

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

IQE PLC,
Petitioner

v.

CORNELL RESEARCH FOUNDATION, INC.,
Patent Owner

Case IPR2024-00609
U.S. Patent No. 7,250,360

**DECLARATION OF DR. STANLEY SHANFIELD IN SUPPORT OF
PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 7,250,360**

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IQE EX1003
U.S. Patent No. 7,250,360

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I, Dr. Stanley Shanfield, declare as follows:

I. INTRODUCTION

1. I have been retained by Sterne, Kessler, Goldstein & Fox PLLC on behalf of IQE PLLC (“IQE” and/or “Petitioner”) for the above-captioned *inter partes* review proceeding. I understand that this proceeding involves U.S. Patent No. 7,250,360 (“the ’360 patent”), titled “Single Step, High Temperature Nucleation Process for a Lattice Mismatched Substrate,” and that the ’360 patent is currently assigned to Cornell Research Foundation, Inc. (“Patent Owner”).

2. Specifically, I have been retained as a technical expert by IQE to study and provide my opinions on the technology claimed in, and the patentability or unpatentability of, claims 1-24 of the ’360 patent (“the challenged claims”). This declaration is directed to the challenged claims of the ’360 patent, and sets forth the opinions I have formed, the conclusions I have reached, and the bases for each. For purposes of this declaration, I was not asked to provide any opinions that are not expressed herein.

3. I am familiar with the technology described in the ’360 patent as of its earliest possible priority date of March 2, 2005. I have been asked to provide my technical review, analysis, insights, and opinions regarding the ’360 patent. I have used my prior experience and insight (outlined in Section III below) along with the references addressed herein as the basis for my opinion on the grounds of

unpatentability set forth in the Petition for *inter partes* review of the '360 patent.

4. I have reviewed and am familiar with the specification of the '360 patent issued on July 31, 2007. I understand that the '360 patent has been provided as EX1001. I will cite to the specification using the following formats: EX1001, '360 patent, 1:1-10 (long form) and EX1001, 1:1-10 (short form). These example citations both point to the '360 patent specification at column 1, lines 1-10.

5. I am being compensated by IQE at my standard hourly rate of \$385 for the time I spend in connection with this proceeding. My compensation is not dependent in any way on the substance of my opinions or in the outcome of this proceeding.

6. I am over 18 years of age. I have personal knowledge of the facts stated in this declaration and could testify competently to them if asked to do so.

II. GROUNDS OF UNPATENTABILITY

7. In forming my opinions about the '360 patent, I have considered the following grounds of unpatentability. Based on my review of the prior art references that form the basis of these grounds, it is my opinion that claims 1-24 of the '360 patent would have been obvious to a person of ordinary skill in the art ("POSA") as of March 2, 2005.

Ground	Basis	Claims	References
1.	§103	1-4 and 6-14	Urashima
2.	§103	5 and 17	Urashima in view of Nagata
3.	§103	15 and 16	Urashima in view of Keiper

Ground	Basis	Claims	References
4.	§103	18-24	Urashima in view of Manabe
5.	§103	1-4, 6-9, and 11-14	Guo
6.	§103	5, 10, 17	Guo in view of Ashby

8. I have been asked to consider how a POSA would have understood the challenged claims in light of the disclosures of the '360 patent. I also have been asked to consider how a POSA would have understood the prior art references Urashima, Nagata, Keiper, Manabe, Guo, and Ashby.

9. Further, I have been asked to consider and provide my technical review, analysis, insights, and opinions regarding whether a POSA would have understood that the combinations of the prior art references listed in the table above render obvious claims 1-24 of the '360 patent.

III. QUALIFICATIONS

10. In formulating my opinions, I have relied upon my training, knowledge, and experience in the relevant art. I have over 35 years of experience working with nucleation and epitaxial growth processes. As detailed below, I have worked on many projects that are highly relevant to the subject matter of the '360 patent.

11. I receive my Bachelor of Science degree in 1977, in Physics, from the University of California, Irvine. I received my Doctor of Philosophy degree in Physics from the Massachusetts Institute of Technology in 1981, with a dissertation on high-field superconductors. During my doctoral program at MIT, I

receive a full scholarship from the US Department of Energy.

12. Upon completing my Ph.D., I worked until 1984 at Spire Corporation as a Staff Scientist, then later as a Senior Staff Scientist. There, I developed new methods for low temperature deposition of plasma-assisted Chemical Vapor Deposition (CVD) epitaxial silicon. I also built, operated, and characterized an ion-assisted deposition system for making coating for semiconductors.

13. In 1985 I joined Raytheon Corporation, where I began as Section Manager in Semiconductors and Integrated Circuits. My work involved developing processes for growing semiconductor materials and using those materials for fabricating high performance multi-function devices and integrated circuits. Among other assignments, I eventually became responsible for the growth of III-V and silicon epitaxial layers by CVD, metallo-organic chemical vapor deposition (MOCVD), and molecular beam epitaxy (MBE). These growth methods and resulting materials were used to investigate and optimize field-effect transistors (FETs), metal-oxide-semiconductor field-effect transistors (MOSFETs), and selected optical devices. I led a team in the design and fabrication of pseudomorphic high-electron-mobility transistors (HEMTs) and hetero-junction bipolar transistors (HBTs) for airborne radio frequency (RF) power applications, including optimization of the material layer structures.

14. I eventually became Manager of Semiconductor Operations in a

recently built Raytheon facility in Andover, MA. In this capacity I was involved in all aspects of device and integrated circuit (IC) production, for both III-V and silicon. Among other responsibilities, I managed the purchase and qualification of key semiconductor equipment, including establishment of a large scale CVD, Low pressure chemical vapor deposition (LPCVD), MOCVD and MBE material growth center. I also became directly involved in product design, circuit design and operations management as it related to delivering high volumes of commercial and military semiconductor products.

15. After 14 years at Raytheon, I co-founded a start-up company, AXSUN Technologies, assuming a variety of roles including VP of Operations. AXSUN produced miniature electro-optical modules for the fiber-optical communications market and was eventually valued at over \$100 million. I designed a complete facility for material growth and semiconductor processing, including establishing a fabrication facility in Belfast, N. Ireland for producing thick-oxide silicon on insulator material.

16. In 2003, I transitioned to Draper Laboratory at the Massachusetts Institute of Technology where I have held the position of Division Leader in Advanced Hardware Development and was promoted to a Distinguished Member of Technical Staff and Technical Director. I have been responsible for development activities in semiconductor technology, including fabrication,

material growth, device and circuit design, ultra-miniature electronic modules, and device and system modeling.

17. I have been a member of many professional societies over the years, including the Institute of Electrical and Electronic Engineers (IEEE) and the American Physical Society (APS).

18. I have received many academic awards and honors over the years, including awards and honors for the best Draper patent and most successful Draper development project.

19. I am a named inventor or co-inventor on more than nine patents covering aspects of semiconductor devices, such as thin film deposition methods, transistor optimization, and advanced semiconductor processing.

20. I have previously testified in patent and trade secret cases, some of which concerned semiconductor materials growth or processing, semiconductor equipment or electronic circuits and components, before various District Courts, the International Trade Commission and the Patent Trial and Appeal Board. I have been qualified in multiple courts to offer expert opinions on semiconductor issues.

21. My curriculum vitae is provided as EX1013, which contains further details on my education, experience, publications, and other qualifications to render an expert opinion.

IV. MATERIALS CONSIDERED

22. In formulating my opinions, I have relied upon my training, knowledge, and experience that are relevant to the '360 patent. I have also reviewed and am familiar with the following documents and materials in addition to any other documents cited in this declaration.

<i>Exhibit No.</i>	<i>Description</i>
1001	U.S. Patent No. 7,250,360 to Shealy et al. (“’360 patent”)
1002	’360 Patent Prosecution History
1004	U.S. Patent Application Pub. No. 2002/0155712 to Urashima et al. (“Urashima”)
1005	JP Patent Application Pub. No. JPH0563305 to Nagata et al. (“Nagata”)
1006	Keiper et al., <i>Metal organic vapour-phase epitaxy (MOVPE) growth of InP and InGaAs using tertiarybutylarsine (TBA) and tertiarybutylphosphine (TBP) in N₂ ambient</i> , Journal of Crystal Growth (1999) (“Keiper”)
1007	U.S. Patent No. 5,122,845 to Manabe et al. (“Manabe”)
1008	U.S. Patent Application Pub. No. 2004/0119063 to Guo et al. (“Guo”)
1009	U.S. Patent Application Pub. No. 2002/0090816 to Ashby et al. (“Ashby”)
1010	Declaration of Sylvia Hall-Ellis, Ph.D.
1011	Herman et al., <i>Epitaxy Physical Principles and Technical Implementation</i> , Material Science (2004) (“Herman”)
1012	<i>Curriculum Vitae</i> of Sylvia Hall-Ellis, Ph.D.

<i>Exhibit No.</i>	<i>Description</i>
1013	<i>Curriculum Vitae</i> of Dr. Stan Shanfield
1015	Zhang et al., <i>Selective Growth of CdTe on Si and GaAs Substrates using Metalorganic Vapor Phase Epitaxy</i> , Journal of Electronic Materials (2000) (“Zhang”)
1016	Uen et al., <i>Epitaxial growth of high-quality GaN on appropriately nitridated Si substrate by metal organic chemical vapor deposition</i> , Journal of Crystal Growth (2005) (“Uen”)
1019	Trifan, <i>Study of the Early Stage of Growth and Epitaxy of GaN Thin Films on Sapphire</i> , College of Arts and Sciences of Ohio University (2003) (“Trifan”)
1020	Connelly, <i>Nomenclature of Inorganic Chemistry</i> , International Union of Pure and Applied Chemistry (2005) (“Connelly”)
1021	Zang et al., <i>Structural analysis of metalorganic chemical vapor deposited AlN nucleation layers on Si (111)</i> , Journal of Crystal Growth (2004) (“Zang”)
1022	Nikishin et al., <i>Growth of AlGaIn on Si(111) by gas source molecular beam epitaxy</i> , Applied Physics Letters (2000) (“Nikishin”)
1023	Nikishin et al., <i>High quality GaN grown on Si(111) by gas source molecular beam epitaxy with ammonia</i> Applied Physics Letters (1999) (“Nikishin II”)
1024	Chen et al., <i>Growth of high quality GaN layers with AlN buffer on Si(111) substrates</i> , Journal of Crystal Growth (2001) (“Chen”)
1025	Marchand et al., <i>Metalorganic chemical vapor deposition of GaN on Si(111): Stress control and application to field-effect transistors</i> , Journal of Applied Physics (2001) (“Marchand”)
1026	Park et al., <i>Growth of GaN Layer from the Single-Source Precursor (Et₂GaNH₂)₃</i> , Chemical Materials (1998) (“Park”)

<i>Exhibit No.</i>	<i>Description</i>
1027	Hull et al., <i>Misfit Dislocations in Lattice-Mismatched Epitaxial Films</i> , Critical Review in Solid State and Material Sciences (1992) (“Hull”)

23. To the best of my knowledge, the above-mentioned documents and materials are true and accurate copies of what they purport to be. An expert in the field would reasonably rely on them to formulate opinions such as those set forth in this declaration.

V. LEGAL UNDERSTANDING

24. I have also relied upon various legal principles (as explained to me by IQE’s counsel) in formulating my opinions. My understanding of these principles is summarized below.

A. My Understanding of Claim Construction

25. I understand that during an *inter partes* review proceeding, claims are to be construed in light of the specification as would be read by a person of ordinary skill in the relevant art at the time the application was filed. I understand that claim terms are given their ordinary and customary meaning as would be understood by a person of ordinary skill in the relevant art in the context of the entire disclosure. A claim term, however, will not receive its ordinary meaning if the patentee acted as his own lexicographer and clearly set forth a definition of the claim term in the specification. In this case, the claim term will receive the

definition set forth in the patent.

B. My Understanding of Obviousness

26. I understand that a patent claim is invalid if the claimed invention would have been obvious to a POSA at the time the application was filed. This means that even if all of the requirements of the claim cannot be found in a single prior art reference that would anticipate the claim, the claim can still be invalid.

27. To obtain a patent, a claimed invention must have, as of the priority date, been nonobvious in view of the prior art in the field. I understand that an invention is obvious when the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a POSA.

28. I understand that to prove that prior art or a combination of prior art renders a patent obvious, it is necessary to:

- (1) identify the particular references that, singly or in combination, render the patent obvious;
- (2) specifically identify which elements of the patent claim appear in each of the asserted references; and
- (3) explain how the prior art references could have been combined in order to create the inventions claimed in the asserted claim.

29. I also understand that prior art references can be combined under several different circumstances. For example, it is my understanding that one such circumstance is when a proposed combination of prior art references results in a

system that represents a predictable variation, which is achieved using prior art elements according to their established functions.

30. I also understand that when considering the obviousness of a patent claim, one should consider whether a teaching, suggestion, or motivation to combine the references exists so as to avoid impermissibly applying hindsight when considering the prior art. I understand this test should not be rigidly applied, but that the test can be important to avoid such hindsight.

31. I understand that certain objective indicia can be important evidence as to whether a patent is obvious or nonobvious. Such indicia include:

(1) commercial success of products covered by the patent claims; (2) a long-felt need for the invention; (3) failed attempts by others to make the invention; (4) copying of the invention by others in the field; (5) unexpected results achieved by the invention as compared to the closest prior art; (6) praise of the invention by the infringer or others in the field; (7) the taking of licenses under the patent by others; (8) expressions of surprise by experts and those skilled in the art at the making of the invention; and (9) the patentee proceeded contrary to the accepted wisdom of the prior art.

32. At this point, I am not aware of any secondary indicia of non-obviousness. But, I reserve the right to review and opine on any evidence of objective indicia of nonobvious that may be presented during this proceeding.

33. I also understand that “obviousness” is a legal conclusion based on the underlying factual issues of the scope and content of the prior art, the differences between the claimed invention and the prior art, the level of ordinary skill in the prior art, and any objective indicia of non-obviousness.

34. For that reason, I am not rendering a legal opinion on the ultimate legal question of obviousness. Rather, my testimony addresses the underlying facts and factual analysis that would support a legal conclusion of obviousness or non-obviousness, and when I use the term obvious, I am referring to the perspective of one of ordinary skill at the time of invention.

C. A Person of Ordinary Skill in the Art

35. I understand that a person of ordinary skill in the relevant art (“POSA”) is presumed to be aware of all pertinent art, thinks along conventional wisdom in the art, and is a person of ordinary creativity—not an automaton.

36. I have been asked to consider the level of ordinary skill in the field that someone would have had at the time the claimed invention was made. In deciding the level of ordinary skill, I considered the following:

- the levels of education and experience of persons working in the field;
- the types of problems encountered in the field; and
- the sophistication of the technology.

37. My opinion below explains how a POSA would have understood the technology described in the references I have identified herein around the March 2, 2005 timeframe. I have been advised that the alleged earliest possible effective filing date for the '360 Patent is March 2, 2005.

38. Regardless of whether I use “I” or a “POSA” during my technical analysis below, all of my statements and opinions are always to be understood to be based on how a POSA would have understood or read a document at the time of the alleged invention.

VI. OVERVIEW OF THE '360 PATENT

39. The '360 patent generally discloses “a single step process for the nucleation and subsequent epitaxial growth on a lattice mismatched substrate.” EX1001, 1:39-41. I have copied Figure 1 below, which is the only figure in the '360 patent, to help illustrate an example of this process.

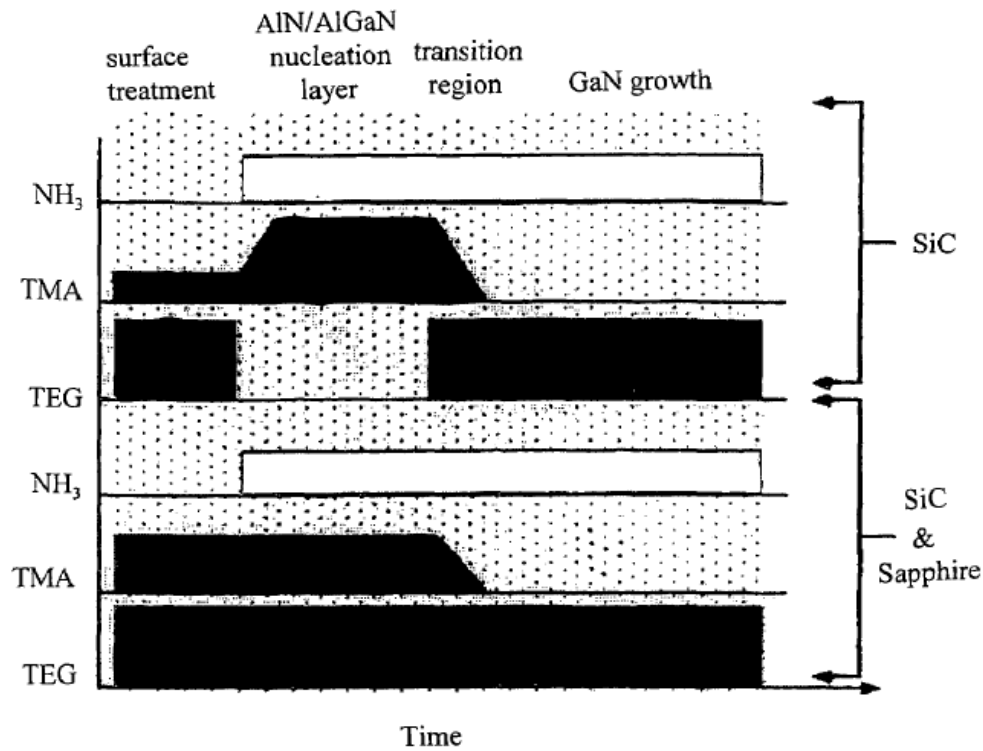


FIG. 1

EX1001, FIG. 1.

40. The '360 patent explains that “a lattice mismatched substrate is pre-treated with a group III reactant or a group II reactant at an elevated growth temperature prior to the addition of a group V reactant or a group VI reactant and the growth of a nucleation layer.” EX1001, 1:53-62. The '360 patent discloses that “[i]n a preferred embodiment, the nucleation layer is $\text{Al}_x\text{Ga}_{1-x}\text{N}$ where x varies from 0 to 1.” *Id.* Subsequently, a “buffer layer, preferably GaN, is formed on the nucleation layer to provide a surface upon which the epitaxial layer is grown,” which is “preferably an epitaxial layer including AlN, AlGa_N, or GaN.” *Id.*, 1:62-

2:2.

41. The '360 patent describes the above process as “a single flow, single pressure, high temperature process.” *Id.*, 2:3-4. The '360 patent alleges that “[t]his single step process eliminates the large temperature ramps and complex flow requirements of the commonly used two-step nucleation technologies.” *Id.*, 2:7-9.

VII. TECHNOLOGY OVERVIEW

42. Before the priority date of the '360 patent, all elements of the claimed technology at issue had been developed and were well-known. For instance, during the epitaxial growth process, it was well-known to pre-treat a substrate with a group III or group II reactant at an elevated temperature. It was also well-known to introduce a group V or group VI reactant at an elevated temperature to grow a nucleation layer on the substrate. It was further well-known to grow a buffer layer over the nucleation layer at an elevated temperature. And finally, it was also well-known to grow an epitaxial layer on the buffer layer at an elevated temperature, where the epitaxial layer and the substrate are lattice mismatched. In the following sections, I explain how the epitaxial growth processes existing before 2005 implemented each of these steps—both individually and as part of a combined overall process.

A. Known epitaxial growth processes pre-treated a substrate with group III or group II reactants at an elevated temperature.

43. Prior to the '360 patent priority date, it was well-known to introduce

group III or group II reactants during a pre-treatment of the substrate step. It was also well-known that such group III and group II reactants were effective materials to pre-treat the substrate and prepare it for later epitaxial growth.

44. Moreover, as early as 2000, it was well-known to perform a pre-treatment step on a substrate, for example, with a group III reactant (e.g., aluminum), prior to subsequent epitaxial growth to improve quality of the nucleation and buffer layers and suppress formation of substrate nitrides. EX1023, Nikishin II, Abstract (“The initial deposition of Al, at 1130–1190 K, resulted in a very rapid transition to a two-dimensional growth mode of AlN. The rapid transition is essential for the subsequent growth of high quality GaN and AlGaN.”), 2073 (“High growth temperature of 1130–1190 K, combined with carefully controlled deposition of an Al layer at the onset of epitaxy, suppress formation of SiN_x islands and result in very rapid transition to two-dimensional (2D) growth mode of AlN.”); EX1022, Nikishin, 3028 (“The growth process was started by formation of an AlN buffer layer at the temperature of 1130–1190 K. This layer was nucleated by exposing the Si surface to the flux of Al, followed by a brief (1–2 s) exposure to ammonia (with the Al flux off). This process, repeated a few times, resulted in formation of a fully relaxed thin nucleation layer of AlN.”).

45. Further, prior to 2005, it was well-known to utilize a pre-treatment step with a metal-organic precursor (e.g., TMA) on a substrate to grow a

nucleation layer by MOCVD to improve layer quality and prevent formation of amorphous layers (e.g., amorphous SiN_x). EX1021, Zang, Abstract (“The AFM results show that with TMA pre-treatments, AlN grows in a pseudo-2-dimensional mode because the lateral growth rate of AlN is increased, and the wetting property of the AlN on silicon is improved. Also, no amorphous SiN_x layer was observed at the interface with TMA pre-treatments and AlN films with good epitaxial crystalline quality were obtained.”); EX1024, Chen, Abstract (“It was found that pre-seeding Al to Si surface is a critical condition for AlN growth on Si. Two-dimensional growth of AlN was achieved under optimized conditions.”); EX1025, Marchand, footnote 30 (“...TMAI preflows corresponding to 2–5 monolayers of aluminum were used...”).

46. Additionally, many studies had been done over the years leading up to 2005 to test the epitaxial growth performance of various group III and group II reactants. One example pre-2005 study examining the growth of gallium nitride (GaN) on sapphire substrates following the introduction of a group III reactant during a pretreatment step is provided in a 2003 dissertation titled “Study of the early stage of growth and epitaxy of GaN thin films on sapphire,” by Eugen Mihai Trifan. EX1019, Trifan.

47. It was also well-known in the 2005 timeframe that performing this pre-treatment step using group III or group II reactants would aid in the adherence

of the materials to the substrate in subsequent epitaxial growth steps, and would help preserve the substrate during the formation of nuclei. EX1021, Abstract; EX1022, 3028; EX1023, Abstract; EX1024, Abstract; EX1025, 7847. It was also well-known prior to 2005 to perform the pre-treatment step at an elevated temperature. EX1004, Urashima, ¶¶[0025], [0028], [0109]; EX1011, Herman, 27, 59-60; EX1016, Uen, 338-340.

B. Known epitaxial growth processes introduced a group V or group VI reactant at an elevated temperature to grow a nucleation layer.

48. The use of a group V or group VI reactant at an elevated temperature to grow a nucleation layer was also well known before the '360 patent priority date. For example, in the commonly practiced epitaxial lateral overgrowth (ELO) method (which utilizes sapphire or SiC substrates) for forming epitaxial GaN, an AlGaN nucleation layer is deposited to allow for smooth growth in the silicon nitride mask openings. EX1011, 411.

49. Additionally, prior to 2005, it was well-known to introduce a nitrogen-based reactant (e.g., ammonia)—a group V reactant—to grow a nucleation layer for subsequent growth of epitaxial layers. EX1021, Abstract (“The microstructures of high-temperature AlN nucleation layers grown by MOCVD on Si (111) substrates with trimethylaluminium pre-treatments have been studied...”); EX1022, 3028 (“This layer was nucleated by exposing the Si surface to the flux of Al, followed by a brief (1–2 s) exposure to ammonia (with the Al flux off). This

process, repeated a few times, resulted in formation of a fully relaxed thin nucleation layer of AlN.”) Similar to the pre-treatment step, it was also well-known prior to 2005 to perform the growing of a nucleation layer at an elevated temperature. EX1021, 151 (“Trimethylaluminum (TMA), and ammonia (NH₃) were used as the precursors for Al and N, respectively. ... TMA was introduced for 6 seconds before the introduction of ammonia into the chamber at 1010°C.”); EX1004, ¶¶[0025], [0028], [0109]; EX1011, 59-60; EX1016, 338-340.

C. Known epitaxial growth processes grew a buffer layer at an elevated temperature.

50. The incorporation of buffer layers in heteroepitaxial growth at high temperatures was commonly employed well prior to the '360 patent priority date. For example, in the case of sapphire substrates, the surface morphology and electrical and optical properties of epitaxial GaN were found to be remarkably improved with the use of an underlying AlN buffer layer. EX1011, 59.

51. Additionally, prior to 2005, it was well-known to grow a buffer layer as a template for subsequent growth of high quality epitaxial layers, for example, to reduce a lattice mismatch between the substrate and the desired epitaxial layer. EX1021, 515 (“Use of AlN as an intermediate buffer layer is one of the most promising ways to achieve high quality of GaN on Si...Compared to Si, AlN has a smaller lattice mismatch (2.4% vs. 19%)...with GaN...Since the buffer layer serves as the crystallographic and morphological template for subsequent GaN

deposition, the microstructure and growth mode of this layer must be understood to achieve device-quality GaN on silicon substrates.”); EX1022, 3028 (“The AlN buffer layer was used to inhibit formation of SiN_x at the Si surface and to assure uniform nucleation of AlGaIn.”); EX1023, 2073 (“Gas source molecular beam epitaxy (GSMBE) with ammonia can be used to grow high quality AlN on Si(111), and thus provide the needed buffer layer for the growth of GaN.”); EX1024, Abstract (“High quality GaN layers were grown on Si(111) substrates using high-temperature-grown AlN as buffer layer by rapid thermal process low-pressure metalorganic chemical vapor deposition.”).

52. Similar to the pre-treatment and nucleation growth steps, it was also well-known prior to 2005 to perform the growing of a buffer layer at an elevated temperature. EX1025, Abstract (“Gallium nitride films grown using a 10–500 nm-thick AlN buffer layer deposited at high temperature (~1050 °C)...AlN-to-GaN graded buffer layer are found to be under compressive stress and are completely crack free.”); EX1004, ¶¶[0025], [0028], [0109]; EX1011, 59-60; EX1016, 338-340.

D. Known epitaxial growth processes grew an epitaxial layer on a lattice mismatched substrate at an elevated temperature.

53. Epitaxial layer growth on lattice mismatched substrates was commonly practiced well before the priority date of the '360 patent. For example, a comprehensive review of defect formation (misfit dislocations) in the growth of

lattice-mismatched epitaxial films was published in the early 1990s. EX1027, Hull. This review highlighted the broad experimental and theoretical understanding that had been established by that time in the causes and mitigation of defects in elevated temperature heteroepitaxial growth.

54. Additional pre-2005 examples of the well-known nature of utilizing epitaxial growth processes to grow an epitaxial layer (e.g., GaN) on a lattice mismatched substrate (e.g., Si) include: EX1021, 151 (“Use of AlN as an intermediate buffer layer is one of the most promising ways to achieve high quality of GaN on Si...”), 153 (“Formation of an amorphous layer was suppressed, and the AlN film provided a better template for the subsequent growth of GaN.”); EX1023, Abstract (“We show that a short period superlattice of AlGa_N/GaN grown on the AlN buffer can be used to block defects propagating through GaN, resulting in good crystal and luminescence quality.”); EX1024, Abstract (“High quality GaN layers were grown on Si(111) substrates using high-temperature-grown AlN as buffer layer by rapid thermal process low-pressure metalorganic chemical vapor deposition.”); EX1025, Abstract (“Gallium nitride films grown using a 10–500 nm-thick AlN buffer layer deposited at high temperature (~1050 °C)...AlN-to-GaN graded buffer layer are found to be under compressive stress and are completely crack free.”).

VIII. PROSECUTION HISTORY SUMMARY

55. The application that ultimately issued as the '360 patent was allowed after receiving only a single office action on November 5, 2006. EX1002, '360 Patent Prosecution History, 0036-40. In the office action, the Examiner rejected claims 1-9 and 13-16 under 35 U.S.C. §102 based on U.S. Patent No. 6,218,280 to Kryliouk et al., allowed claims 18-24, and indicated that claims 10-12 and 17 would be allowable if rewritten in independent form. *Id.*, 0038-39. In response, Applicant argued that the recited “pre-treating step includes subjecting the surface of the substrate to at least one group III reactant or at least one group II reactant prior to introducing a group V reactant or a group VI reactant,” whereas the Kryliouk reference “specifically teaches simultaneously subjecting the substrate to a group III reactant (TMG reacted with HCl) and a group V reactant (NH₃).”¹ *Id.*, 0047. The Examiner then issued a notice of allowance on April 9, 2007. *Id.*, 0057-62.

IX. LEVEL OF ORDINARY SKILL IN THE ART

56. A person of ordinary skill in the art (“POSA”) would have a bachelor’s degree in electrical engineering, computer engineering, chemical engineering, or an equivalent field, or an advanced degree in those fields, as well

¹ Emphasis in original.

as least 3-5 years of academic or industry experience in nucleation and epitaxial growth processes, or comparable industry experience. I am well qualified to determine the level of ordinary skill in the art. I am very familiar with the technology of the '360 patent during the March 2005 timeframe. As mentioned above, by 2005, I had obtained both my Bachelor of Science degree, in Physics, and my Doctor of Philosophy degree in Physics, and had acquired extensive experience relating to nucleation and epitaxial growth processes. Specifically, by 2005 I had acquired experience in the growth of group III-V and silicon epitaxial layers by CVD, MOCVD, MBE, and other methods. I thus also qualify as a POSA for the '360 patent.

X. CLAIM CONSTRUCTION

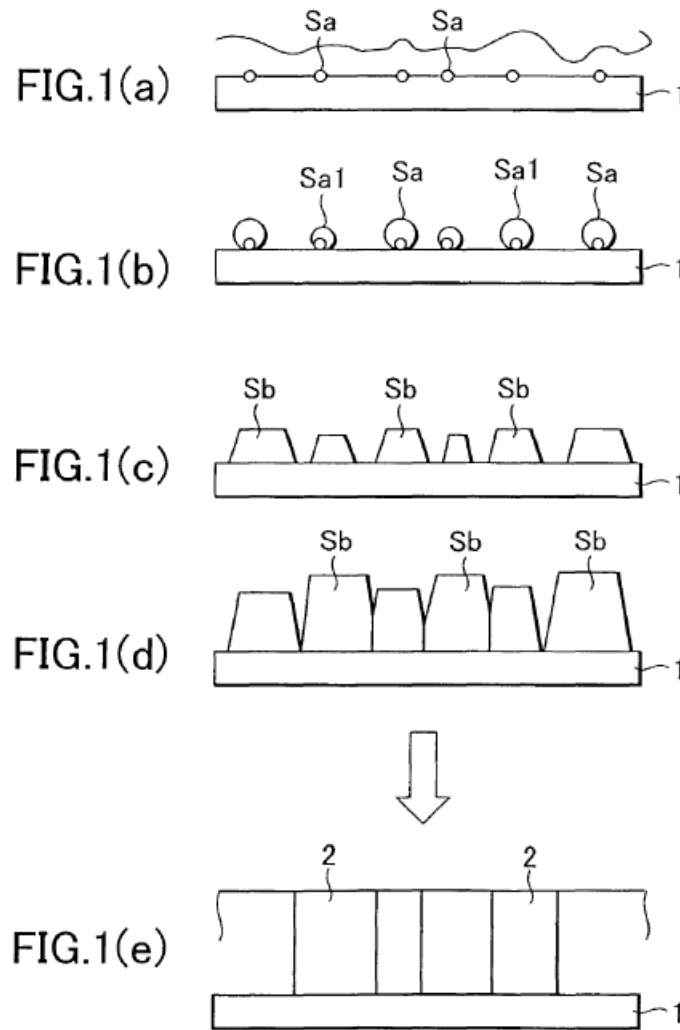
57. I have been instructed that the challenged claims of the '360 patent are to be given their ordinary and customary meaning as understood by one of ordinary skill in the art at the time of the invention in light of the specification and the prosecution history pertaining to the patent. Based on my review of the challenged claims, it is my opinion that none of the claim terms require explicit constructions. Accordingly, all claim terms should receive their plain and ordinary meaning, in the context of the '360 patent specification.

XI. OVERVIEW OF THE PRIOR-ART

A. Urashima

58. Like the '360 patent, Urashima describes “a method of fabricating a

group-III nitride semiconductor crystal that enables high-quality group-III nitride semiconductor crystal to be epitaxially grown on a sapphire substrate by a simplified method.” EX1004, ¶[0012]. I have copied Figure 1 from Urashima below to illustrate the disclosed simplified fabrication method.



EX1004, FIGs. 1(a)-(e).

59. Urashima explains that its method includes “a first step of depositing particles of a group III metal on a substrate surface,” as shown in Figure 1(a).

EX1004, ¶¶[0016], [0107]. Next, “a second step of nitriding the particles in an atmosphere containing a nitrogen source” is performed as shown in Figure 1(c). *Id.* Subsequently, “step D is performed ... for further growth of gallium nitride-based compound on the growth nuclei Sb” as shown in Figure 1(d). *Id.*, ¶[0109]. After the additional GaN-based compound semiconductor layer is grown in step D, Urashima discloses that “it is therefore possible to form a layer of gallium nitride-based compound semiconductor 2 of a desired thickness and crystallinity,” as illustrated in Figure 1(e). *Id.*, ¶[0114]. Urashima also discloses that its fabrication method is performed at an elevated temperature of “not lower than 900° C.” *Id.*, ¶[0028].

B. Nagata

60. Nagata discloses “a method for manufacturing a semiconductor quantum well box that that does not require an electron beam exposure process or an etching process, and cleverly utilizes only the initial process of epitaxial growth.” EX1005, ¶[0008]. Specifically, Nagata discloses “a method for manufacturing a semiconductor quantum well box of a 2-6 group compound or a 3-5 group compound characterized in comprising a step of supplying a raw material on a substrate having poor wettability with group 2 or group 3 molten metals and forming fine droplets comprising group 2 or group 3 atoms, and a subsequent step of supplying a raw material containing group 6 or group 5 atoms to diffuse the

group 6 or group 5 atoms into the group 2 or group 3 droplets, respectively” *Id.*

C. Keiper

61. Keiper is a paper that examines the use of “the metal organic vapour-phase epitaxy (MOVPE) process” in the manufacture of semiconductor crystal. EX1006, 256-57. Specifically, Keiper discloses a method to “provide an inherently ‘safe process’ for MOVPE of III-V materials and in addition has the potential for increased wafer uniformity.” *Id.*, 257. Keiper explains that its investigated process “eliminates both the explosive H₂ and the toxic hydrides as precursors,” and also that the “uniformity improves and the electrical characteristics are comparable or better than those of the standard MOVPE process.” *Id.*, Abstract.

D. Manabe

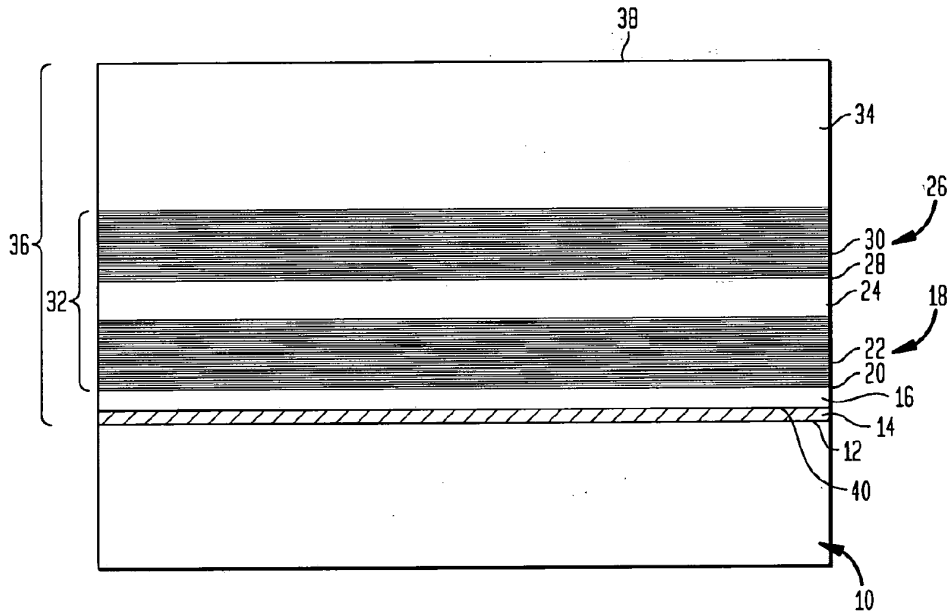
62. Manabe discloses a process that can be used to “grow a high-quality single crystalline gallium nitride compound-semiconductor having fewer lattice defects on a sapphire substrate.” EX1007, Manabe, 1:39-42. Specifically, Manabe discloses a process where at least one group III metal continues to be introduced during the introduction of a nitrogen source: “Such system constitution enables to mix a mixed gas comprising TMG, TMA [group III compounds], which is introduced through the first gas pipe 28, with a NH₃ and H₂ mixed gas [nitrogen source], introduced through the second gas pipe 29.” *Id.*, 4:39-43. Manabe explains that by providing such a mixed atmosphere during the nitriding process, “the flow

of the reaction gas on the sapphire substrate 50 gets constant and uniform[], so that high-quality crystal with less position-dependency may grow.” *Id.*, 4:48-51.

E. Guo

63. Like the '360 patent, Guo discloses “a method of making a semiconductor structure including the steps of depositing a small amount of aluminum directly on a silicon substrate to provide an aluminum protected substrate, and then depositing a nucleation layer of a nitride semiconductor on the aluminum protected substrate ... [and] further includes the step of epitaxially growing a buffer structure including one or more superlattices of nitride semiconductor on the nucleation layer, and then epitaxially growing an operative structure including one or more gallium nitride-based semiconductors on the buffer structure.” EX1008, ¶[0011]. I have copied Figure 1 from Guo below to illustrate an example of Guo’s method of making a semiconductor structure.

FIG. 1



EX1008, FIG. 1.

64. Guo explains that its method of manufacturing the above semiconductor structure is performed at an elevated temperature, which can include temperatures between 900° C and 1100° C. *Id.*, ¶¶[0004], [0031]-[0032], [0035].

F. Ashby

65. Ashby discloses a “process of growing a material on a substrate, particularly growing a Group II-VI or Group III-V material” (EX1009, Ashby, Abstract) including “producing materials with relatively few defects” (*id.*, ¶[0013]). Specifically, Ashby discloses an initial step where “[t]he substrate is cleaned in the growth chamber and the surface prepared for growth.” *Id.*, ¶[0028].

Ashby explains that “[o]ne typical pre-growth treatment involves heating in ambient H₂ for less than approximately 10 minutes.” *Id.*

XII. GROUND 1: URASHIMA RENDERS OBVIOUS CLAIMS 1-4 AND 6-14.

66. It is my opinion that the Urashima renders obvious claims 1-4 and 6-14 for the reasons provided below.

A. Independent Claim 1

1. [1.P]: A process for growing an epitaxial layer on a lattice mismatched substrate comprising the steps of:

67. To the extent that the preamble of claim 1 is limiting, Urashima discloses the preamble.

68. Urashima discloses “an object of the invention is to provide **a method of fabricating** a group-III nitride semiconductor crystal that enables **high-quality group-III nitride semiconductor crystal to be epitaxially grown on a sapphire substrate** by a simplified method.”² EX1004, ¶¶[0012], [0025], [0089]-[0090], [0109]. Based on my extensive experience (outlined in Section III above), it is my opinion that a POSA would have understood that Urashima’s group-III nitride semiconductor crystal represents “*an epitaxial layer*.” My opinion is also informed by the fact that the ’360 patent explains that its “epitaxial layer includes a III-V compound or a II-VI compound.” EX1001, 3:2-4, 1:43-44. The ’360 patent also

² Emphasis added throughout unless otherwise noted.

explains that “[p]referably, the group V reactant contains a nitrogen reactant”

Id., 2:59-60. A POSA would have therefore understood that the claimed “*epitaxial layer*” can include a group III-nitrogen reactant compound, and that Urashima discloses such a compound—i.e., a “group-III nitride semiconductor crystal.” EX1004, ¶[0012].

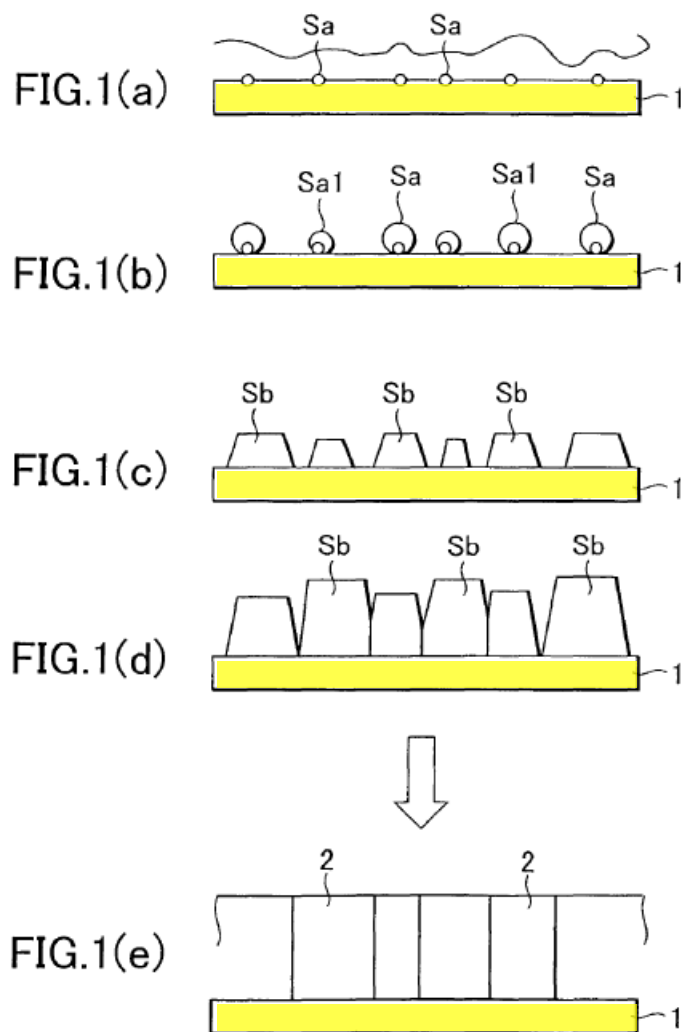
69. Additionally, Urashima unequivocally makes clear that its group-III nitride semiconductor crystal is in fact a “*layer*.” *Id.*, ¶¶[0013] (“a crystal **layer**”), [0035], [0047] (“a **layer** of gallium nitride-based compound semiconductor crystal”), [0106]-[0108]. This is also consistent with my understanding of how a POSA would have interpreted Urashima’s group-III nitride semiconductor crystal in the 2005 timeframe.

70. Urashima also discloses that its sapphire substrate is “*a lattice mismatched substrate*.” Indeed, Urashima explains that “[t]here is a large **lattice mismatch** between such a [sapphire] substrate and the group-III nitride compound semiconductor crystal that is epitaxially grown on the substrate.” *Id.*, ¶¶[0004], [0003], [0133], [0153].

71. Therefore, it is my opinion that a POSA would have understood that Urashima discloses a “*process for growing an epitaxial layer on a lattice mismatched substrate*,” as recited in the preamble.

2. [1.a] providing a substrate;

72. Urashima illustrates an example of its method of fabricating a group-III nitride semiconductor crystal in Figure 1. EX1004, ¶[0067]. Urashima discloses that, in this example, a gallium reactant can be used as its group-III reactant. *Id.*, ¶[0106]; Such disclosure is consistent with the explanation provided in the '360 patent. EX1001, 2:36-38 (“The group III reactant is preferably selected from the group consisting of a **gallium reactant**, an aluminum reactant, a boron reactant, and an indium reactant”). Figure 1 of Urashima illustrates example steps “used to form the layer of gallium nitride-based compound semiconductor **on the substrate.**” EX1004, ¶[0107]. I have copied Figure 1 of Urashima below to illustrate Urashima’s method of fabricating a group-III nitride semiconductor crystal. In Figure 1 below, I have also added annotations such that the substrate is highlighted in yellow.

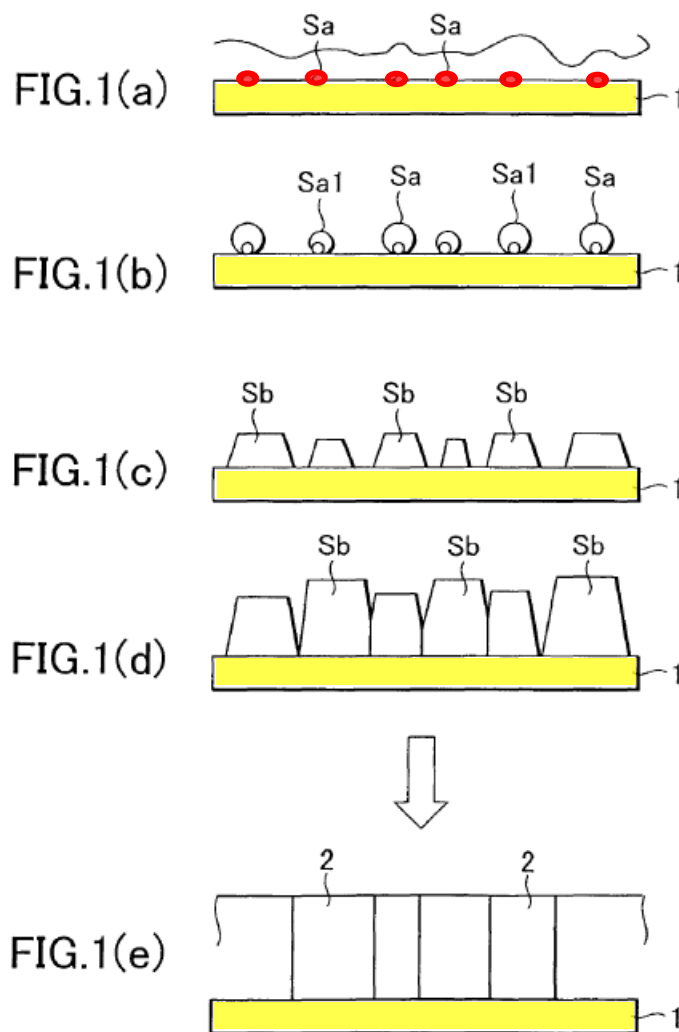


EX1004, FIGs. 1(a)-(e) (annotated).

73. Therefore, it is my opinion that a POSA would have understood that Urashima's fabrication method includes "*providing a substrate*," as recited in claim element [1.a].

3. [1.b] pre-treating a surface of the substrate with at least one group III reactant or at least one group II reactant at an elevated growth temperature prior to introducing a group V reactant or a group VI reactant;

74. First, Urashima discloses “*pre-treating a surface of the substrate with at least one group III reactant.*” Indeed, Urashima discloses that “[t]he invention achieves the foregoing objects by providing a method of fabricating a group-III nitride semiconductor crystal according to a first aspect, comprising **a first step of depositing particles of a group III metal on a substrate surface.**” EX1004, ¶¶[0016], [0089], Abstract. Urashima illustrates this “*pre-treating*” step in Figure 1(a), where “in step A (the first step), a metal element, preferably metal nuclei (droplets) Sa of a group III metal element are adhered to a substrate 1.” *Id.*, ¶[0107]. Like the ’360 patent, Urashima discloses that its group III metal can include aluminum, gallium, and/or indium. *Compare id.*, ¶[0081] with EX1001, 2:36-38. I have again copied Figure 1 of Urashima below, and this time I have added annotations such that the group III metal Sa is highlighted in red.



EX1004, FIGs. 1(a)-(e) (annotated).

75. Urashima also discloses that the first step of adhering the group III metal Sa to substrate 1 is performed “*at an elevated growth temperature.*” As an initial matter, the ’360 patent explains that “[i]n a preferred embodiment, the elevated growth temperature is 900 to 1100° C.” EX1001, 2:50-51. Urashima discloses performing the first step within the same example elevated temperature range. Specifically, Urashima discloses setting the temperature of the epitaxial

growth apparatus at “**1100° C.** in the case of FIG. 2,” and that “[s]teps A [the first step], B and C are implemented at that temperature.” EX1004, ¶¶[0109] (“Before implementing step A, the substrate of, for example, sapphire is thermally cleaned inside the MOCVD apparatus at a temperature of 1000° C. to 1200° C. The temperature of the epitaxial growth apparatus is then reduced, for example [by] 5° C. to 200° C., and maintained at that temperature ...”), [0025] (performing the first step “at a temperature T1”), [0028] (“temperature T1 is **not lower than 900° C.**”).

76. Finally, Urashima discloses that the group III metal Sa is introduced “*prior to introducing a group V reactant or a group VI reactant.*” As discussed above, the ’360 patent explains that “[p]referably, the group V reactant contains a nitrogen reactant” EX1001, 2:59-60. It is my opinion that a POSA would have therefore understood this claim limitation to include instances where the group III reactant is introduced before the introduction of a nitrogen reactant. Urashima discloses such an ordering of fabrication steps: “it is preferable to perform the first step [of depositing particles of a group III metal on a substrate] in an atmosphere that **does not contain a nitrogen source.**” EX1004, ¶¶[0083], [0025], [0081], [0089], [0119], Abstract.

77. Therefore, it is my opinion that a POSA would have understood that Urashima discloses a “*pre-treating a surface of the substrate with at least one group III reactant or at least one group II reactant at an elevated growth*

temperature prior to introducing a group V reactant or a group VI reactant,” as recited in claim element [1.b].

4. [1.c] introducing a group V reactant or a group VI reactant to grow a nucleation layer on the surface of the substrate; and

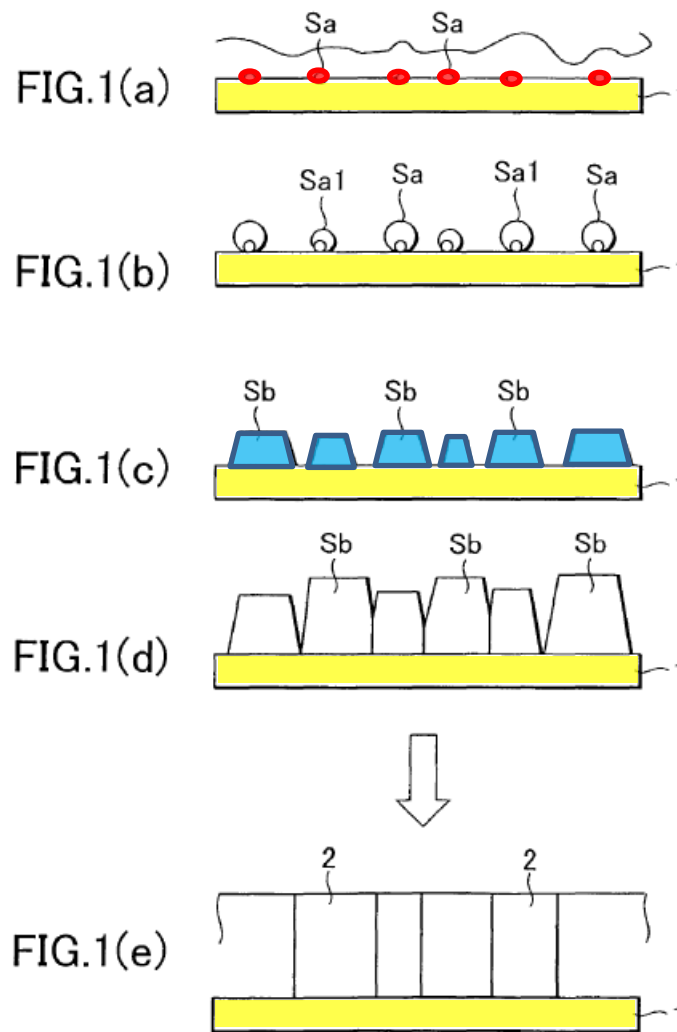
78. Urashima discloses “*introducing a group V reactant.*” Again, the ’360 patent explains that “[p]referably, the group V reactant contains a nitrogen reactant” EX1001, 2:59-60. Thus, similar to my explanation for the previous claim element, it is my opinion that a POSA would have understood this claim limitation to include instances where a nitrogen reactant is introduced after the group III reactant is introduced. Urashima discloses such a fabrication step: after performing a “first step of depositing particles of a group III metal on a substrate surface, [performing] **a second step of nitriding the particles in an atmosphere containing a nitrogen source.**”³ EX1004, ¶¶[0016], [0089], [0113], Abstract.

³ In some instances, Urashima discloses the step of nitriding the particles as “the third step” depending on whether an additional annealing step is performed prior to nitriding the particles. EX1004, ¶[0107]. Urashima discloses that annealing is optional and can be omitted. *Id.*, ¶¶[0205], [0216]. Thus, it is my opinion that a POSA would have understood that whether referred to as the second step or the

Based on both my prior experience and the disclosure of the '360 patent, it is my opinion that a POSA would have understood that “nitriding the particles in an atmosphere containing a nitrogen source” is an example of “*introducing a group V [nitrogen] reactant.*” In fact, ammonia is disclosed as being a preferred reactant for both of these steps. *Compare id.*, ¶¶[0085] (“For the second step, **an atmosphere can be used that contains ammonia or hydrazine as a nitrogen source**”), [0123] *with* EX1001, 3:22-25 (“Once the pre-treatment of the surface is complete, **a nitrogen source, preferably ammonia, is introduced** into the growth chamber to commence the deposition of a nucleation layer”), 2:60-62.

79. Urashima also discloses that nitriding the particles is carried out in order to “*grow a nucleation layer on the surface of the substrate.*” Specifically, Urashima discloses “in step C (the third step), the annealed **metal nuclei Sa1 are nitrided to form growth nuclei Sb** (FIG. 1(c)).” EX1004, ¶[0107]. Urashima similarly discloses that “the **metal nuclei Sa1 are nitrided to transform them to growth nuclei Sb that form the nitride semiconductor.**” *Id.*, ¶[0113]. I have again copied Figure 1 of Urashima below, and this time I have added annotations such that the growth nuclei Sb are highlighted in blue.

third step, Urashima’s disclosure of nitriding the particles relates to the same step of the same fabrication method.



EX1004, FIGs. 1(a)-(e) (annotated).

80. In my opinion, a POSA would have understood that Urashima's growth nuclei Sb collectively represent "*a nucleation layer.*" The only guidance provided by the '360 patent as to the proper interpretation of "*a nucleation layer*" is: (i) it is "formed by introducing the group V reactant or the group VI reactant into the growth chamber;" and (ii) is it composed of " $\text{Al}_x\text{Ga}_{1-x}\text{N}$ where x varies from 0 to 1." EX1001, 1:59-62. Urashima's growth nuclei Sb satisfy both of these

criteria.

81. First, Urashima's growth nuclei Sb are formed by subjecting the group III metal particles, Sa or Sa1, to a nitrogen source ("*introducing a group V reactant*"). EX1004, ¶¶[0016], [0089], [0107], [0113].

82. Second, in at least some instances, the resulting growth nuclei Sb are composed of a combination of Al (aluminum) and/or Ga (gallium), and N (nitrogen), because the group III metal particles, Sa or Sa1, include "at least one metal element selected from among In, Ga and Al." *Id.*, ¶¶[0025], [0018], [0037], [0081], [0089]. Thus, when the nitrogen source is introduced to the group III metal particles, Sa or Sa1, the resulting growth nuclei Sb are composed of some combination of In, Ga, and/or Al, and N.

83. Urashima also discloses that "it is preferable to use nuclei of a group III metal represented by $In_uGa_vAl_w$ (where $u+v+w=1$, $0 \leq u \leq 1$, $0 \leq v \leq 1$, $0 \leq w \leq 1$)."
Id., ¶[0117]. Thus, group III metal particles, Sa or Sa1, could be represented as GaAl when "u" is set to zero, and "v" and "w" are set to non-zero values. In this instance, when the nitrogen source is introduced to the group III metal particles, Sa or Sa1, the resulting growth nuclei Sb would comprise a GaAlN compound. Thus, like the '360 patent, Urashima also discloses a layer of growth nuclei Sb having a composition of $Al_xGa_{1-x}N$, where x varies from 0 to 1—e.g., AlN, GaN, or GaAlN. EX1001, 1:59-62.

84. To the extent that Urashima does not explicitly disclose the composition of the resulting growth nuclei Sb, it is my opinion that a POSA would have nonetheless found it obvious based on the above disclosure from Urashima that growth nuclei Sb would have a composition of $\text{Al}_x\text{Ga}_{1-x}\text{N}$, where x varies from 0 to 1. Indeed, a POSA would have understood that Urashima's process for creating growth nuclei Sb amounts to subjecting known materials (group III reactants, e.g., Ga and/or Al) to a known gas (group V reactant, e.g., nitrogen) to yield predictable results (a layer of growth nuclei Sb having a composition of $\text{Al}_x\text{Ga}_{1-x}\text{N}$, where x varies from 0 to 1—e.g., AlN, GaN, or GaAlN).

85. Therefore, because Urashima's layer of growth nuclei Sb are formed in the same manner, and can have the same resulting composition as the nucleation layer in the '360 patent, it is my opinion that a POSA would have understood that Urashima's growth nuclei Sb disclose or render obvious "*a nucleation layer.*"

86. Additionally, Urashima's discussion of growth nuclei Sb is also consistent with the other portions of the '360 patent discussing its "*nucleation layer.*" For example, the '360 patent discloses that "[i]n a preferred embodiment, aluminum reacts with the surface of the substrate providing the needed **nucleation sites.**" EX1001, 1:65-2:2. It is my opinion that a POSA would have recognized that Urashima's growth nuclei Sb similarly provide the nucleation sites needed during the epitaxial growth process. Not only is Urashima's discussion of growth nuclei

Sb consistent with the '360 patent's description of its alleged invention, it is also consistent with how nucleation layers were generally understood in the 2005 timeframe. Indeed, in the '360 patent's "Description of Related Art" section, it explains that "[h]eteroepitaxial growth of GaN and related alloys on severely mismatched substrates such as sapphire, SiC and silicon requires thin nucleation layers to provide **nucleation sites** to initiate crystal growth." *Id.*, 1:21-24.

87. Further, a POSA would have understood that because both Urashima and the '360 patent describe performing their respective epitaxial growth processes at temperatures at, or greater than 900° C—which is higher than the melting point of aluminum (660° C) and gallium (30° C)—the metals used in the pre-treatment processes (Al and/or Ga) would form as particles that wet the substrate. EX1004, ¶[0083] ("It is desirable to carry out the first step at a temperature at or above the melting point of the group III metal, since this facilitates migration of metal atoms on the substrate."). Indeed, a POSA would have understood that if any particles form from the vapor, the Al-Ga phase diagram indicates they would be in liquid form. EX1021, Abstract ("The AFM results show that with TMA pre-treatments, AlN grows in a pseudo-2-dimensional mode because the lateral growth rate of AlN is increased, and the wetting property of the AlN on silicon is improved."), 152 ("TMA pre-treatment increase[s] the wetting of AlN on silicon and the surface mobility of Al and nitrogen is increased as indicated by the increased lateral

growth rate of AlN to form a wetting layer of AlN on the silicon surface.”). As such, a POSA would have understood that upon the introduction of a nitrogen source to these metal particles during the nucleation process, nucleation sites consisting of $\text{Al}_x\text{Ga}_{1-x}\text{N}$ compounds would ultimately be formed. And as explained by the '360 patent, such nucleation sites make up its nucleation layer. For at least these reasons, it is my opinion that a POSA would have understood that there is no meaningful distinction between Urashima's growth nuclei Sb and the '360 patent's claimed “*nucleation layer*.”

88. Finally, Urashima's growth nuclei Sb are “*on the surface of the substrate*” as illustrated in Figure 1 above. EX1004, ¶¶[0108] (“...substrate 1 having the growth nuclei Sb...”), [0113] (“...the growth nuclei Sb should be trapezoidal in shape, with a flat top parallel to the substrate...”).

89. Therefore, it is my opinion that a POSA would have understood that Urashima discloses, and/or renders obvious, “*introducing a group V reactant or a group VI reactant to grow a nucleation layer on the surface of the substrate*,” as recited in claim element [1.c].

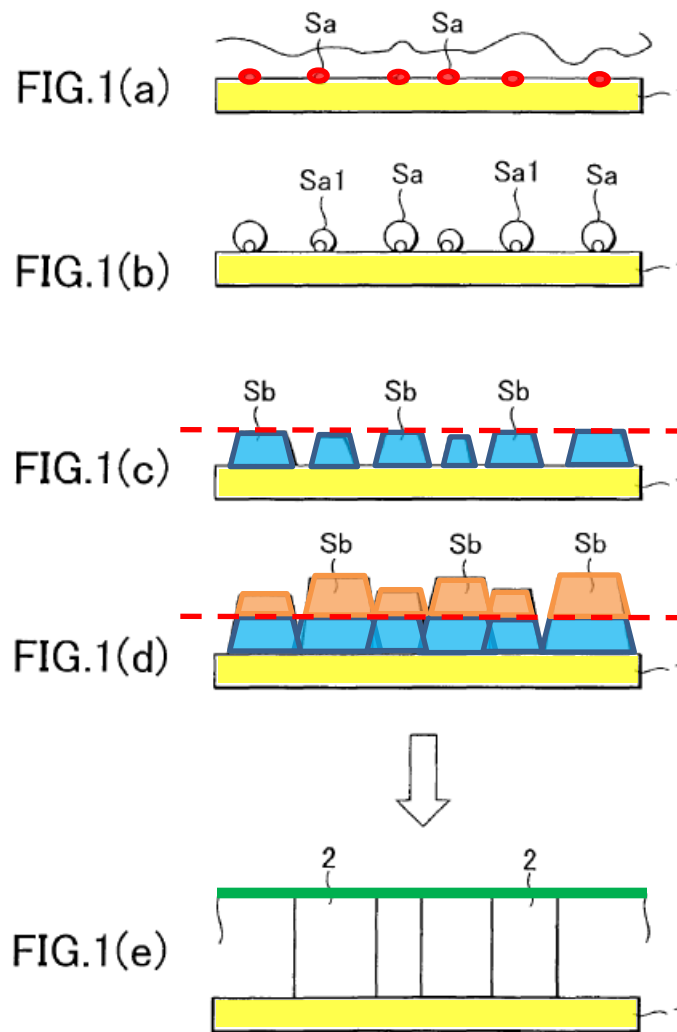
5. [1.d] growing a buffer layer on said nucleation layer, said buffer layer providing a surface upon which said epitaxial layer is grown.

90. Urashima discloses “*growing a buffer layer on said nucleation layer*.” The only guidance provided by the '360 patent as to the proper interpretation of “*a*

buffer layer” is that it is preferably “a GaN buffer layer [that] provides a surface on which GaN-based materials can subsequently be deposited.” EX1001, 3:39-42.

Like the '360 patent, Urashima discloses that after growth nuclei Sb are formed, as shown in Figure 1(c) (“*said nucleation layer*”), an additional “**gallium nitride-based compound semiconductor layer** is grown on the substrate 1 having the growth nuclei Sb (FIG. 1(d))” [in] step D (the fourth step).” EX1004, ¶¶[0108], [0109]. Urashima similarly discloses that “[m]ore **gallium nitride-based compound semiconductor is grown on the growth nuclei Sb ... forming a flat layer.**” *Id.*, ¶[0114].

91. I have again copied Figure 1 of Urashima below, and this time I have added annotations to illustrate the growth of the additional gallium nitride-based compound semiconductor layer. Specifically, in step C (the third step), growth nuclei Sb are formed having an initial layer depth as shown in Figure 1(c) below—i.e., the layer below the red dashed line. *Id.*, ¶¶[0108], [0109]. Subsequently, “step D is performed ... **for further growth of gallium nitride-based compound on the growth nuclei Sb**” as shown in Figure 1(d), which I annotated below with the additional GaN-based compound semiconductor layer—above the red dashed line—highlighted in orange. *Id.*, ¶[0109].



EX1004, FIGs. 1(a)-(e) (annotated).

92. It is my opinion that a POSA would have therefore understood that the additional GaN-based compound semiconductor layer grown in step D represents “growing a buffer layer on said nucleation layer.”

93. Urashima also discloses “said buffer layer providing a surface upon which said epitaxial layer is grown.” Specifically, Urashima discloses that after the additional GaN-based compound semiconductor layer is grown in step D (“said

buffer layer”), “it is therefore possible to form a layer of gallium nitride-based compound semiconductor 2 of a desired thickness and crystallinity,” as illustrated in Figure 1(e) above (highlighted in green). EX1004, ¶¶[0114], [0140]. Urashima similarly discloses that “[t]he growth proceeds horizontally, mostly accompanying the dislocation, ensuring an adequate layer depth (for example 2 μm), thereby providing a flat, horizontal layer of gallium nitride-based compound semiconductor 2 (FIG. 1(e).” *Id.*, ¶[0108]. Urashima explains that “[b]y means of the above method, group-III nitride semiconductor crystal having good crystallinity can be epitaxially grown on a sapphire substrate.” *Id.*, ¶¶[0090], [0089], [0115]. And as I discussed in Section XII.A.1 above, it is my opinion that a POSA would have understood that Urashima’s group-III nitride semiconductor crystal—e.g., gallium nitride-based compound semiconductor 2—is “*an epitaxial layer*.”

94. As explained above, and illustrated in Figure 1, Urashima discloses that GaN-based compound semiconductor 2 (“*an epitaxial layer*”) is grown on the additional GaN-based compound semiconductor layer grown in step D (“*said buffer layer*”). But, to the extent that such disclosure is not explicit, Urashima additionally discloses stacking multiple layers of GaN-based compound semiconductor 2. *Id.*, ¶¶[0046] (“The above method encompasses a case in which a separate layer of gallium nitride-based compound semiconductor crystal is grown

on the gallium nitride-based compound semiconductor crystal layer formed in the fourth step”), [0055], claim 77. When such stacking is performed, a second layer of GaN-based compound semiconductor 2 would necessarily be grown on the GaN-based compound semiconductor layer grown in step D (“*said buffer layer*”).

95. Therefore, it is my opinion that a POSA would have understood that Urashima discloses, and/or renders obvious, “*growing a buffer layer on said nucleation layer, said buffer layer providing a surface upon which said epitaxial layer is grown,*” as recited in claim element [1.d].

B. Dependent Claim 2

96. Claim 2 recites, “*wherein said substrate is selected from the group consisting of silicon, sapphire and SiC.*” Urashima discloses claim 2.

97. Specifically, Urashima discloses that “[t]he **substrate** used in the above fabrication method may be glass, **SiC**, **Si** [silicon], GaAs, **sapphire**, or other such substances.” EX1004, ¶¶[0080], [0116].

C. Dependent Claim 3

98. Claim 3 recites, “*wherein said group III reactant is selected from the group consisting of a gallium reactant, an aluminum reactant, a boron reactant, and an indium reactant.*” Urashima discloses claim 3 for at least the same reasons discussed in Sections XII.A.3 and XII.A.4 above. EX1004, ¶¶[0025], [0018], [0037], [0081] (“The **group III metal** particles deposited on the substrate in the

first step may be particles of **Al, Ga**, In and the like”), [0089], [0117].

D. Dependent Claim 4

99. Claim 4 recites “*wherein said group III reactant is selected from the group consisting of triethyl gallium, trimethyl gallium, triethylaluminum, trimethyl aluminum, triethylboron, trimethylboron, triethylindium and trimethylindium.*”

Urashima discloses claim 4.

100. Specifically, Urashima discloses that gases containing group III metals that can be used “include trimethyl gallium (TMG), triethyl gallium (TEG), trimethyl aluminum (TMA), trimethyl indium (TMI), bicyclopentadienyl indium (Cp_2In).” EX1004, ¶¶[0118], [0082], [0096].

E. Dependent Claim 6

101. Claim 6 recites “*wherein said step of pre-treating includes pre-treating the surface of the substrate with an aluminum reactant and a gallium reactant.*”

Urashima discloses claim 6 for at least the same reasons discussed in Section XII.A.3 and for claim 3 above. EX1004, ¶¶[0016] (“... **a first step of depositing particles of a group III metal on a substrate surface ...**”), [0025], [0018], [0037], [0081] (“The **group III metal** particles deposited on the substrate in the first step may be particles of **Al, Ga**, In and the like. In this invention, it is desirable to use particles of $\text{In}_u\text{Ga}_v\text{Al}_w$ (where $u+v+w=1$, $0 \leq u \leq 1$, $0 \leq v \leq 1$, $0 \leq w \leq 1$)”), [0089], [0117].

F. Dependent Claim 7

102. Claim 7 recites “*wherein said nucleation layer is AlN or AlGaN.*”

Urashima discloses claim 7 for at least the same reasons discussed in Section XII.A.4 and for claim 6 above. EX1004, ¶¶[0016], [0025], [0018], [0037], [0081], [0089], [0107], [0113], [0117].

G. Dependent Claim 8

103. Claim 8 recites “*wherein said buffer layer is GaN.*” Urashima discloses claim 8 for at least the same reasons discussed in Section XII.A.5 above. EX1004, ¶¶[0108] (an additional “**gallium nitride-based compound semiconductor layer** is grown on the substrate 1 having the growth nuclei Sb (FIG. 1(d))” “[in]step D (the fourth step)”), [0046], [0055], [0109], [0114], claim 77.

H. Dependent Claim 9

104. Claim 9 recites “*wherein said epitaxial layer includes a compound selected from the group comprising AlN, GaN, AlGaN, BGaN, BInN, BAlN, CdTe, and ZnS.*” Urashima discloses claim 9 for at least the same reasons discussed in Section XII.A.5 above.

105. Specifically, Urashima discloses that after the additional GaN-based compound semiconductor layer is grown in step D (“*said buffer layer*”), “it is therefore possible to form a layer of **gallium nitride-based compound semiconductor 2** of a desired thickness and crystallinity,” as illustrated in Figure

1(e) above. EX1004, ¶¶[0114], [0046], [0055], [0108], [0140]. Urashima explains that “[b]y means of the above method, **group-III nitride semiconductor crystal** having good crystallinity can be **epitaxially grown** on a sapphire substrate.” *Id.*, ¶¶[0090], [0081], [0089], [0115]. A POSA would have understood that GaN, AlGaN, and BGaN are all examples of gallium nitride-based compounds.

I. Dependent Claim 10

106. Claim 10 recites “*further comprising the step of preheating said substrate in hydrogen prior to pre-treating the surface of the substrate with at least one group III reactant or at least one group II reactant.*” Urashima discloses claim 10.

107. Urashima discloses that “[t]he method of fabrication can include a **known heat treatment step prior to the first step** [the “*pre-treating the surface*” step] known as thermal annealing. Thermal annealing, which is widely employed when sapphire substrates are used, is a type of cleaning treatment implemented in an epitaxial reactor. It usually involves **heating the substrate** at 1000° C. to 1200° C. **in an atmosphere containing hydrogen** or nitrogen.” EX1004, ¶¶[0101], [0140].

J. Dependent Claim 11

108. Claim 11 recites “*wherein said elevated growth temperature is 900 to 1100° C.*” Urashima discloses claim 11 for at least the same reasons discussed in

Section XII.A.3 above. Specifically, Urashima discloses setting the temperature of the epitaxial growth apparatus at “**1100° C.** in the case of FIG. 2,” and that “[s]teps A, B and C are implemented at that temperature.” EX1004, ¶¶[0109] (“Before implementing step A, the substrate of, for example, sapphire is thermally cleaned inside the MOCVD apparatus at a temperature of 1000° C. to 1200° C. The temperature of the epitaxial growth apparatus is then reduced, for example [by] 5° C. to 200° C., and maintained at that temperature ...”), [0025] (performing the first step “at a temperature T1”), [0028] (“temperature T1 is **not lower than 900° C.**”).

K. Dependent Claim 12

109. Claim 12 recites “*wherein the step of introducing a group V reactant or a group VI reactant includes growing a nucleation layer at a growth temperature of 900 to 1100° C. and the step of growing a buffer layer includes growing a buffer layer at a growth temperature of 900 to 1100° C.*” Urashima discloses claim 12 for at least the same reasons discussed in Section XII.A.3 above.

110. As mentioned, Urashima discloses setting the temperature of the epitaxial growth apparatus at “**1100° C.** in the case of FIG. 2,” and that “[s]teps A, B and C [*“the step of introducing a group V reactant”/“growing a nucleation layer”*] are implemented at that temperature.” EX1004, ¶[0109]. Urashima also discloses that “the heating pattern is not limited to the one shown in FIG. 2,” and

that “step D [*“the step of growing a buffer layer”*] can be effected **at a lower temperature than steps A to C, or at the same temperature.**” *Id.*, ¶[0110].

111. Urashima also discloses in another example, “a second step of nitriding the deposited metal [*“the step of introducing a group V reactant”/“growing a nucleation layer”*] at a temperature T_2 , where $T_2 \geq T_1$,” and “a third step in which a metallo-organic chemical vapor deposition method is used to epitaxially grow, at a temperature T_3 , where $T_3 \geq T_2$, a group-III nitride semiconductor crystal on the sapphire substrate on which the metal has been deposited.” *Id.*, ¶[0025]. Urashima explains that “ T_1 is not lower than 900°C . and temperature T_3 is not lower than 1000°C .” *Id.*, ¶[0028]. Therefore, it is my opinion that a POSA would have understood that in this example, Urashima discloses nitriding the deposited metal [*“the step of introducing a group V reactant”/“growing a nucleation layer”*] at a temperature $\geq 900^\circ\text{C}$ and growing an additional GaN-based compound semiconductor layer (“*growing a buffer layer*”) at a temperature $\geq 1000^\circ\text{C}$.

L. Dependent Claim 13

112. Claim 13 recites “*wherein said group V reactant is a group V hydride.*” Urashima discloses claim 13. As explained in Section XII.A.4 above, a POSA would have understood that Urashima’s step of “nitriding the particles in an atmosphere containing a nitrogen source” is an example of introducing a “*group V*

reactant.” EX1004, ¶¶[0016]. Urashima explains that this nitrogen source (“*group V reactant*”) can be ammonia or hydrazine. *Id.*, ¶¶[0085], [0123]. A POSA would have understood that ammonia and hydrazine are both examples of “*a group V hydride.*” EX1020, Connelly, 85 (Table IR-6.1, Parent names of mononuclear hydrides, “NH₃ azane...naming derivatives of ammonia”), 86 (“hydrazine”), 105 (“ammonium”). Indeed, the ’360 patent confirms the same: “In one preferred embodiment, the group V reactant is a group V hydride, most preferably ammonia, arsine or phosphine.” EX1001, 2:60-62.

M. Dependent Claim 14

113. Claim 14 recites “*wherein said group V hydride is selected from the group consisting of ammonia, arsine, and phosphine.*” Urashima discloses claim 14 for at least the same reasons discussed for claim 13 above. EX1004, ¶¶[0016], [0085], [0123].

XIII. GROUND 2: THE COMBINATION OF URASHIMA AND NAGATA RENDERS OBVIOUS CLAIMS 5 AND 17.

114. It is my opinion that the combination of Urashima and Nagata renders obvious claims 5 and 17 for the reasons provided below.

A. A POSA would have been motivated to combine Urashima and Nagata.

115. In my opinion, a POSA would have been motivated to modify Urashima’s method of fabricating a film of group-III nitride semiconductor crystal to use one or more group II reactants in Urashima’s first step of depositing metal

particles on a substrate surface, as taught by Nagata. A POSA would have been further motivated to modify Urashima's fabrication method to use one or more group VI reactants in Urashima's step of forming growth nuclei, as also taught by Nagata.

116. As discussed above, Urashima discloses a "method of fabricating a film of group-III nitride semiconductor crystal [that] includes a step of using metal material to deposit particles of a group III metal on a substrate surface in an atmosphere containing no nitrogen source" EX1004, Abstract. Urashima additionally discloses that "elements other than group III metals" can also be used during this first step. *Id.*, ¶¶[0096], [0081], [0117]. Urashima provides a small number of non-limiting examples of some "other such non-group III metals" that can be used, but Urashima does not provide an exhaustive list. *Id.*, ¶¶[0081], [0096]. Urashima also does not disclose why other non-group III metals may be used.

117. As also discussed above, Urashima discloses that its fabrication method additionally includes "a step of nitriding the particles in an atmosphere containing a nitrogen source" (a group V reactant). *Id.*, Abstract. Urashima explains that "[t]he shape of the growth nuclei Sb can be controlled by controlling the conditions used during the nitriding process. In particular, the gas used during the nitriding" *Id.*, ¶¶[0113], [0107], [0129]. Urashima discloses that "[t]hese

conditions have to be appropriately selected according to the type of metal used for the metal nuclei Sa that adhere to the substrate” *Id.* Although Urashima discloses that other non-group III metals may be used for the metal nuclei Sa that adhere to the substrate (*id.*, ¶¶[0081], [0096], [0117]), Urashima does not disclose the reactants that should be used when growing semiconductors of these other non-group III metals.

118. It is my opinion that a POSA would have thus looked to the prior art for guidance on what other non-group III metals may be used in Urashima’s fabrication method, and on what reactants should be used when growing semiconductors of these other non-group III metals. Nagata is such a prior art reference.

119. Like Urashima, Nagata discloses “a method for manufacturing a semiconductor quantum well box that ... cleverly utilizes only the initial process of epitaxial growth.” EX1005, ¶[0008], Abstract, claim 1. Specifically, Nagata discloses “a method for manufacturing a semiconductor quantum well box of a 2-6 group compound or a 3-5 group compound characterized in comprising a step of supplying a raw material on a substrate having poor wettability with group 2 or group 3 molten metals and forming fine droplets comprising group 2 or group 3 atoms, and a subsequent step of supplying a raw material containing group 6 or group 5 atoms to diffuse the group 6 or group 5 atoms into the group 2 or group 3

droplets, respectively” *Id.* Thus, Nagata discloses that the metal particles adhered to the substrate can be non-group III metals—i.e., “group 2 ... molten metals”—and when such group 2 metals are used, “raw material containing group 6 ... atoms” are introduced later in the fabrication method. *Id.*

120. Based on the teachings of Nagata, it is my opinion that a POSA would have been motivated to modify Urashima to use a group II reactant in Urashima’s first step of depositing metal particles on a substrate surface, and to use a group VI reactant in Urashima’s step of forming growth nuclei. Nagata discloses that its fabrication method can be used to form “a 2-6 group compound or a 3-5 group compound.” *Id.*, ¶[0008]. In fact, it was common by the 2005 timeframe for certain epitaxial growth processes to be applicable to both group III-V compounds and group-II-VI compounds. EX1011, 189-190 (illustrating the same growth experiments performed on “several group II, III, V, and VI alkyls,” and indicating that these alkyls are all “useful for MOVPE growth”). Nagata and Urashima also disclose using the same or similar crystal growth techniques. *Compare* EX1005, ¶[0004] (“using crystal growth techniques such as MOVPE (metal organic vapor phase deposition) and MBE (molecular beam epitaxy)”) *with* EX1004, ¶[0088] (“the group-III nitride semiconductor crystal can be formed by various vapor phase growth methods including the metallo-organic chemical vapor deposition (MOCVD) method [and] the molecular beam epitaxy (MBE) method ...”). Indeed,

a POSA would have understood that MOVPE and MOCVD actually refer to the same method and are often used interchangeably by those in the industry.

121. Thus, it is my opinion that a POSA would have recognized that Nagata's techniques are applicable to Urashima, and that modifying Urashima to use group II and group VI reactants would have required minimal modifications. Indeed, in the combined system, Urashima's crystal growth technique would use a group II reactant in the first step of depositing metal particles on a substrate surface, and would use a group VI reactant in the step of forming growth nuclei. All other steps and conditions disclosed in Urashima could remain largely unchanged. This would then result in the formation of a group II-VI compound semiconductor in the same way as Urashima's group III element growth technique to form a group III-V compound semiconductor.

122. Moreover, it is my opinion that a POSA would have recognized that in some situations such a modification would have the added benefit of providing better adherence of the materials to the substrate, more favorable conditions for preservation of the substrate during the formation of nuclei, and lower unit cost when using certain other non-group III metals.

123. Based on my experience in the industry, it is also my opinion that a POSA would have recognized that the combination of group II and group VI reactants to form nuclei would have also been appropriate in the 2005 timeframe

for the subsequent growth of industrial or militarily valuable material combinations like CdS, CdTe, and ZnS, each of which are group II-VI compounds. Such materials were often used in the 2005 timeframe for optical and infrared sensors and emitters, for example. Therefore, a POSA would have recognized that there would have also been certain economic motivations for using group II and group VI reactants in Urashima's crystal growth technique, as taught by Nagata.

124. Further, a POSA would have understood that selecting a group II-VI binary compound for use in Urashima's crystal growth technique represents a selection from a finite number of identified, predictable binary compounds that are useful in semiconductor electronic or optical devices. Indeed, a POSA would have understood that only a few binary compounds have proven economic interest for use in devices, all of which are comprised of group II, III, V, or VI reactants:

- **Group III-V:**

- AlSb, AlAs, AlN, AlP, BN, BP, BAs, GaSb, GaAs, GaN, GaP, InSb, InAs, InN, InP

- **Groups II-VI:**

- CdSe, CdS, CdTe, ZnO, ZnSe, ZnS, ZnTe

EX1020, ii (IUPAC Periodic Table of the Elements); EX1011, 21, 59, 139, 143, 152, 187. Therefore, it is my opinion that a POSA would have found it obvious to use group II and group VI reactants in Urashima's crystal growth technique, as

taught by Nagata.

125. Similarly, it is also my opinion that a POSA would have been motivated to substitute Nagata's group II reactant for Urashima's group III reactant, since it is merely a simple substitution of one known element for another to obtain predictable results. *See generally* EX1014, Zhang (disclosing successful lateral semiconductor growth using group II and group VI compounds). The fact that this is nothing more than a simple substitution is also evidenced by the fact that Nagata discloses that its fabrication method can be used to form "a 2-6 group compound or a 3-5 group compound." EX1005, ¶[0008].

126. It is my opinion that a POSA would have been further motivated to combine Urashima and Nagata because both are in the same general field of semiconductor crystal growth via an epitaxial process, and address the same problem—formation of a semiconductor crystal film having crystallinity that is good enough for semiconductor device applications. Accordingly, it is my opinion that a POSA would have had a reasonable expectation of success in implementing group II and group VI reactants in Urashima's crystal growth technique, as taught by Nagata.

127. Thus, because crystal growth techniques using group II and group VI reactants were well-known and compatible with Urashima's method, it is also my opinion that a POSA would not have experienced any unreasonable technical

hurdles in implementing these modifications. In this manner, it is my opinion that a POSA would have understood that modifying Urashima's method to use group II and group VI reactants would merely amount to combining prior art elements (Urashima's crystal growth techniques and Nagata's use of group II and group VI reactants) according to known methods (selecting a group II reactant for use in a first step of depositing metal particles on a substrate surface, and selecting a group VI reactant for use in a step of forming growth nuclei) to yield predictable results (e.g., the formation of a group II-VI compound semiconductor).

B. Dependent Claim 5

128. Claim 5 recites "*wherein said group II reactant is a cadmium reactant or a zinc reactant.*" The combination of Urashima and Nagata discloses claim 5.

129. Specifically, Nagata discloses that using its techniques, "semiconductors comprising **group 2-6 compounds such as CdSe, CdSSe, ZnSe, ZnSSe, and CdTe** can also be produced," EX1005, ¶[0013]. It is my opinion that a POSA would have understood that CdSe, CdSSe, and CdTe are each formed using "*a cadmium reactant,*" and that ZnSe and ZnSSe are each formed using "*a zinc reactant.*" For at least the reasons discussed in Section XIII.A above, it is my opinion that a POSA would have been motivated to use each of these reactants in Urashima's crystal growth techniques.

130. Further, based on my experience, a POSA would have understood that

at least CdSe, CdTe, and ZnSe were known to be used in optical emitters and detectors at least by the 2005 timeframe. It is my opinion that a POSA would have also known that CdSSe was used for quantum dots (e.g., fluorescent tagging) and optical filters at least by the 2005 timeframe. Therefore, the group 2-6 compounds disclosed in Nagata were both well-known, and were known to provide significant economic value. For at least these additional reasons, it is my opinion that a POSA would have again been motivated to use Nagata's group 2-6 compounds in Urashima's crystal growth techniques.

C. Dependent Claim 17

131. Claim 17 recites “*wherein said group VI reactant is a tellurium reactant or a sulfur reactant.*” The combination of Urashima and Nagata discloses claim 17.

132. Again, Nagata discloses that “semiconductors comprising **group 2-6 compounds such as CdSe, CdSSe, ZnSe, ZnSSe, and CdTe** can also be produced,” EX1005, ¶[0013]. It is my opinion that a POSA would have understood that CdTe is formed using “*a tellurium reactant,*” and that CdSSe and ZnSSe are each formed using “*a sulfur reactant.*” For at least the reasons discussed in Section XIII.A and for claim 5 above, it is my opinion that a POSA would have been motivated to use each of these reactants in Urashima's crystal growth techniques.

**XIV. GROUND 3: THE COMBINATION OF URASHIMA AND KEIPER
RENDERS OBVIOUS CLAIMS 15 AND 16.**

133. It is my opinion that the combination of Urashima and Keiper renders obvious claims 15 and 16 for the reasons provided below.

A. A POSA would have been motivated to combine Urashima and Keiper.

134. It is my opinion that a POSA would have been motivated to modify Urashima's method of fabricating semiconductor crystal to use a group V *organic* precursor in place of Urashima's group V *hydride* precursor during the semiconductor growth process, as taught by Keiper.

135. As explained in Sections XII.A.4 and XII.L above, it is my opinion that a POSA would have understood that Urashima's step of "nitriding the particles in an atmosphere containing a nitrogen source" is an example of introducing a group V reactant. EX1004, ¶[0016]. Urashima explains that this nitrogen source (group V reactant) can be ammonia or hydrazine, which a POSA would have understood are examples of a group V hydride precursor. *Id.*, ¶¶[0085], [0123]; EX1001, 2:60-62. Urashima also discloses that its fabrication method "is not limited to these examples." EX1004, ¶[0138]. Specifically, Urashima discloses that "[t]he shape of the growth nuclei Sb can be controlled by controlling the conditions used during the nitriding process. In particular, the gas used during the nitriding" *Id.*, ¶¶[0113], [0107], [0129]. Urashima explains that the nitriding conditions

“have to be appropriately selected according to the type of metal used for the metal nuclei Sa that adhere to the substrate, the nitrogen material used for the nitriding, the shape of the reactor, and so forth.” *Id.*, ¶[0113].

136. Although Urashima discloses that other materials may be used during the step of forming growth nuclei, Urashima does not specifically identify these other materials or reasons why these other materials may be used. It is my opinion that a POSA would have nonetheless recognized that there are reasons that a skilled artisan would *not* have wanted to use Urashima’s group V hydride precursor during the formation of growth nuclei, including potential safety reasons and a choice to use less toxic group V sources, for example. EX1026, Park, 2252 (“With the use of a ‘single-source’ precursor having a preformed Ga–N bond, an alternative route to GaN is possible. The main advantages of this new method are significantly lower growth temperatures, the absence of large quantities of toxic ammonia gas, and easy process control.”). It is my opinion that a POSA would have thus looked to the prior art for guidance on what other group V reactants may be used in Urashima’s semiconductor growth process. Keiper is such a prior art reference.

137. Like Urashima, Keiper examines the use of “the metal organic vapour-phase epitaxy (MOVPE) process” in the manufacture of semiconductor crystal. EX1006, 256-57. Specifically, Keiper discloses a method to “provide an

inherently ‘safe process’ for MOVPE of III-V materials and in addition has the potential for increased wafer uniformity.” *Id.*, 257. Keiper explains that its investigated process “eliminates both the explosive H₂ and the toxic hydrides as precursors,” and also that the “uniformity improves and the electrical characteristics are comparable or better than those of the standard MOVPE process.” *Id.*, Abstract, 256-57, 259-60. Keiper also explains that “[f]or safety reasons [] many alternative, less toxic group V-sources have been investigated,” including “the alternative group V-sources tertiarybutylarsine (TBA) and tertiarybutylphosphine (TBP).” *Id.*, 256.

138. Based on the teachings of Keiper, it is my opinion that a POSA would have been motivated to modify Urashima to use a safer, alternative group V reactant—e.g., TBA or TBP—in Urashima’s semiconductor growth process. Like Urashima, Keiper discloses that its proposed method can be used to form “III–V materials.” *Id.*, 257. Keiper and Urashima also disclose using the same or similar crystal growth techniques. *Compare id.*, 256-57 (using a “metal organic vapour-phase epitaxy (MOVPE) process”) with EX1004, ¶[0088] (disclosing the “metallo-organic chemical vapor deposition (MOCVD) method”). Indeed, a POSA would have understood that MOVPE and MOCVD actually refer to the same method and are often used interchangeably by those in the industry. Thus, it is my opinion that a POSA would have recognized that Keiper’s techniques are applicable to

Urashima, and that modifying Urashima to use a safer, alternative group V reactant would have required minimal modifications.

139. In the combined system, Urashima's crystal growth technique would use a group V *organic* precursor (e.g., TBA or TBP) in place of Urashima's group V *hydride* precursor during the step of forming growth nuclei. All other steps and conditions disclosed in Urashima could remain largely unchanged. The end result would still be the formation of a group III-V compound semiconductor that could be used for the applications disclosed in Urashima—e.g., “for fabricating a light-emitting diode (LED), a laser diode (LD), an electronic device and the like.”

EX1004, ¶[0001]. Moreover, it is my opinion that a POSA would have recognized that such a modification would have the added benefit of “eliminat[ing] both the explosive H₂ and the toxic hydrides as precursors,” as well as providing improved wafer uniformity and electrical characteristics. EX1006, Abstract, 256-57, 259-60.

140. In my opinion, a POSA would have also been motivated to substitute Keiper's group V *organic* precursor for Urashima's group V *hydride* precursor, since it is merely a simple substitution of one known element for another to obtain predictable results. Indeed, by the 2005 timeframe it was well-known that group V *organic* precursors and group V *hydride* precursors could be used in similar situations to achieve similar results. It is my opinion that a POSA would have been further motivated to combine Urashima and Keiper because both are in the same

general field of semiconductor crystal growth via an epitaxial process, and address the same problem—formation of a semiconductor crystal film having good crystallinity and providing improved electrical characteristics. EX1004, ¶[0137]; EX1006, Abstract, 256-57, 259-60. Accordingly, it is my opinion that a POSA would have had a reasonable expectation of success in implementing group V organic precursors in Urashima’s crystal growth technique, as taught by Keiper.

141. Thus, because crystal growth techniques using group V organic precursors were well-known and compatible with Urashima’s method, it is my opinion that a POSA would not have experienced any unreasonable technical hurdles in implementing these modifications. In this manner, it is my opinion that a POSA would have understood that modifying Urashima’s method to use group V organic precursors would merely amount to combining prior art elements (Urashima’s crystal growth techniques and Keiper’s use of group V organic precursors) according to known methods (selecting a group V organic precursor for use in a step of forming growth nuclei) to yield predictable results (e.g., the formation of a group III-V compound semiconductor).

B. Dependent Claim 15

142. Claim 15 recites “*wherein said group V reactant is a group V organic precursor.*” The combination of Urashima and Keiper discloses claim 15.

143. Keiper discloses using “the alternative group V-sources

tertiarybutylarsine (TBA) and tertiarybutylphosphine (TBP).” EX1006, 256-57, 259-60, Abstract. In my opinion, a POSA would have understood that TBA and TBP are examples of “*a group V organic precursor*.” EX1001, claim 16. For at least the reasons discussed in Section XIV.A above, it is my opinion that a POSA would have been motivated to use TBA or TBP in Urashima’s crystal growth techniques.

C. Dependent Claim 16

144. Claim 16 recites “*wherein said group V organic precursor is tertiarybutylarsine or tertiarybutylphosphine*.” The combination of Urashima and Keiper discloses claim 16 for at least the same reasons discussed for claim 15 above. EX1006, 256-57, 259-60, Abstract.

XV. GROUND 4: THE COMBINATION OF URASHIMA AND MANABE RENDERS OBVIOUS CLAIMS 18-24.

145. It is my opinion that the combination of Urashima and Manabe renders obvious claims 18-24 for the reasons provided below.

A. A POSA would have been motivated to combine Urashima and Manabe.

146. In my opinion, a POSA would have been motivated to modify Urashima’s method of fabricating a film of group-III nitride semiconductor crystal to use the techniques disclosed in Manabe for introducing and stopping the flow of group III compounds during growing of Urashima’s nucleation layer.

147. As discussed above, Urashima discloses “a method of fabricating a

group-III nitride semiconductor crystal according to a first aspect, comprising a first step of depositing particles of a group III metal on a substrate surface, [and] a second step of nitriding the particles in an atmosphere containing a nitrogen source.” EX1004, ¶[0016]. Urashima also discloses that “[t]he above method encompasses a case in which the first step comprises two steps,” in which two different group III metals are introduced. *Id.*, ¶¶[0043], [0047], [0128]. Urashima further discloses stopping the flow of the group III metals in the first step before introducing the nitrogen source in the second step to form the nucleation layer. *Id.*, ¶¶[0081], [0083], [0089], [0119], Abstract. Urashima also discloses that its fabrication method is “is not limited to these examples.” *Id.*, ¶[0138]. Specifically, Urashima discloses that the shape of nucleation layer “can be controlled by controlling the conditions used during the nitriding process.” *Id.*, ¶¶[0113], [0107], [0129].

148. Although Urashima discloses that other conditions can be used during the nitriding process, Urashima does not specifically identify many of these other conditions, or reasons why these other conditions may be used. It is my opinion that a POSA would have nonetheless recognized that there are reasons that a skilled artisan would *not* have wanted to stop the flow of both the group III metals in the first step before introducing the nitrogen source in the second step, including the potential for improved uniformity and reduced lattice defects, for example. It is

my opinion that a POSA would have thus looked to the prior art for guidance on what other conditions may be used in Urashima's nitriding process, including continuing to introduce at least one group III metal during the introduction of the nitrogen source. Manabe is such a prior art reference.

149. Like Urashima, Manabe discloses a process that can be used to “grow a high-quality single crystalline gallium nitride compound-semiconductor having fewer lattice defects on a sapphire substrate.” EX1007, 1:39-42, Abstract, claim 1. Specifically, Manabe discloses a process where at least one group III metal continues to be introduced during the introduction of a nitrogen source: “Such system constitution enables to mix a mixed gas comprising TMG, TMA [group III compounds], which is introduced through the first gas pipe 28, with a NH_3 and H_2 mixed gas [nitrogen source], introduced through the second gas pipe 29.” *Id.*, 4:39-43. Manabe explains that by providing such a mixed atmosphere during the nitriding process, “the flow of the reaction gas on the sapphire substrate 50 gets constant and uniform[], so that high-quality crystal with less position-dependency may grow.” *Id.*, 4:48-51, 1:38-42.

150. Based on the teachings of Manabe, it is my opinion that a POSA would have been motivated to modify Urashima to continue the flow of at least one of the group III metals from the first step during the introduction of the nitrogen source in the second step. Like Urashima, Manabe discloses that its

method can be used to grow a high-quality single crystalline gallium nitride compound-semiconductor. *Id.*, 1:39-42, Abstract, claim 1; EX1004, ¶¶[0016], [0047]. Manabe and Urashima also disclose using the same or similar crystal growth techniques. *Compare* EX1007, claim 1 (“formed by the metalorganic vapor phase epitaxy method (MOVPE)”), claim 6 *with* EX1004, ¶[0088] (disclosing “the metallo-organic chemical vapor deposition (MOCVD) method”). Indeed, a POSA would have understood that MOVPE and MOCVD actually refer to the same method and are often used interchangeably by those in the industry.

151. Thus, it is my opinion that a POSA would have recognized that Manabe’s techniques are applicable to Urashima, and that modifying Urashima to use Manabe’s mixed atmosphere during the nitriding process would have required minimal modifications. Indeed, in the combined system, Urashima’s crystal growth technique would stop the flow of only the first of the two group III metals after the first pre-treatment step, allow the second group III metal to continue to flow during the introduction of the nitrogen source in the second step, and then resume the flow of the first group III metal to form Urashima’s additional GaN-based compound semiconductor layer (“*a buffer layer*”). All other steps and conditions disclosed in Urashima could remain largely unchanged. The end result would still be the formation of a group III-nitride compound semiconductor that could be used for the applications disclosed in Urashima—e.g., “for fabricating a light-emitting

diode (LED), a laser diode (LD), an electronic device and the like.” EX1004, ¶[0001]; EX1007, 1:7-10. Moreover, it is my opinion that a POSA would have recognized that such a modification would have the added benefit of growing “high-quality crystal with less position-dependency” and improved uniformity, as well as producing “fewer lattice defects on a sapphire substrate.” EX1007, 4:48-51, 1:38-42.

152. Further, Urashima discloses performing “the first step at a temperature at or above the melting point of the group III metal, since this **facilitates migration of metal atoms on the substrate.**” EX1004, ¶[0083]. Based on these teachings of Urashima, a POSA would have understood that the increased temperature during the first pre-treatment step could be used to avoid any potential reduction in migration therefore enabling continued flow of a group III metal during the introduction of the nitrogen source. Therefore, by implementing this heightened temperature and allowing the second group III metal to continue to flow during the introduction of the nitrogen source in Urashima’s second step, any transients in gas density and mixture are avoided thereby allowing for better uniformity, as explained and confirmed by Manabe. EX1007, 4:48-51, 1:38-42.

153. In my opinion, a POSA would have also been motivated to combine Urashima and Manabe because both are in the same general field of semiconductor crystal growth via an epitaxial process, and address the same problem—formation

of a semiconductor crystal film having good crystallinity and fewer defects, and that is good enough for semiconductor device applications. EX1004, ¶[0137]; EX1007, 4:48-51, 1:38-42. Accordingly, it is my opinion that a POSA would have had a reasonable expectation of success in implementing a mixed atmosphere during Urashima's nitriding process, as taught by Manabe.

154. Thus, because crystal growth techniques using a mixed atmosphere during a nitriding process were well-known and compatible with Urashima's method, it is my opinion that a POSA would not have experienced any unreasonable technical hurdles in implementing these modifications. In this manner, it is my opinion that a POSA would have understood that modifying Urashima's nitriding process to Manabe's mixed atmosphere would merely amount to combining prior art elements (Urashima's crystal growth techniques and Manabe's mixed atmosphere consisting of group III compounds and a nitrogen source) according to known methods (allowing at least one group III metal from Urashima's pre-treatment step to continue flowing during the introduction of the nitrogen source in Urashima's second step) to yield predictable results (e.g., the formation of a group III-nitride compound semiconductor).

B. Independent Claim 18

1. [18.P]: A process for growing an epitaxial layer on a lattice mismatched substrate comprising the steps of:

155. To the extent that the preamble of claim 18 is limiting, Urashima

discloses the preamble for at least the same reasons discussed in Section XII.A.1 above. EX1004, ¶¶[0003]-[0004], [0012]-[0013], [0025], [0035], [0047], [0089]-[0090], [0106]-[0109], [0133], [0153].

2. [18.a] providing a substrate;

156. Urashima discloses this limitation for at least the same reasons discussed in Section XII.A.2 above. EX1004, FIG. 1, ¶¶[0106], [0107].

3. [18.b] pre-treating a surface of the substrate with at least a first group III reactant and a second group III reactant at a growth temperature of 900 to 1100° C. prior to introducing a nitrogen source;

157. Urashima discloses “*pre-treating a surface of the substrate with at least a first group III reactant ... at a growth temperature of 900 to 1100° C. prior to introducing a nitrogen source*” for at least the same reasons discussed in Section XII.A.3 above. EX1004, FIG. 1, Abstract, ¶¶[0016], [0025], [0028], [0081], [0083], [0089], [0109], [0119].

158. As additionally discussed above in Section XII.A.4, Urashima discloses that the “*pre-treating a surface of the substrate*” step can include introducing **both** “*a first group III reactant and a second group III reactant.*” Specifically, Urashima discloses that the group III metal particles introduced during the first step, Sa or Sa1, include “**at least one** metal element selected from among In, Ga and Al.” *Id.*, ¶¶[0025], [0018], [0037], [0081], [0089]. Urashima similarly discloses that “it is preferable to use nuclei of a group III metal

represented by $\text{In}_u\text{Ga}_v\text{Al}_w$ (where $u+v+w=1$, $0 \leq u \leq 1$, $0 \leq v \leq 1$, $0 \leq w \leq 1$).” *Id.*,

¶[0117]. In (indium), Ga, (gallium), and Al (aluminum) are all examples of group III reactants. EX1001, 2:36-38. Thus, Urashima discloses that the “first step of depositing particles of a group III metal on a substrate surface” (“*pre-treating a surface of the substrate*”), EX1004, ¶[0016], includes depositing two or more of In, Ga, and Al (“*at least a first group III reactant and a second group III reactant*”).

159. Urashima further discloses that when depositing two or more of In, Ga, and Al in the first step, these different metals can either be deposited concurrently (as explained above) or in separate pre-treating steps, both of which still occur “*prior to introducing a nitrogen source*.” Specifically, Urashima discloses “[t]he above method encompasses a case in which **the first step comprises two steps**, which are a first-stage step of flowing a gas containing vapor of at least one member selected from among metallo-organic material containing aluminum, metallo-organic material containing gallium and metallo-organic material containing indium, and a second-stage step of flowing a gas containing vapor of a different metallo-organic material from that of the first-stage step.” *Id.*, ¶¶[0043], [0047], [0128].

160. Thus, it is my opinion that a POSA would have understood that Urashima’s metallo-organic material containing gallium discloses the “*first group III reactant*,” and Urashima’s metallo-organic material containing aluminum

discloses the “*second group III reactant.*”

161. Accordingly, it is my opinion that a POSA would have understood that Urashima discloses “*pre-treating a surface of the substrate with at least a first group III reactant and a second group III reactant at a growth temperature of 900 to 1100° C. prior to introducing a nitrogen source,*” as recited in claim element [18.b].

4. [18.c] stopping a flow of the first group III reactant;

162. Urashima discloses this limitation for at least the same reasons discussed in Section XII.A.3 above. Specifically, Urashima discloses that “it is preferable to perform the first step [of pre-treating the substrate with group III reactants] in an atmosphere that **does not contain a nitrogen source**”—i.e., prior to introducing a nitrogen source. EX1004, ¶¶[0083], [0119], Abstract. Urashima also discloses that “[the first step] **is followed by** a second step of nitriding the metal 1 deposited at a temperature T2 (where $T2 \geq T1$) **in an atmosphere that does not contain metallo-organic material** and does contain a nitrogen source.” *Id.*, ¶[0089]. Thus, it is my opinion that a POSA would have understood that the flow of the group III reactants in Urashima’s first step would be stopped before Urashima’s second step such that these group III reactants were not present in the atmosphere during Urashima’s nitriding process.

163. Therefore, it is my opinion that a POSA would have understood that

Urashima discloses “*stopping a flow of the first group III reactant*,” as recited in claim element [18.c].

5. [18.d] introducing a nitrogen source to grow a nucleation layer on the surface of the substrate;

164. Urashima discloses this limitation for at least the same reasons discussed in Section XII.A.4 above. EX1004, FIG. 1, Abstract, ¶¶[0016], [0018], [0025], [0037], [0081], [0085], [0089], [0107]-[0108], [0113], [0117], [0123].

6. [18.e] resuming the flow of the first group III reactant and reducing a flow of the second group III reactant;

165. The combination of Urashima and Manabe discloses this limitation. As explained above, Urashima discloses stopping a flow of the group III reactants prior to introducing the nitrogen source. EX1004, ¶¶[0083], [0089], [0119]. However, Urashima does not expressly disclose stopping only the first group III reactant (Urashima’s metallo-organic material containing gallium) while allowing the second group III reactant (Urashima’s metallo-organic material containing aluminum) to continue flowing during the nitriding process. But, Manabe discloses this limitation.

166. Manabe discloses an epitaxial process that is able to “mix a mixed gas comprising TMG [trimethylgallium], TMA [trimethylaluminium] ..., which is introduced through the first gas pipe 28, with a NH₃ and H₂ mixed gas, introduced through the second gas pipe 29.” EX1007, 4:39-43, FIG. 1. Thus, Manabe

discloses allowing the flow of TMA to continue during the introduction of the NH₃ (ammonia) mixture—e.g., a nitrogen source. *Id.*, 6:43-48 (“H₂, NH₃ and TMA at 15° C. were supplied on the single crystal sapphire substrate 60”), 5:5-8, 6:32-37. Manabe also discloses that after the TMA—nitrogen source mixture is introduced, for example “[o]ne minute later, **the supply of TMA was eased** to keep the sapphire substrate 60 at a temperature of 970° C.” *Id.*, 6:48-53. Manabe further discloses that at some point after the supply of TMA began to be eased, a “**supply of H₂, NH₃ and TMG**” **was introduced** “for 60 min.” *Id.*

167. In my opinion, a POSA would have understood that TMA (trimethylaluminium) is an example of a “metallo-organic material containing aluminum” (“*the second group III reactant*”) that Urashima discloses using in its pre-treatment step (discussed in Section XV.B.3 above). Similarly, it is my opinion that a POSA would have also understood that TMG (trimethylgallium) is an example of a “metallo-organic material containing gallium” (“*the first group III reactant*”) that Urashima also discloses using in its pre-treatment step (discussed in Section XV.B.3 above).

168. Therefore, when the teachings of Manabe are incorporated into Urashima’s crystal growth technique, the resulting process would include allowing Urashima’s metallo-organic material containing aluminum—e.g., TMA—(“*the second group III reactant*”) to continue to flow during the introduction of the

nitrogen source, and subsequently ensuring that “the supply of TMA was eased”

(“*reducing a flow of the second group III reactant*”). *Id.*, 5:5-8, 6:32-53.

Additionally, the resulting combined process would include re-introducing Urashima’s metallo-organic material containing gallium—e.g., TMG—(“*the first group III reactant*”) after the gallium material was initially stopped prior to Urashima’s introduction of the nitrogen source (“*resuming the flow of the first group III reactant*”), as taught by Manabe. *Id.*, 6:48-53.

169. For at least the reasons discussed in Section XV.A above, it is my opinion that a POSA would have been motivated to use the techniques disclosed in Manabe for introducing and stopping the flow of group III compounds during growing of Urashima’s nucleation layer and buffer layer.

170. Therefore, it is my opinion that a POSA would have understood that Urashima discloses “*resuming the flow of the first group III reactant and reducing a flow of the second group III reactant,*” as recited in claim element [18.e].

7. [18.f] stopping the flow of the second group III reactant; and

171. The combination of Urashima and Manabe discloses this limitation. Specifically, Manabe discloses that the “H₂, NH₃ and TMA” mixture is introduced “for one minute ... to produce the AlN buffer layer [61].” EX1007, 6:43-48. Subsequently, “the supply of TMA was eased,” and after which “an N layer 62 comprising N-type GaN of a thickness of about 7 μm was formed under the supply

of H₂, NH₃ and TMG at -15° C. at 2.5 l/min, 1.5 l/min and 100 cc/min, respectively, for 60 min.” *Id.*, 6:43-53. In my opinion, a POSA would have understood that the supply of TMA would have been completely stopped at some point (“*stopping the flow of the second group III reactant*”) to allow for the formation of the N layer 62 comprising N-type GaN and the application of subsequent layers 63-65—i.e., layers substantially devoid of aluminum. *Id.*, FIG. 1.

172. Therefore, it is my opinion that a POSA would have understood that Urashima discloses “*stopping the flow of the second group III reactant*,” as recited in claim element [18.f].

8. [18.g] growing a buffer layer on said nucleation layer, said buffer layer providing a surface upon which said epitaxial layer is grown.

173. Urashima discloses this limitation for at least the same reasons discussed in Section XII.A.5 above. EX1004, FIG. 1, ¶¶[0046], [0055], [0089]-[0090], [0108]-[0109], [0114]-[0115], [0140], claim 77.

C. Dependent Claim 19

174. Claim 19 recites “*wherein said first group III reactant is a gallium reactant and said second group III reactant is an aluminum reactant.*” The combination of Urashima and Manabe discloses claim 19 for at least the same reasons discussed in Section XV.B.3 above. EX1004, ¶¶[0016], [0018], [0025], [0037], [0043], [0047], [0081], [0089], [0117], [0128].

D. Dependent Claim 20

175. Claim 20 recites “*wherein said gallium reactant is triethylgallium and said aluminum reactant is trimethylaluminum.*” The combination of Urashima and Manabe discloses claim 20 for at least the same reasons discussed for claim 4 above. EX1004, ¶¶[0082], [0096], [0118].

E. Dependent Claim 21

176. Claim 21 recites “*wherein said nucleation layer is AlN or AlGaN.*” The combination of Urashima and Manabe discloses claim 21 for at least the same reasons discussed for claim 7 above. EX1004, ¶¶[0016], [0025], [0018], [0037], [0081], [0089], [0107], [0113], [0117].

F. Dependent Claim 22

177. Claim 22 recites “*wherein said buffer layer is GaN.*” The combination of Urashima and Manabe discloses claim 22 for at least the same reasons discussed for claim 8 above. EX1004, ¶¶[0108], [0046], [0055], [0109], [0114], claim 77.

G. Dependent Claim 23

178. Claim 23 recites “*wherein said epitaxial layer includes a compound selected from the group comprising AlN, GaN, AlGaN, BGaN, BInN, and BAlN.*” The combination of Urashima and Manabe discloses claim 23 for at least the same reasons discussed for claim 9 above. EX1004, ¶¶[0046], [0055], [0081], [0089]-[0090], [0108], [0114]-[0115], [0140].

H. Dependent Claim 24

179. Claim 24 recites “*further comprising the step of preheating said substrate in hydrogen prior to pre-treating the surface of the substrate with the first group III reactant and the second group III reactant.*” The combination of Urashima and Manabe discloses claim 24 for at least the same reasons discussed for claim 9 above. EX1004, ¶¶[0101], [0140].

XVI. GROUND 5: GUO RENDERS OBVIOUS CLAIMS 1-4, 6-9, AND 11-14.

180. It is my opinion that the Guo renders obvious claims 1-4, 6-9, and 11-14 for the reasons provided below.

A. Independent Claim 1

181. Before addressing each of the individual limitations of claim 1 below, the clear similarities between the '360 patent and Guo is best introduced by way of the following chart that matches the limitations of claim 1 to those of claim 34 of Guo.

'360 Patent	Guo
1. A process for growing an epitaxial layer on a lattice mismatched substrate comprising the steps of:	34. A method of making a semiconductor structure comprising the steps of:
a) providing a substrate;	(a) depositing aluminum directly on a surface of a silicon substrate to
b) pre-treating a surface of the substrate with at least one group III	

reactant or at least one group II reactant at an elevated growth temperature prior to introducing a group V reactant or a group VI reactant;	provide an aluminum-protected substrate; then
c) introducing a group V reactant or a group VI reactant to grow a nucleation layer on the surface of the substrate; and	(b) depositing a nucleation layer of a nitride semiconductor on said aluminum-protected substrate; then
d) growing a buffer layer on said nucleation layer, said buffer layer providing a surface upon which said epitaxial layer is grown.	(c) epitaxially growing a buffer structure including one or more superlattices of nitride semiconductors on said nucleation layer; and then (d) epitaxially growing an operative structure including one or more gallium nitride-based semiconductors on said buffer structure.

182. As illustrated in the above chart, and further explained below, each and every limitation of claim 1 of the '360 patent was disclosed in the same or substantially similar way by Guo.

1. [1.P]: A process for growing an epitaxial layer on a lattice mismatched substrate comprising the steps of:

183. To the extent that the preamble of claim 1 is limiting, Guo discloses the preamble.

184. Guo discloses “[o]ne aspect of the present invention provides a

method of making a semiconductor structure including the steps of depositing a small amount of aluminum directly **on a silicon substrate** to provide an aluminum protected substrate, and then depositing a nucleation layer of a nitride semiconductor on the aluminum protected substrate ... [and] further includes the step of epitaxially growing a buffer structure including one or more superlattices of nitride semiconductor on the nucleation layer, and then **epitaxially growing an operative structure including one or more gallium nitride-based semiconductors** on the buffer structure.” EX1008, ¶¶[0011]-[0012], [0014], Abstract, claim 1, claim 34. It is my opinion that a POSA would have understood that Guo’s operative structure including gallium nitride-based semiconductors is “*an epitaxial layer*.”

185. Indeed, the ’360 patent explains that its epitaxial layer can include “a III-V compound” (EX1001, 3:2-4, 1:43-44), where the group III reactant can include “a gallium reactant” (*id.*, 2:36-38), and where “the group V reactant contains a nitrogen reactant ...” (*id.*, 2:59-60). It is my opinion that a POSA would have therefore understood that the claimed “*epitaxial layer*” can include a gallium nitride-based compound, and that Guo discloses such a compound—i.e., “an operative structure including one or more gallium nitride-based semiconductors.” EX1008, ¶[0011].

186. Guo also discloses that its silicon substrate is “*a lattice mismatched*

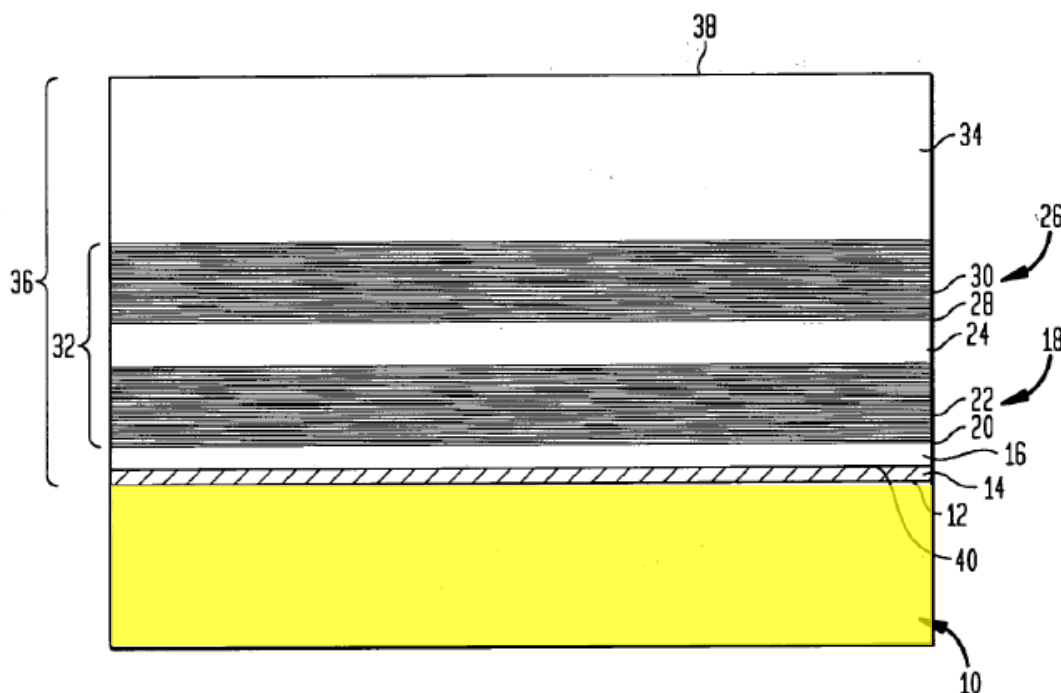
substrate”: “**the lattice spacing of silicon is not well matched to that of gallium nitride.**” *Id.*, ¶¶[0007], [0008] (“Various proposals have been advanced to compensate for the **lattice mismatch** ... between the nitride semiconductors and silicon”).

187. Therefore, it is my opinion that a POSA would have understood that Guo discloses a “*process for growing an epitaxial layer on a lattice mismatched substrate*,” as recited in the preamble of claim 1.

2. [1.a] providing a substrate;

188. Figure 1 of Guo illustrates an example of a semiconductor structure formed using Guo’s fabrication method. EX1008, ¶[0023]. As shown in Figure 1, Guo’s “invention begins with a **doped silicon substrate 10.**” *Id.*, ¶¶[0031], [0011], [0014], Abstract, claim 1, claim 34. I have copied Figure 1 of Guo below to illustrate Guo’s method of fabricating a group-III nitride semiconductor crystal. In Figure 1 below, I have also added annotations such that the substrate is highlighted in yellow.

FIG. 1



EX1008, FIG. 1 (annotated).

189. Therefore, it is my opinion that a POSA would have understood that Guo's method of making a semiconductor structure includes "*providing a substrate,*" as recited in claim element [1.a].

3. [1.b] **pre-treating a surface of the substrate with at least one group III reactant or at least one group II reactant at an elevated growth temperature prior to introducing a group V reactant or a group VI reactant;**

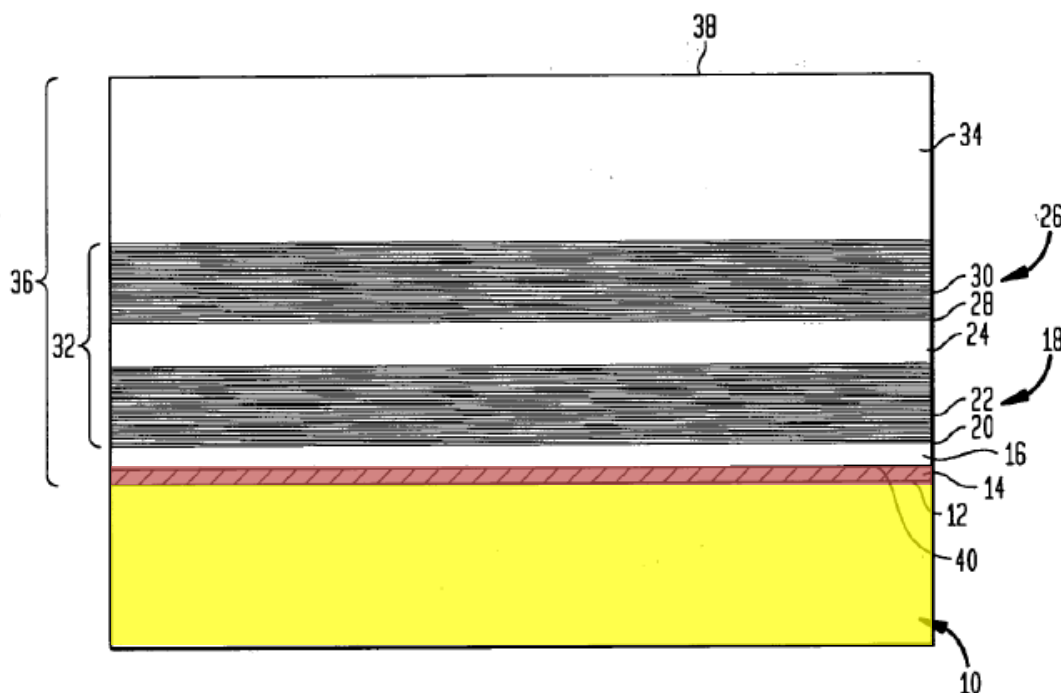
190. First, Guo discloses "*pre-treating a surface of the substrate with at least one group III reactant.*" Indeed, Guo discloses that "[o]ne aspect of the present invention provides a method of making a semiconductor structure including the steps of **depositing a small amount of aluminum directly on a**

silicon substrate to provide an aluminum protected substrate” EX1008,

¶¶[0011], [0014], Abstract, claim 1, claim 34. Guo explicitly refers to this step of depositing aluminum on the silicon substrate as a “pretreatment of the substrate.”

Id., ¶[0013] (“It is additionally believed that **pretreatment of the substrate with aluminum**, prior to deposition of the nucleation layer, protects the substrate from etching by ammonia”). Guo illustrates the results of this “*pre-treating*” step in Figure 1, where after substrate 10 is “exposed to an organo-aluminum compound, most preferably a lower alkyl aluminum compound such as trimethyl aluminum (‘TMA’) ... [t]he aluminum compound decomposes to deposit a thin aluminum layer 14 on the top surface 12 of the wafer.” *Id.*, ¶[0031]. I have again copied Figure 1 of Guo below, and this time I have added annotations such that the aluminum layer 14 is highlighted in red.

FIG. 1



EX1008, FIG. 1 (annotated).

191. In my opinion, a POSA would have understood that Guo’s aluminum layer 14 is deposited using a “*group III reactant*” for at least two reasons. First, Guo explains that “**III-V semiconductors [are]** used in the preferred embodiments.” EX1008, ¶[0048] (“the aluminum layer and aluminum-protected silicon substrate discussed above can be utilized in growth of other nitride semiconductor structures and other **III-V semiconductor structures**”). Second, the ’360 patent similarly explains that “[t]he group III reactant is preferably selected from the group consisting of a gallium reactant, **an aluminum reactant**, a boron reactant, and an indium reactant.” EX1001, 2:36-38.

192. Guo also discloses that pretreatment of the substrate is performed “*at an elevated growth temperature.*” The ’360 patent does not define what is specifically meant by “*an elevated growth temperature.*” However, the ’360 patent does disclose that in some embodiments, temperatures in the range of 900° C to 1100° C constitute an elevated growth temperature. *Id.*, 2:50-51. In my opinion, a POSA would have understood that additional temperature ranges, including those lower than 900° C would also be considered elevated growth temperatures. Indeed, based on my experience, a POSA in the 2005 timeframe would often use the phrase “elevated temperature” as a way to distinguish from room temperature. EX1011, 209 (“Figure 9.6 shows as an example an absorption spectrum of trimethylgallium (TMGa) **at room and elevated temperature** which displays clearly the decomposition of the precursor into gallium radicals and Gallium atoms.”). Thus, a POSA would have understood that at least in some instances, elevated temperatures could include those temperatures that are above room temperature. Alternatively, a POSA in the 2005 timeframe could have used the phrase “elevated temperature” to mean temperatures that are greater than the lowest melting point of the elements used in the semiconductor fabrication process. A POSA would have understood that such a temperature range would include temperatures greater than 660° C for the Guo’s fabrication method, which uses aluminum.

193. In either event, Guo discloses performing the pretreatment of the substrate within such elevated temperature ranges. Specifically, Guo discloses that “[i]n the first stage of the process, the wafer is brought to a temperature of about 600-900° C. in a conventional chemical vapor deposition apparatus and exposed to an organo-aluminum compound, most preferably a lower alkyl aluminum compound such as trimethyl aluminum (‘TMA’) in vapor form for a few seconds.” EX1008, ¶[0031]. Thus, it is my opinion that a POSA would have understood that 600-900° C represents “*an elevated growth temperature*,” and that the step of depositing the aluminum compound on the substrate occurs at such a temperature, including 900° C.

194. To the extent that Guo does not explicitly disclose that the aluminum compound is actually deposited on the substrate at a temperature of 900° C, it is my opinion that a POSA would have nonetheless found it obvious that the growth apparatus would have been 900° C—e.g., remained at 900° C, or higher, even after the wafer (substrate) is brought to a temperature of about 900° C—during the step of depositing the aluminum compound on the substrate. Indeed, Guo discloses that certain steps after depositing the aluminum compound on the substrate are also performed at temperatures of 900° C—e.g., growing the nucleation layer at 900° C (*id.*, ¶[0032])—or above—e.g., growing a buffer structure at “about 950 to about 1100° C” (*id.*, ¶[0035]). Therefore, it is my opinion that a POSA would have found

it obvious that a temperature of 900° C or above would have been maintained throughout Guo's fabrication method following the initial heating of the substrate.

195. Guo also discloses that it was well-known to expose the substrate to metals, such as aluminum compounds, **“while the substrate is at an elevated temperature, typically on the order of 700-1100° C.”** *Id.*, ¶[0004]. Therefore, it is my opinion that a POSA would have also found it obvious to apply these well-known elevated temperatures to Guo's fabrication method such that Guo's pretreatment of the substrate is performed at temperatures above 900° C, including up to 1100° C. Indeed, in my opinion, a POSA would have understood that such a modification to Guo's fabrication method amounts to subjecting known materials (III-V semiconductors) to known temperatures (900-1100° C) to yield predictable results (formation of high-quality gallium nitride-based semiconductors on silicon substrates).

196. In fact, by the 2005 timeframe, a POSA would have understood that there would have been benefits to performing Guo's fabrication method at temperatures above 900° C, including “reduc[ing] the number of cracks and result[ing] in a smoother surface,” and providing improved “optical performance ... especially for laser diodes,” and allowing for the growth of “high-quality GaN on Si,” for example. EX1016, 338-340.

197. A POSA would have also had a reasonable expectation of success in

implementing these well-known elevated temperatures into Guo's fabrication method, and would not have experienced any unreasonable technical hurdles in implementing this modification at least because it was known in the 2005 timeframe that epitaxial growth processes could be performed at temperatures above 900° C. EX1016, 335, 338-340; EX1011, 59-60; EX1004, ¶¶[0025], [0028], [0109].

198. Finally, Guo discloses that aluminum layer 14 (deposited using a “*group III reactant*”) is introduced “*prior to introducing a group V reactant or a group VI reactant.*” As discussed above, the '360 patent explains that “[p]referably, the group V reactant contains a nitrogen reactant ...,” which is “preferably ammonia.” EX1001, 2:59-60, 3:22-25. In my opinion, a POSA would have therefore understood this claim limitation to include instances where the group III reactant is introduced before the introduction of a nitrogen reactant, such as ammonia. Guo discloses such an ordering of fabrication steps. Specifically, Guo discloses “a method of making a semiconductor structure including the steps of depositing a small amount of aluminum directly on a silicon substrate to provide an aluminum protected substrate, **and then depositing a nucleation layer of a nitride semiconductor** on the aluminum protected substrate.” EX1008, ¶¶[0011], [0013] (“pretreatment of the substrate with aluminum, **prior to deposition of the nucleation layer**, protects the substrate from etching **by ammonia**”), [0031] (“the

aluminum layer serves to protect the silicon substrate from etching **during exposure to ammonia in subsequent process steps ...**”), Abstract, claim 34.

199. Therefore, it is my opinion that a POSA would have understood that Guo discloses, and/or renders obvious, a “*pre-treating a surface of the substrate with at least one group III reactant or at least one group II reactant at an elevated growth temperature prior to introducing a group V reactant or a group VI reactant,*” as recited in claim element [1.b].

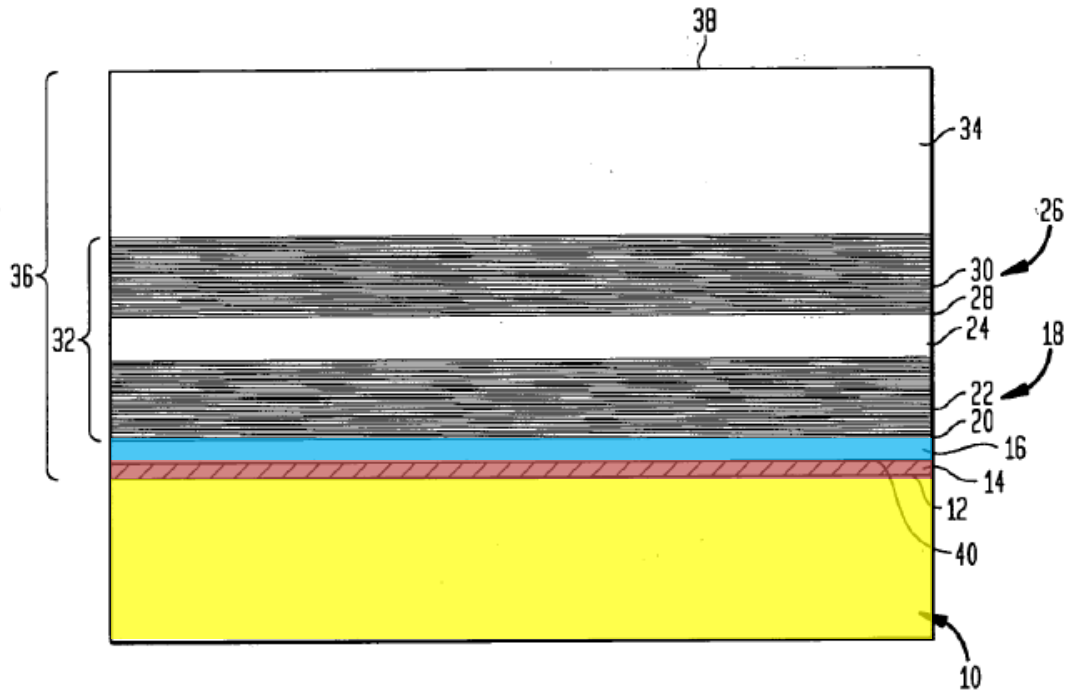
4. [1.c] introducing a group V reactant or a group VI reactant to grow a nucleation layer on the surface of the substrate; and

200. Guo discloses “*introducing a group V reactant ... to grow a nucleation layer.*” Specifically, Guo discloses that after pretreatment of the substrate (depositing aluminum on the silicon substrate), “the aluminum-protected substrate is exposed to a mixture of **an organo-metallic compound**, most preferably an organo-aluminum compound, and **ammonia**, together with a carrier gas, so as to deposit **a thin layer 16 of a nitride semiconductor**, most preferably AlN.” EX1008, ¶¶[0032] (“Nucleation layer 16”), [0011], [0012], Abstract, claim 34. Thus, Guo explains that ammonia can be used to deposit nucleation layer 26. *Id.*, ¶¶[0031]-[0032], [0038]. It is my opinion that a POSA would have understood that Guo’s ammonia is a “*group V reactant*” for at least two reasons. First, Guo explains that “**III-V semiconductors [are]** used in the preferred embodiments.”

Id., ¶[0048]. Second, the '360 patent similarly explains that “[p]referably, the group V reactant contains a nitrogen reactant ...,” which is “preferably ammonia.” EX1001, 2:59-60, 3:22-25.

201. Guo also discloses that introducing the organo-metallic compound and ammonia (“*introducing a group V reactant*”) results in the nucleation layer being grown “*on the surface of the substrate.*” EX1008, ¶[0011] (“**depositing a nucleation layer** of a nitride semiconductor **on the aluminum protected substrate**”); [0032] (“**the aluminum-protected substrate is exposed** to a mixture of an organo-metallic compound, most preferably an organo-aluminum compound, and ammonia, together with a carrier gas, so as **to deposit a thin layer 16 of a nitride semiconductor**, most preferably AlN”), claim 34. I have again copied Figure 1 of Guo below, and this time I have added annotations such that nucleation layer 16 is highlighted in blue.

FIG. 1



EX1008, FIG. 1 (annotated).

202. Therefore, it is my opinion that a POSA would have understood that Guo discloses “*introducing a group V reactant or a group VI reactant to grow a nucleation layer on the surface of the substrate,*” as recited in claim element [1.c].

5. [1.d] **growing a buffer layer on said nucleation layer, said buffer layer providing a surface upon which said epitaxial layer is grown.**

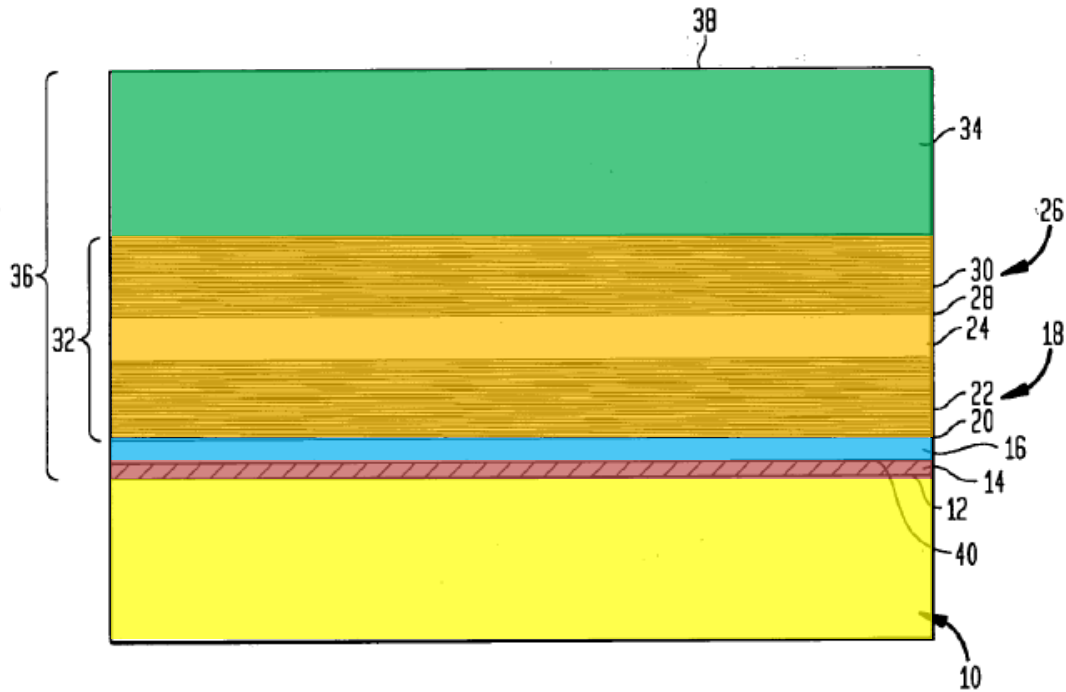
203. Guo discloses “*growing a buffer layer on said nucleation layer.*” Specifically, Guo discloses “**epitaxially growing a buffer structure** including one or more superlattices of nitride semiconductor **on the nucleation layer.**” EX1008, ¶¶[0011]-[0012], [0014], [0037], Abstract, claim 34. Guo explains that in some

instances, “the step of growing the buffer structure includes growing an intermediate layer of a gallium nitride-based semiconductor over the first superlattice of the buffer structure and growing a second superlattice of nitride semiconductors over the intermediate layer.” *Id.*, ¶[0012]. But, in other instances “the intermediate layer and second superlattice can be omitted.” *Id.*, ¶[0048].

204. Guo also discloses “*said buffer layer providing a surface upon which said epitaxial layer is grown.*” Specifically, Guo discloses “**epitaxially growing an operative structure** including one or more gallium nitride-based semiconductors **on the buffer structure.**” *Id.*, ¶¶[0011], [0014], [0037], claim 34. As discussed, in Section XVI.A.1 above, it is my opinion that a POSA would have understood that Guo’s operative structure including one or more gallium nitride-based semiconductors is “*an epitaxial layer.*”

205. I have again copied Figure 1 of Guo below, and this time I have added annotations such that buffer structure 32 is highlighted in orange and operative structure 34 is highlighted in green.

FIG. 1



EX1008, FIG. 1 (annotated).

206. Therefore, it is my opinion that a POSA would have understood that Guo discloses “growing a buffer layer on said nucleation layer, said buffer layer providing a surface upon which said epitaxial layer is grown,” as recited in claim element [1.d].

B. Dependent Claim 2

207. Claim 2 recites, “wherein said substrate is selected from the group consisting of silicon, sapphire and SiC.” Guo discloses claim 2 for at least the same reasons discussed in Section XVI.A.2 above. EX1008, Abstract (“A nitride semiconductor is grown on a **silicon substrate** ...”), ¶¶[0006] (disclosing that

“**sapphire** wafers” and “**silicon carbide** wafers” are well-known), [0011], [0014], [0031].

C. Dependent Claim 3

208. Claim 3 recites, “*wherein said group III reactant is selected from the group consisting of a gallium reactant, an aluminum reactant, a boron reactant, and an indium reactant.*” Guo discloses claim 3.

209. Specifically, Guo discloses that its method of making a semiconductor structure includes “depositing a small amount of **aluminum** directly on a silicon substrate to provide an aluminum protected substrate.” EX1008, ¶¶[0011], [0013], [0014], [0031] (substrate 10 is “exposed to an organo-aluminum compound, most preferably a lower alkyl **aluminum** compound such as trimethyl aluminum (‘TMA’)...”), Abstract, claim 1, claim 34. Guo also discloses that “the aluminum layer and aluminum-protected silicon substrate discussed above can be utilized in growth of other nitride semiconductor structures and **other III-V semiconductor structures.**” *Id.*, ¶[0048]. Further, Guo explains that it was well-known to deposit compounds such as “**aluminum indium gallium** nitride, **indium gallium** nitride or **aluminum gallium** nitride” on a silicon substrate. *Id.*, ¶[0008]. Thus, it is my opinion that a POSA would have found it obvious to additionally, or alternatively, use a gallium reactant and/or an indium reactant in the formation of these “other III-V semiconductor structures.”

D. Dependent Claim 4

210. Claim 4 recites “*wherein said group III reactant is selected from the group consisting of triethyl gallium, trimethyl gallium, triethylaluminum, trimethyl aluminum, triethylboron, trimethylboron, triethylindium and trimethylindium.*”

Guo discloses claim 4 for at least the same reasons discussed in Section XVI.A.3 and for claim 3 above. EX1008, ¶¶[0008], [0011], [0013]-[0014], [0031] (substrate 10 is “exposed to an organo-aluminum compound, most preferably a lower alkyl aluminum compound such as **trimethyl aluminum (‘TMA’)**...”), [0048], Abstract, claim 1, claim 34.

E. Dependent Claim 6

211. Claim 6 recites “*wherein said step of pre-treating includes pre-treating the surface of the substrate with an aluminum reactant and a gallium reactant.*” Guo discloses claim 6 for at least the same reasons discussed in Section XVI.A.3 and for claim 3 above. EX1008, ¶¶[0011], [0013] (“... **pretreatment of the substrate with aluminum** ... protects the substrate from etching by ammonia”), [0014], [0031], [0048], Abstract, claim 1, claim 34. Guo also explains that it was well-known to deposit compounds such as “**aluminum gallium** nitride” on a silicon substrate. *Id.*, ¶[0008]. Additionally, Guo teaches that the addition of superlattice mixtures of composition $\text{Al}_R\text{Ga}_{(1-R)}\text{N}$ (with variable R) can induce desired “compressive stress” in the operative structure and thereby “suppress

formation of defects.” *Id.*, ¶¶[0034], [0038]. Maintaining both aluminum and gallium reactant flow simultaneously obtains substrate protection from the presence of aluminum and avoids the need to create undesirable pressure and flow transients associated with later “switching on” the gallium reactant to form superlattice structures. Thus, it is my opinion that a POSA would have found it obvious to use both an aluminum reactant and a gallium reactant during Guo’s pretreatment step to avoid defect-inducing flow and pressure transients while maintaining the benefit of incorporating compressive stress-inducing superlattices.

F. Dependent Claim 7

212. Claim 7 recites “*wherein said nucleation layer is AlN or AlGaN.*” Guo discloses claim 7 for at least the same reasons discussed in Section XVI.A.4 above.

213. Specifically, Guo discloses that “the aluminum-protected substrate is exposed to a mixture of an organo-metallic compound, most preferably an organo-aluminum compound, and ammonia, together with a carrier gas, so as to deposit a **thin layer 16 of a nitride semiconductor, most preferably AlN.**” EX1008, ¶¶[0032], [0011]-[0012], Abstract, claim 34. Guo also discloses that “the aluminum layer and aluminum-protected silicon substrate discussed above can be utilized in growth of **other nitride semiconductor structures and other III-V semiconductor structures.**” *Id.*, ¶[0048]. Further, Guo explains that it was well-known to deposit compounds such as “**aluminum gallium nitride**” (“*AlGaN*”) on

a silicon substrate. *Id.*, ¶[0008]. Thus, for at least the reasons discussed for claim 6 above, it is my opinion that a POSA would have found it obvious to additionally, or alternatively, use AlGa_xN_{1-x} in the formation of these “other nitride semiconductor structures and other III-V semiconductor structures.” Indeed, implementing Guo’s nucleation layer 16 as a AlGa_xN_{1-x} compound would have the added benefit of inducing compressive stress in the operative layer. *Id.*, ¶[0038].

G. Dependent Claim 8

214. Claim 8 recites “*wherein said buffer layer is GaN.*” Guo discloses claim 8 for at least the same reasons discussed in Section XVI.A.5 above.

215. Specifically, Guo discloses “epitaxially growing a **buffer structure** including one or more superlattices of **nitride semiconductor** on the nucleation layer.” EX1008, ¶¶[0011]-[0012], [0014]-[0015], [0037], Abstract, claim 34. Guo explains that in some instances, “the step of growing the buffer structure includes growing an **intermediate layer of a gallium nitride-based semiconductor** over the first superlattice of the buffer structure and growing a second superlattice of nitride semiconductors over the intermediate layer.” *Id.*, ¶[0012]. Additionally, “the superlattices desirably are formed from multiple layers of semiconductor compounds according to the formula **Al_RGa_(1-R)N**, where **R is from 0 to 1 inclusive**”—e.g., GaN, when R is 0. *Id.*, ¶[0015], [0034]-[0036]. Guo also discloses that, in some instances, “the intermediate layer and second superlattice

can be omitted.” *Id.*, ¶[0048]. Thus, it is my opinion that a POSA would have understood that Guo’s buffer structure can include one or more layers of GaN.

H. Dependent Claim 9

216. Claim 9 recites “*wherein said epitaxial layer includes a compound selected from the group comprising AlN, GaN, AlGaN, BGaN, BInN, BAlN, CdTe, and ZnS.*” Guo discloses claim 9 for at least the same reasons discussed in Section XVI.A.5 above.

217. Specifically, Guo discloses “epitaxially growing an operative structure [*said epitaxial layer*] including one or more **gallium nitride-based semiconductors** on the buffer structure.” *Id.*, ¶¶[0011]-[0012], [0014], [0037] (“In its simplest form, **operative structure 34 may include** one a single relatively thick layer of a gallium nitride based semiconductor such as pure **GaN**”), claim 34. Guo also discloses that “the aluminum layer and aluminum-protected silicon substrate discussed above can be utilized in growth of **other nitride semiconductor structures** and **other III-V semiconductor structures.**” *Id.*, ¶[0048]. As one example, Guo discloses that the operative substrate can also include a layer of “**Al_{0.3}Ga_{0.7}N.**” *Id.*

I. Dependent Claim 11

218. Claim 11 recites “*wherein said elevated growth temperature is 900 to 1100° C.*” Guo discloses claim 11 for at least the same reasons discussed in Section

XVI.A.3 above. EX1008, ¶[0004] (“the substrate is exposed to an atmosphere containing organic compounds of the metals and a reactive, nitrogen-containing gas, most commonly ammonia, **while the substrate is at an elevated temperature**, typically on the order of 700-1100° C”), [0031] (“that “[i]n the first stage of the process, the wafer is brought to a temperature of about 600-900° C. in a conventional chemical vapor deposition apparatus and exposed to an organo-aluminum compound, most preferably a lower alkyl aluminum compound such as trimethyl aluminum (‘TMA’) in vapor form for a few seconds”).

J. Dependent Claim 12

219. Claim 12 recites “*wherein the step of introducing a group V reactant or a group VI reactant includes growing a nucleation layer at a growth temperature of 900 to 1100° C. and the step of growing a buffer layer includes growing a buffer layer at a growth temperature of 900 to 1100° C.*” Guo discloses claim 12 for at least the same reasons discussed in Section XVI.A.3 above.

220. First, Guo discloses that nucleation layer 16 is “deposited at substrate temperature on the order of 600-900° C.” EX1008, ¶[0032]. Second, Guo discloses that intermediate layer 24 “is deposited by exposing the substrate to a mixture of an organo-gallium compound, ammonia and a carrier gas, at a temperature of about **950 to about 1100° C.**” *Id.*, ¶[0035]. Guo explains that intermediate layer 24 is included in buffer structure 32. *Id.*, ¶[0037].

221. Additionally, or alternatively, Guo also discloses that it was well known that a substrate can be “exposed to an atmosphere containing organic compounds of the metals and a reactive, nitrogen-containing gas, most commonly ammonia, **while the substrate is at an elevated temperature**, typically on the order of 700-**1100° C.**” *Id.*, ¶[0004]. Thus, it is my opinion that a POSA would have found it obvious that an elevated temperature of 900° C-1100° C could have been maintained throughout Guo’s fabrication method, including during “*growing a nucleation layer*” and “*growing a buffer layer.*”

K. Dependent Claim 13

222. Claim 13 recites “*wherein said group V reactant is a group V hydride.*” Guo discloses claim 13.

223. Specifically, Guo discloses “**depositing the nitride semiconductor** to form the nucleation layer.” EX1008, ¶¶[0012], [0011], [0032], Abstract, claim 34. Guo explains that ammonia can be “used to deposit the nitride semiconductors.” *Id.*, ¶¶[0038], [0031], [0032]. It is my opinion that a POSA would have understood that Guo’s nitride semiconductor (e.g., ammonia) is a “*group V reactant*,” as explained in Section XVI.A.4 above. *Id.*, ¶[0048]. In my opinion, a POSA would have understood that ammonia is an example of “*a group V hydride.*” Indeed, the ’360 patent confirms the same: “In one preferred embodiment, the group V reactant is a group V hydride, most preferably ammonia, arsine or phosphine.”

EX1001, 2:60-62.

L. Dependent Claim 14

224. Claim 14 recites “*wherein said group V hydride is selected from the group consisting of ammonia, arsine, and phosphine.*” Guo discloses claim 14 for at least the same reasons discussed for claim 13 above. EX1008, ¶¶[0031]-[0032], [0038] (“the **ammonia** used to deposit the nitride semiconductors”), claim 66.

**XVII.GROUND 6: THE COMBINATION OF GUO AND ASHBY
RENDERS OBVIOUS CLAIMS 5, 10, AND 17.**

225. It is my opinion that the combination of Guo and Ashby renders obvious claims 5, 10, and 17 for the reasons provided below.

A. A POSA would have been motivated to combine Guo and Ashby.

**1. A POSA would have been motivated to modify Guo’s
method of making a semiconductor structure to incorporate
Ashby’s cleaning step.**

226. As discussed above, Guo discloses “a method of making a semiconductor structure” that includes several fabrication steps. EX1008, ¶¶[0011], [0012], Abstract, claim 34. Guo also discloses that “[o]ptionally, between deposition of layers having differing compositions as, for example, between deposition of the aluminum layer 14 and the buffer layer 16, and both before and after deposition of each superlattice, the chamber can be purged of metals from the preceding layer by flushing it with a mixture of the hydrogen or nitrogen carrier gas and ammonia for a prolonged period.” *Id.*, ¶[0039]. But, Guo

does not disclose that this purging step can be performed as part of a preheating step prior to Guo's "pretreatment of the substrate with aluminum." *Id.*, ¶[0013].

227. In my opinion, a POSA would have recognized the benefits to also performing this purging step prior to pretreatment of the substrate with aluminum. For example, a POSA would have recognized that deposited elemental aluminum at elevated temperatures is extremely reactive, for example forming unwanted defects with even trace oxygen contamination. It is therefore my opinion that a POSA would have understood that an effective contaminant purging operation prior to the deposition of the protective aluminum layer would be important to producing high quality epitaxy. Thus, it is my opinion that a POSA would have looked to the prior art for guidance on how to implement such an initial purging step. Ashby is such a prior art reference.

228. Like Guo, Ashby discloses a "process of growing a material on a substrate, particularly growing a Group II-VI or Group III-V material" (EX1009, Abstract) including "producing materials with relatively few defects" (*id.*, ¶[0013]). Specifically, Ashby discloses an initial step where "[t]he substrate is cleaned in the growth chamber and the surface prepared for growth." *Id.*, ¶¶[0028], [0039] ("The substrate was cleaned and the surface prepared for growth in-situ ..."). Ashby explains that "[o]ne typical pre-growth treatment involves heating in ambient H₂ for less than approximately 10 minutes." *Id.*, ¶¶[0028], [0039] ("...

heating the wafer to 1080° C. at 50 Torr flowing 10 liters/minute H₂ for 5 minutes”).

229. Based on the teachings of Ashby, a POSA would have been motivated to modify Guo to use an initial cleaning step prior to Guo’s pretreatment of the substrate with aluminum. Indeed, Ashby explains that its cleaning step is a first step in order to get “the surface prepared for growth.” *Id.*, ¶¶[0028], [0039].

230. Ashby and Guo also disclose using the same or similar crystal growth techniques. *Compare id.*, ¶[0018] (“[t]he growth of the material is performed by standard vapor-phase growth techniques well known in the art, such as by metalorganic chemical vapor deposition (MOCVD) ...”) *with* EX1008, ¶[0037] (“[t]he gallium nitride based semiconductors in the operative structure may be deposited at conventional growth temperatures using MOCVD techniques.”). Additionally, Ashby and Guo both disclose that their respective fabrication methods are used to form III-V semiconductors. *Compare* EX1009, Abstract (“growing a Group II-VI or Group III-V material”) *with* EX1008, ¶[0048] (“the III-V semiconductors used in the preferred embodiments”). Further, both Ashby and Guo disclose an initial step of preheating the substrate. *Compare* EX1009, ¶[0039] (“[t]he substrate was cleaned and the surface prepared for growth in-situ by heating the wafer to 1080° C.”) *with* EX1008, ¶[0031] (“[i]n the first stage of the process, the wafer is brought to a temperature of about 600-900° C”).

231. Thus, it is my opinion that a POSA would have recognized that Ashby's techniques are applicable to Guo, and that modifying Guo to implement an initial H₂ (hydrogen) cleaning step would have required minimal modifications. Indeed, in the combined system, Guo's initial step of preheating the substrate would have also included cleaning the substrate with hydrogen at the elevated temperature. All other steps and conditions disclosed in Guo could remain largely unchanged. This would result in improved quality of epitaxial layers in Guo's fabrication method by cleaning the substrate with a pre-growth treatment in hydrogen prior to growing the group III element.

232. It is my opinion that a POSA would have been further motivated to combine Guo and Ashby because both are in the same general field of semiconductor crystal growth via an epitaxial process, and address the same problem—formation of a semiconductor structure with relatively few defects. EX1008, ¶¶[0013], [0038]; EX1009 ¶[0013]. Accordingly, a POSA would have had a reasonable expectation of success in incorporating Ashby's cleaning step into Guo's initial step of preheating the substrate.

233. Thus, because substrate cleaning techniques incorporating hydrogen were well-known and compatible with Guo's method, it is my opinion that a POSA would not have experienced any unreasonable technical hurdles in implementing these modifications. In this manner, it is my opinion that a POSA would have

understood that modifying Guo's method to use Ashby's cleaning step would merely amount to combining prior art elements (Guo's fabrication method including an initial substrate preheating step, and Ashby's initial substrate cleaning step) according to known methods (cleaning the substrate using hydrogen during a preheating step) to yield predictable results (e.g., formation of a semiconductor structure with relatively few defects).

2. A POSA would have also been motivated to use group II and group VI reactants in Guo's method of making a semiconductor structure.

234. As discussed above, Guo discloses methods for forming group III-V semiconductors. EX1008, ¶¶[0011], [0030], [0048], Abstract. Guo additionally discloses that “[n]umerous variations and combinations of the features set forth above can be utilized without departing from the present invention.” *Id.*, ¶¶[0048], [0057]. But, Guo does not disclose an exhaustive list of what variations and combinations of materials could be used, or why such variations and combinations may be used.

235. A POSA would have thus looked to the prior art for guidance on what variations and combinations of materials may be used in Guo's fabrication method. Ashby is such a prior art reference.

236. Like Guo, Ashby discloses a “process of growing a material on a substrate,” which is applicable to “growing a ... Group III-V material.” EX1009,

Abstract, ¶[0013]. But, Ashby also discloses that its method can be used for “growing a Group II-VI ... material.” *Id.* Based on the teachings of Ashby, it is my opinion that a POSA would have been motivated to modify Guo’s fabrication method to generate a Group II-VI material. These motivations for combining Guo and Ashby include at least those discussed above in Section XIII.A.

237. It is my opinion that a POSA would have recognized that Ashby’s techniques are applicable to Guo, and that modifying Guo to use group II and group VI reactants would have required minimal modifications. Indeed, in the combined system, Guo’s fabrication method would use a group II reactant during the pretreatment of the substrate, and would use a group VI reactant in the step of forming growth nuclei. All other steps and conditions disclosed in Guo could remain largely unchanged. This would then result in the formation of a group II-VI semiconductor in the same way as Guo’s method of making a group III-V semiconductor. Moreover, it is my opinion that a POSA would have recognized that in some situations such a modification would have the added benefit of providing better adherence of the materials to the substrate, more favorable conditions for preservation of the substrate during the formation of nuclei, and lower unit cost when using certain other non-group III metals.

238. Based on my experience in the industry, it is also my opinion that a POSA would have recognized that the combination of group II and group VI

reactants to form nuclei would have also been appropriate in the 2005 timeframe for the subsequent growth of industrial or militarily valuable material combinations like CdS, CdTe, and ZnS, each of which are group II-VI compounds. Such materials were often used in the 2005 timeframe for optical and infrared sensors and emitters, for example. Therefore, a POSA would have recognized that there would have also been certain economic motivations for substituting Ashby's group II and VI reactants for Guo's group III and V reactants.

239. Further, it is also my opinion that a POSA would have found the proposed modification to be obvious because it represents selecting two of a finite number of identified, predictable binary compounds that are useful in semiconductor electronic or optical devices. Indeed, as discussed above, a POSA would have understood that only a few binary compounds have proven economic interest for use in devices, all of which are comprised of group II, III, V, or VI reactants:

- **Group III-V:**

- AlSb, AlAs, AlN, AlP, BN, BP, BAs, GaSb, GaAs, GaN, GaP, InSb, InAs, InN, InP

- **Groups II-VI:**

- CdSe, CdS, CdTe, ZnO, ZnSe, ZnS, ZnTe

EX1020, ii (IUPAC Periodic Table of the Elements); EX1011, 21, 59, 139, 143,

152, 187.

240. In my opinion, a POSA would have also been motivated to substitute Ashby's group II and VI reactants for Guo's group III and V reactants, since it is merely a simple substitution of one known element for another to obtain predictable results. *See generally* EX1014 (disclosing successful lateral semiconductor growth using group II and group VI compounds). The fact that this is nothing more than a simple substitution is also evidenced by the fact that Ashby discloses that its fabrication method can be used to grow both Group II-VI materials and Group III-V materials. EX1009, Abstract, ¶[0013]. Accordingly, it is my opinion that a POSA would have had a reasonable expectation of success in implementing group II and group VI reactants in Guo's fabrication method, as taught by Ashby.

241. Thus, because semiconductor fabrication techniques using group II and group VI reactants were well-known and compatible with Guo's method, it is my opinion that a POSA would not have experienced any unreasonable technical hurdles in implementing these modifications. In this manner, a POSA would have understood that modifying Guo's method to use group II and group VI reactants would merely amount to combining prior art elements (Guo's fabrication method including a pretreating of the substrate step and a depositing the nitride semiconductor step, and Ashby's use of group II and group VI reactants) according

to known methods (selecting a group II reactant for use in pretreating of the substrate, and selecting a group VI reactant for use in depositing the nitride semiconductor) to yield predictable results (e.g., the formation of a group II-VI semiconductor).

B. Dependent Claim 5

242. Claim 5 recites “*wherein said group II reactant is a cadmium reactant or a zinc reactant.*” The combination of Guo and Ashby discloses claim 5. Specifically, Ashby discloses growing Group II-VI materials, which “include at least one of the Group II elements **Zn**, **Cd**, and Hg.” EX1009, ¶[0013]. In my opinion, a POSA would have understood that Cd is formed using “*a cadmium reactant,*” and that Zn is formed using “*a zinc reactant.*” For at least the reasons discussed in Section XVII.A.2 above, it is my opinion that a POSA would have been motivated to use each of these reactants in Guo’s fabrication method.

243. Further, based on my experience, a POSA would have understood that at least CdSe, CdTe, and ZnSe were known to be used in optical emitters and detectors at least by the 2005 timeframe. It is my opinion that a POSA would have also known that other Cd-based compounds, like CdSSe, were used for quantum dots (e.g., fluorescent tagging) and optical filters at least by the 2005 timeframe. Therefore, the Group II elements (Zn and Cd) disclosed in Ashby were both well-known, and were known to provide significant economic value. For at least these

additional reasons, it is my opinion that a POSA would have again been motivated to use Ashby's Group II elements (Zn and Cd) in Guo's fabrication method.

C. Dependent Claim 10

244. Claim 10 recites "*further comprising the step of preheating said substrate in hydrogen prior to pre-treating the surface of the substrate with at least one group III reactant or at least one group II reactant.*" The combination of Guo and Ashby discloses claim 10.

245. First, both Guo and Ashby disclose "*preheating said substrate.*" Compare EX1008, ¶[0031] ("[i]n the first stage of the process, the wafer is brought to a temperature of about 600-900° C") with EX1009, ¶[0039] ("[t]he substrate was cleaned and the surface prepared for growth in-situ by heating the wafer to 1080° C."). Ashby also discloses that its preheating step includes cleaning the substrate using "*hydrogen.*" Specifically, Ashby discloses that "[t]he substrate is cleaned in the growth chamber and the surface prepared for growth. One typical pre-growth treatment involves **heating in ambient H₂**." EX1009, ¶¶[0028], [0039] ("flowing 10 liters/minute **H₂**").

246. It is my opinion that a POSA would have understood that Ashby's cleaning step (including "*preheating said substrate*") is performed "*prior to pre-treating the surface of the substrate,*" because Ashby discloses that its cleaning step is a "pre-growth treatment." *Id.*, ¶[0028], In my opinion, a POSA would have

understood that the growth steps that take place after Ashby's cleaning step would include Guo's pretreatment of the substrate with aluminum ("*pre-treating the surface of the substrate*"), at least because Guo's pretreatment results in a layer of aluminum being deposited on the substrate. For at least the reasons discussed in Section XVII.A.1 above, it is my opinion that a POSA would have been motivated to use Ashby's cleaning step in Guo's fabrication method.

D. Dependent Claim 17

247. Claim 17 recites "*wherein said group VI reactant is a tellurium reactant or a sulfur reactant.*" The combination of Guo and Ashby discloses claim 17. Specifically, Ashby discloses growing Group II-VI materials, which include "at least one of the Group VI elements O, S, Se, and Te." EX1009, ¶[0013]. It is my opinion that a POSA would have understood that Te is formed using "*a tellurium reactant,*" and that S is formed using "*a sulfur reactant.*" For at least the reasons discussed in Section XVII.A.2 and for claim 5 above, it is my opinion that a POSA would have been motivated to use each of these reactants in Guo's fabrication method.

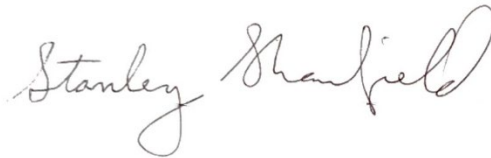
XVIII. CONCLUSION

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 within the United States during the time allotted for cross-examination.

I hereby 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 these statements were made with the 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.

Executed this 29th day of February, 2024.

Respectfully submitted,

A handwritten signature in cursive script, reading "Stanley Shanfield". The signature is written in dark ink and is positioned above a horizontal line.

Dr. Stanley Shanfield

21887027