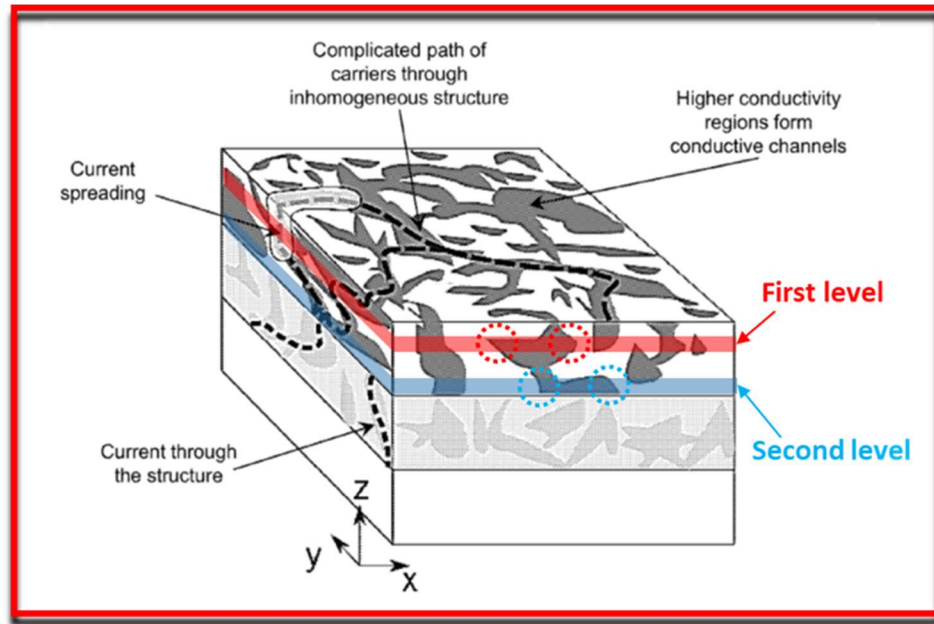
(Annotated FIG. 5)

116. Furthermore, as shown below, the “inhomogeneous regions” of Shur are consistent with the infringement allegations made by the Patent Owner.



[1e] “wherein some of the inhomogeneous regions in a first level of the semiconductor layer are vertically offset from inhomogeneous regions in a second level of the semiconductor layer, and”

117. Shur discloses this limitation. Reproduced from above, annotated Figure 5 shows red-circled inhomogeneous regions in a first level of the semiconductor layer that are vertically offset from blue-circled inhomogeneous regions in a second level of the semiconductor layer. In my opinion, each of the red circle or blue circle constitutes an inhomogeneous region within the semiconductor layer; thus, Shur discloses this limitation.



(Annotated FIG. 5)

[1f] “wherein the plurality of inhomogeneous regions include one or more of a set of transparent regions, a set of reflective regions and/or a set of conductive regions,”

118. Shur discloses this limitation. For example, Shur teaches that “the inhomogeneities will result in lower band gap regions, which ... form a set of **higher conductive regions** of carrier conductive channels in the semiconductor layer. ... Additionally, the inhomogeneities also will result in high band gap regions, which form a set of at least **partially transparent regions** within the layer.” *Id.*, [0042]; emphasis added. In my opinion, the inhomogeneous regions of Shur constitute either transparent regions or conductive regions; thus, Shur discloses this limitation.

[1g] “each of the inhomogeneous regions having a set of attributes differing from a group III nitride material forming the semiconductor layer.”

119. Shur discloses this limitation. For example, Shur describes that “[t]hese inhomogeneities provide **variation of band gap energy** in a lateral direction of the layer, which results in a complicated energy landscape for a lateral cross section of the layer. In particular, the inhomogeneities will result in **lower band gap regions**, which become places of charge localization and form a set of **higher conductive regions** of carrier conductive channels in the semiconductor layer. These higher conductive regions have an improved vertical conductivity over that of a substantially homogenous layer of the material. Additionally, the inhomogeneities also will result in **high band gap regions**, which form a set of at least **partially transparent regions** within the layer, each of which has an improved vertical transparency over that of a substantially homogenous layer of the material.” *Id.*, [0042]. As a result, each of the inhomogeneous regions has a set of material attributes—*e.g.*, variation of band gap energy, higher conductive regions, improved vertical conductivity, and improved vertical transparency—differing from a group III nitride material forming the semiconductor layer. Thus, Shur discloses this limitation.

120. Accordingly, Shur discloses each and every limitation of Claim 1.

D. Ground 4: Saxler Anticipates and/or Renders Obvious Claim 1

121. I will provide a brief overview of the Saxler before explaining how it discloses each and every limitation of the challenged claim.

122. Saxler discloses a “Group III nitride based semiconductor structure.” Ex. 1007, [0016]. The semiconductor structure includes, *e.g.*, a vertical diode structure of FIG. 4 comprising a quantum well layer 36, a third layer 38 and contact 50. *Id.*, [0026]. The vertical diode structure of FIG. 4 of Saxler is shown below:

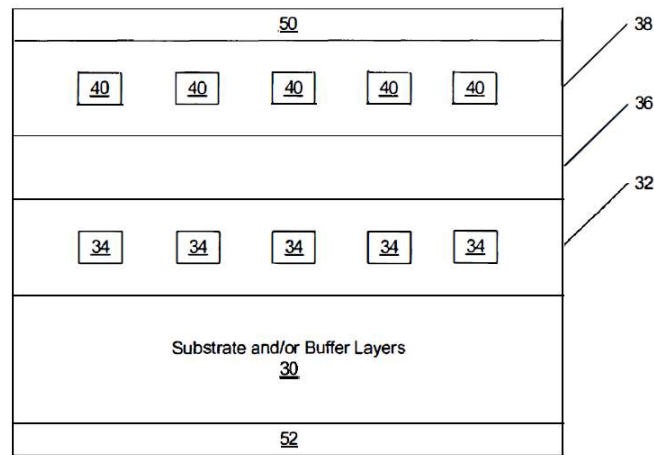


Figure 4

123. FIG. 4 shows that the third layer 38 of the diode structure can include multiple regions 40 embedded therein. Further, Saxler teaches that the nitride-based III-V compound semiconductor layer (*e.g.*, layer 20) can include “multiple courses of regions 22” that are embedded within the same semiconductor layer. *Id.*, [0021]. Figure 3 of Saxler, below, shows a schematic representation of the embedded and staggered regions 22 within the semiconductor layer 20.

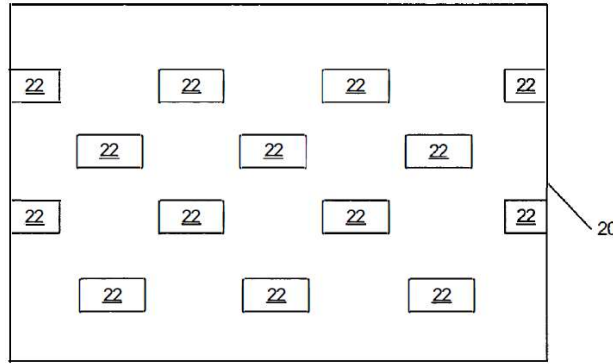


Figure 3

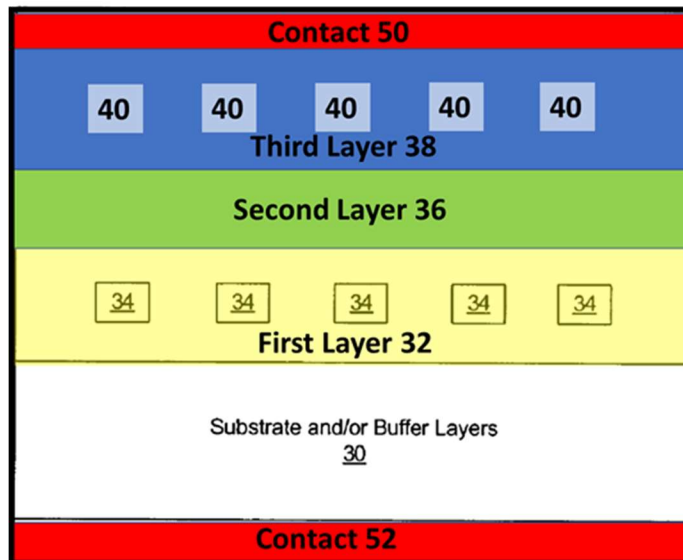
1. Claim 1

[1.Preamble] “A semiconductor heterostructure, comprising:”

124. To the extent the preamble is limiting, Saxler discloses a semiconductor heterostructure. For example, as noted above, Saxler discloses a Group III nitride based semiconductor structure (e.g., gallium nitride-based light emitting diode) and a vertical semiconductor diode structure. *Id.*, [0016]-[0017]; FIG. 4. Accordingly, Saxler discloses a semiconductor heterostructure.

[1a] “an active region;”

125. Saxler discloses an active region. For example, Saxler discloses that an “optional second layer 36 of a third semiconductor material(s) may be provided between the first layer 32 and a third layer 38 and may have a lower bandgap than that of the first layer 32 and the third layer 38 to provide a well region for the device.” Ex. 1007, [0026]. Annotated FIG. 4 of Saxler, below, shows the active region (layer 36; shown in green):



(Annotated FIG. 4 of Saxler)

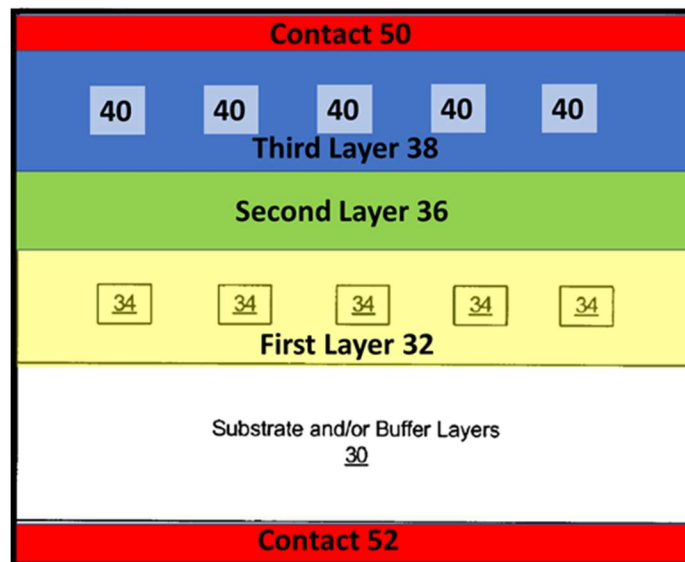
Saxler further discloses “the first layer 32, second layer 36 and/or third layer 38 may be multiple layers, for example, in a multi-quantum well embodiment of the present invention.” *Id.*, [0028]. A POSITA would understand that because FIG. 4 represents a vertical diode structure that can be applied to light emitting devices, the “well region” or “multi-quantum well” semiconductor layers disclosed by Saxler are active regions for the semiconductor device.

[1b] “a metallic contact;”

126. Saxler discloses a metallic contact. For example, Saxler teaches contact 50 can be provided above the third layer 38. *Id.*, [0026]; FIG. 4. A POSITA would understand that contact 50 (and alternatively, contact 52) is a metallic contact of the semiconductor device; specifically, a POSITA would understand that contact 50 is an ohmic contact made of metal. Indeed, Saxler

incorporates by reference U.S. Patent No. 6,201,262 (Ex. 1019), which teaches forming an ohmic contact to a conductive substrate. *See* Ex. 1019, Claim 1.

Further, annotated FIG. 4 of Saxler, below, shows a metallic contact (contact 50 or contact 52; shown in red):



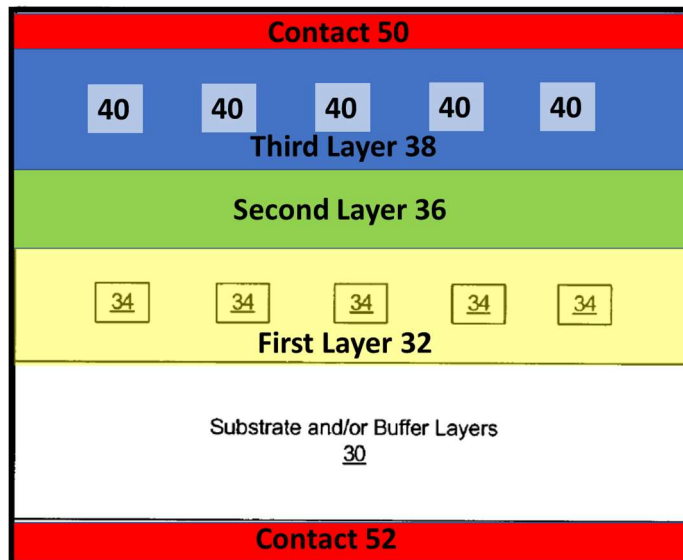
(Annotated FIG. 4 of Saxler)

[1c] “a group III nitride semiconductor layer located between the active region and the metallic contact,”

127. Saxler discloses this limitation. For example, Saxler teaches that “In particular embodiments of the present invention, the third layer 38 and the regions 40 are both AlInGaN based materials.” *Id.*, [0027]. Saxler also teaches that the “third layer 38 is a fourth wide bandgap semiconductor material” and “incorporated in the third layer 38 are regions 40 of a fifth wide bandgap semiconductor material”. *Id.*

128. A POSITA would understand that the “wide bandgap semiconductor material” and “AlInGaN based material” of Saxler are group III nitride semiconductor materials. Indeed, Saxler discloses, “In particular embodiments of the present invention, the wide bandgap material is a Group III nitride. In further embodiments of the present invention, the wide bandgap material is a gallium nitride based semiconductor material, such as GaN, AlGaN, AlInGaN or the like.” *Id.*, [0010]. Thus, third layer 38 (and first layer 32) of Saxler is a group III nitride semiconductor layer.

129. Saxler further discloses that first layer 32 or third layer 38 (each is a group III nitride semiconductor layer) is located between the active region and the metallic contact. Annotated FIG. 4 of Saxler, below, shows a group III nitride semiconductor layer (first layer 32 or third layer 38) located between the active region (layer 36; shown in green) and the metallic contact (contact 50 or contact 52; shown in red).



(Annotated FIG. 4 of Saxler)

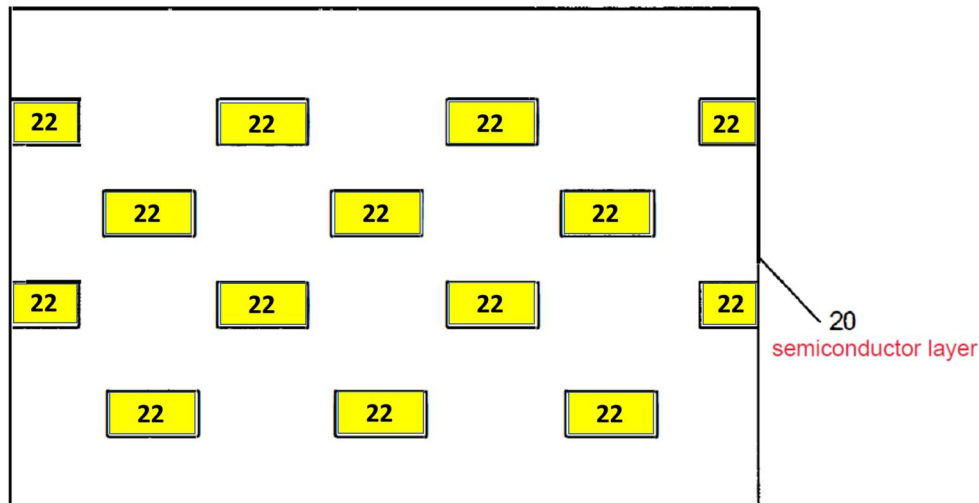
[1d] “the semiconductor layer including a plurality of inhomogeneous regions arranged within multiple levels of the semiconductor layer along a height direction of the semiconductor layer,”

130. Saxlar discloses this limitation. For example, Saxler teaches “a first layer 20 of wide bandgap semiconductor material having a first bandgap has included therein regions 22 of wide bandgap semiconductor material having a second bandgap,” “the layer 20 has a narrower bandgap than the regions 22,” “most of the doping is provided in the regions 22 to minimize ionized impurity scattering and maximize ionization of dopants,” “[b]y providing regions 22, rather than continuous layers, improved electrical conductivity in the vertical direction (i.e. a direction substantially orthogonal to the growth plane) may be achieved,” and “regions 22 may be provided that are aligned, staggered and/or random relative to each other.” *Id.*, [0018] - [0021]. Saxlar further teaches that “regions 22 may be

provided by a blanket formation of a layer of the wider bandgap semiconductor material and the patterning of that layer.” *Id.*, [0023].

131. In my opinion, the regions 22 constitute inhomogeneous regions because these regions can include wider bandgap material, transparent regions, and contribute to higher electrical conductivity of the semiconductor layer 20 in which the regions 22 are embedded. Indeed, the ’117 Patent describes, “Each inhomogeneous region has **one or more attributes that differ** from a material forming the semiconductor layer. The inhomogeneous regions can include one or more regions configured based on radiation having a target wavelength. These regions can include **transparent and/or reflective regions**. The inhomogeneous regions also can include one or more regions having a **higher conductivity** than a conductivity of the radiation-based regions, e.g., at least ten percent higher” (Ex. 1001, 2:5-13; emphasis added); “A conductive region can be configured to promote conductivity of carriers in the semiconductor structure. A **conductive region** can have a higher concentration of carriers due to, for example, a locally reduced band gap of the semiconductor layer, **a local high doping of the semiconductor layer**, and/or the like” (*Id.*, 5:60-65; emphasis added); and “The semiconductor structure can include inhomogeneous regions formed by one or more of patterning, masking, epitaxial growth, epitaxial overgrowth, deposition techniques, and/or the like.” Ex. 1001, 4:11-14.

132. Annotated FIG. 3 of Saxler, below, shows the semiconductor layer 20 including a plurality of inhomogeneous regions (the regions 22; shown in yellow) arranged within multiple levels of the semiconductor layer (layer 20) along a height direction (vertical direction) of the semiconductor layer.



(Annotated FIG. 3 of Saxler)

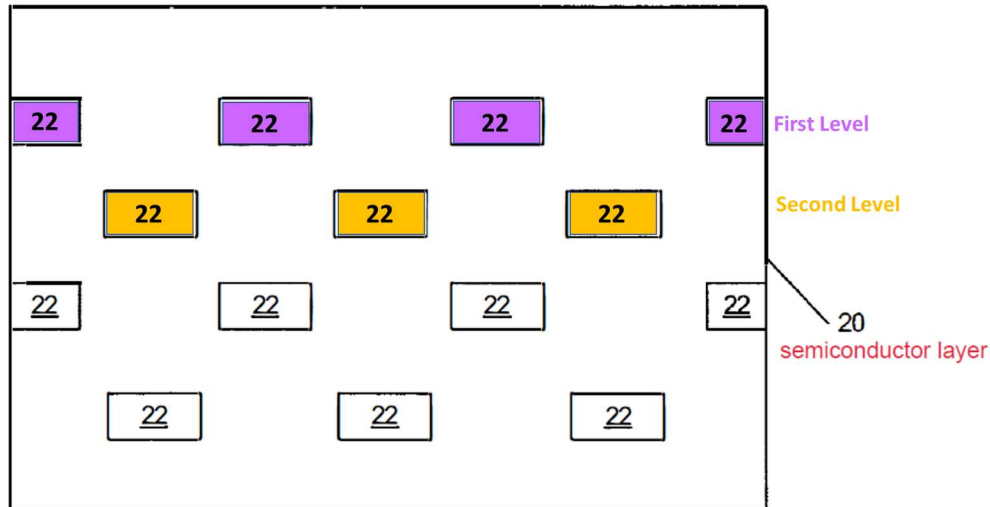
133. It is my opinion that based on the teachings of Saxler, a POSITA would have understood that layer 20 with embedded regions 22 can be applied to the diode structure shown in FIG. 4 of Saxler. Indeed, Saxler's teaching of the regions 22 embedded in the layer 20 can be applied to any light emitting diode structure. Ex. 1007, [0030]. For example, Saxler discloses, "FIG. 4 illustrates the **utilization of embodiments of the present invention** in a simplified **vertical diode** structure" and "third layer 38 is a fourth wide bandgap semiconductor material. Incorporated in the third layer 38 are **regions 40** of a fifth wide bandgap semiconductor material where the bandgap of the fourth wide bandgap

semiconductor material is **narrower** than the bandgap of the fifth wide bandgap semiconductor material.” *Id.*, [0024], [0027]; emphasis added.

134. Thus, a POSITA would understand that Saxler’s teaching of the regions 22 embedded in the layer 20 can be applied to first layer 32 (which includes embedded regions 34) and third layer 38 (which includes embedded regions 40) of FIG. 4 of Saxler. Indeed, Saxler expressly discloses that embodiments of its invention (*e.g.*, its teaching of the regions 22 embedded in the layer 20) can be applied to other light emitting diode structures and incorporated by reference several disclosures. *See* Ex. 1007, [0030]. Saxler therefore discloses this limitation or at least renders it obvious.

[1e] “wherein some of the inhomogeneous regions in a first level of the semiconductor layer are vertically offset from inhomogeneous regions in a second level of the semiconductor layer, and”

135. Saxler discloses this limitation. For example, Saxler discloses, “in the embodiments illustrated in FIG. 3, the layer 20 includes differing courses of regions 22 that are staggered.” *Id.*, [0021]. Annotated FIG. 3 of Saxler, below, shows the inhomogeneous regions in a first level (the regions 22; shown in purple) of the semiconductor layer are vertically offset from inhomogeneous regions in a second level (the regions 22; shown in orange) of the semiconductor layer.



(Annotated FIG. 3 of Saxler)

[1f] “wherein the plurality of inhomogeneous regions include one or more of a set of transparent regions, a set of reflective regions and/or a set of conductive regions,”

136. Saxler discloses this limitation. For example, Saxler teaches “a first layer 20 of wide bandgap semiconductor material having a first bandgap has included therein regions 22 of wide bandgap semiconductor material having a second bandgap,” “the layer 20 has a **narrower** bandgap than the regions 22,” “most of the doping is provided in the regions 22 to minimize ionized impurity scattering and maximize ionization of dopants,” and “[b]y providing regions 22, rather than continuous layers, **improved electrical conductivity** in the vertical direction (i.e. a direction substantially orthogonal to the growth plane) may be achieved.” *Id.*, [0018] - [0020]; emphasis added.

137. The '117 Patent describes that “A **conductive region** can be configured to **promote conductivity** of carriers in the semiconductor structure. A

conductive region can have a **higher concentration of carriers** due to, for example, a locally reduced band gap of the semiconductor layer, a local **high doping** of the semiconductor layer, and/or the like.” Ex. 1001, 5:60-65; emphasis added. The ’117 Patent went on to define “conductive region” and explains, “In an embodiment, a conductive region has **a conductivity at least ten percent higher** than a conductivity of a transparent region and a conductivity of a reflective region and a **higher conductivity than a base semiconductor material** for the layer.” *Id.*, 6:5-9; emphasis added. The ’117 Patent also defines “transparent region” and explains that “a region is a **transparent region** when the region **allows at least ten percent of radiation having a target wavelength**, which is radiated at a normal incidence to an interface of the region, to pass there through.” *Id.*, 5:46-49.

138. A POSITA would understand that because the regions 22 have higher doping and contribute to improved electrical conductivity, the regions 22 are conductive regions. A POSITA would also understand that because Saxler teaches regions 22 have wider bandgap than the layer 20 in which the regions 22 are embedded, the regions 22 allows for higher optical transmission and are transparent regions.

139. Indeed, Saxler’s teaching of the regions 22 embedded in the layer 20 can be applied to any light emitting diode structure. Ex. 1007, [0030]. For example, Saxler discloses, “FIG. 4 illustrates the utilization of embodiments of the

present invention in a simplified **vertical diode** structure” and “third layer 38 is a fourth wide bandgap semiconductor material. Incorporated in the third layer 38 are **regions 40** of a fifth wide bandgap semiconductor material where the bandgap of the fourth wide bandgap semiconductor material is **narrower** than the bandgap of the fifth wide bandgap semiconductor material.” *Id.*, [0024], [0027]; emphasis added.

140. A POSITA would understand that in the exemplary diode structure of FIG. 4 of Saxler, the third layer 38 (which is the p-type layer) and first layer 32 (which is the n-type layer) must have a wider bandgap than the quantum well light emitting layer 36 so that third layer 38 and first layer 32 are transparent to the target wavelength of the light emitting diode and the light emitted from the light emitting layer 36 is not absorbed. Additionally, a POSITA would understand that because the regions 40 embedded in the third layer 38 (and regions 34 embedded in the first layer 32) have **wider** bandgap than third layer 38 (and first layer 32), such regions 40 (and regions 34) are likewise transparent to the target wavelength of the light emitting diode. Accordingly, a POSITA would further understand that similar to the regions 22, the regions 40 (and regions 34) are also transparent regions.

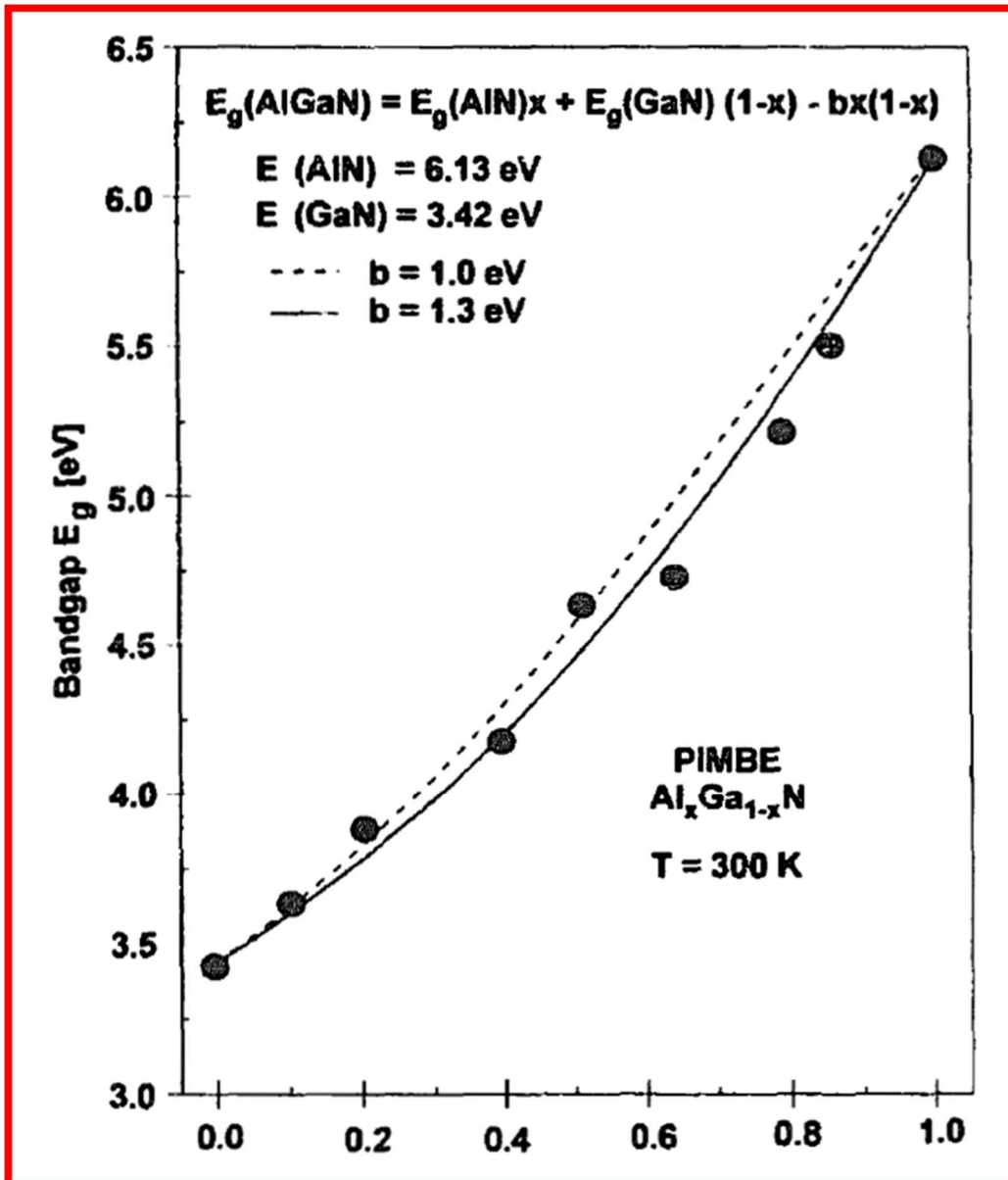
141. Therefore, Saxler discloses wherein the plurality of inhomogeneous regions include one or more of a set of transparent regions, a set of reflective regions and/or a set of conductive regions.

[1g] “each of the inhomogeneous regions having a set of attributes differing from a group III nitride material forming the semiconductor layer.”

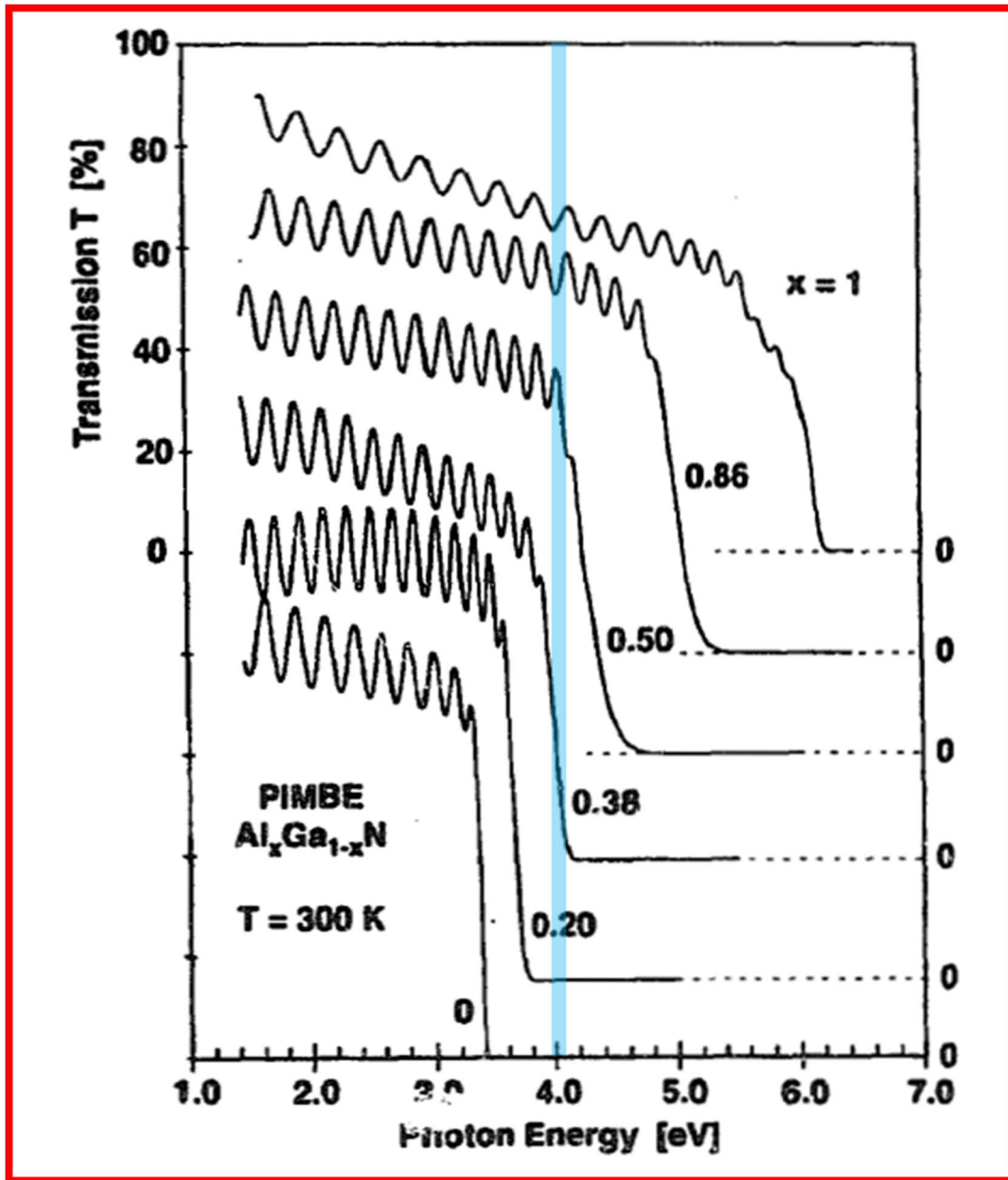
142. Saxler discloses this limitation. For example, Saxler describes that the regions 22 and regions 40 (and regions 34) have **wider bandgap** than the layer 20/layer 38 (and layer 32) in which they are embedded: “In any case, the layer 20 has a **narrower bandgap** than the regions 22,” “the composition of the regions 22 and the layer 20 may be the same, however, the **mole fractions** may be varied to provide differing bandgaps,” and “[t]he third layer 38 is a fourth wide bandgap semiconductor material. Incorporated in the third layer 38 are regions 40 of a fifth wide bandgap semiconductor material where the bandgap of the fourth wide bandgap semiconductor material is **narrower** than the bandgap of the fifth wide bandgap semiconductor material.” Ex. 1007, [0019], [0027]; emphasis added.

143. A POSITA would understand that because the regions 22/regions 40/regions 34 have **wider bandgap** and **different composition mole fraction** than the layer 20/layer 38/layer 32 in which the regions 22/regions 40/regions 34 are embedded, the regions 22/regions 40/regions 34 have material attributes (*e.g.*, bandgap, composition mole fraction, and/or optical transmission) from the layer

20/layer 38/layer 32. Indeed, the common knowledge of a POSITA would have included Stutzmann, which is a 1998 publication titled “Electrical and structure properties of AlGa_N: a comparison with CVD diamond.” **Ex. 1017.** FIG. 3 of Stutzmann shows that higher Al concentration in AlGa_N results in a wider bandgap; FIG. 4 of Stutzmann shows that the optical transmission for AlGa_N increases with higher Al concentration. For example, for a photon energy of 4 eV (which equates to UV emission at about 310 nm; shown by a vertical blue bar), FIG. 4 of Stutzmann shows that the optical transmission is about 60% when the Al concentration, $x = 0.86$, and about 40% when $x = 0.5$.



(FIG. 3 of Stutzmann)



(Annotated FIG. 4 of Stutzmann)

144. Therefore, Saxler teaches that each of the inhomogeneous regions having a set of attributes differing from a group III nitride material forming the semiconductor layer.

145. Accordingly, Saxler discloses each and every limitation of Claim 1.

XII. SECONDARY CONSIDERATIONS

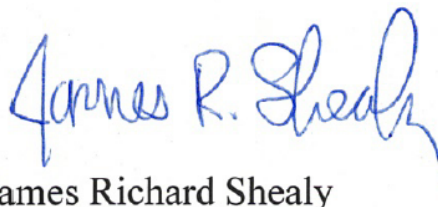
146. It is my opinion that secondary considerations do not support the non-obviousness of the challenged claim. I have seen no evidence that supports any secondary considerations tending to show non-obviousness, including commercial success, long-felt need, failure of others, skepticism, praise, teaching away, recognition of a problem, or copying by competitors.

147. Should the Patent Owner assert that secondary considerations support a finding of non-obviousness, I reserve the right to submit a Declaration addressing those new assertions.

XIII. DECLARATION

In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination.

I declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true, and further that all statements are made with knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.



James Richard Shealy