UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAVANT TECHNOLOGIES LLC d/b/a GE LIGHTING,
ELONG INTERNATIONAL USA INC., and
XIAMEN LONGSTAR LIGHTING CO. LTD.,
Petitioners,

v.

FEIT ELECTRIC COMPANY, INC.,
Patent Owner.

Case IPR2025-00698
U.S. Patent No. 8,614,539

DECLARATION OF E. FRED SCHUBERT, PH.D. IN SUPPORT OF PATENT OWNER'S PRELIMINARY RESPONSE

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I, E. Fred Schubert, Ph.D., hereby declare the following:

I. INTRODUCTION

1. My name is E. Fred Schubert, Ph.D. I have been retained by counsel for Patent Owner as a technical expert in the above-captioned *Inter Partes* Review ("IPR") matter. Specifically, I have been asked to study and provide my opinions on the technology described and claimed by U.S. Patent No. 8,614,539 (the "'539 Patent"). I understand that the Challenged Claims are claims 1-11, 18-20, 23-25, and 28 from the '539 Patent. My opinions in this Declaration are limited to those Challenged Claims.

2. My compensation in this matter is not based on the substance of my opinions or the outcome of this matter. I have no financial interest in the Patent Owner. I am being compensated at an hourly rate of $600 for my analysis and testimony in this case.

II. BACKGROUND AND QUALIFICATIONS

3. I am currently an active, tenured, full professor in the Department for Electrical, Computer, and Systems Engineering at the Rensselaer Polytechnic Institute ("RPI") located in Troy, New York.

4. I also held other positions at RPI. For example, from 2002 to 2012, I was a professor in the Department of Physics, Applied Physics, and Astronomy. In 2008–2009, I served as the founding director for RPI's Engineering Research Center

for Smart Lighting, which was funded by the U.S. National Science Foundation ("NSF").

5. Before I moved to RPI, I was a professor in the Department of Electrical and Computer Engineering at Boston University, from 1995 to 2002. I also served as the director of Boston University's Semiconductor Devices Research Laboratory.

6. Prior to my university career, I was a post-doctoral member of the technical staff, member of the technical staff, principal investigator, and member of management at AT&T Bell Laboratories in Holmdel and Murray Hill, New Jersey, from 1985 to 1995.

7. I earned my Ph.D. in 1986, Master of Science in 1981, and Bachelor's degree in 1978, all in Electrical Engineering, at the University of Stuttgart, Germany.

8. My Curriculum Vitae ("CV") is Exhibit 2002 to this proceeding. As shown by my CV, I have substantial experience in the design and implementation of light emitting devices, including the design, fabrication, processing, and packaging of the components that are commonly used in light emitting diode ("LED") lighting and displays.

9. I have published over 300 technical articles, mostly at competitive technical conferences and rigorously refereed technical journals. These articles relate to liquid crystal displays ("LCDs"), LEDs, semiconductor electronics (e.g., field-effect transistors and bipolar junction transistors), semiconductor lasers, and

photo-detectors, that is, the technologies which form the foundations of microelectronic and optoelectronic devices.

10. For more than 25 years, I have worked on virtually all aspects of light emitting diode (LED) technology, including chip design, chip fabrication, chip characterization, packaging of LEDs, heat conduction in LEDs, light-extraction from LEDs, phosphors for LEDs (including remote phosphors), UV LEDs, white LEDs, IR LEDs, as well as applications of LEDs such as general lighting and LCD backlighting applications. I have written numerous journal articles, patents, books, and review articles on LEDs. My published work has been highly cited as evidenced by more than 45,000 citations that my publications have received.

11. I am also the author or editor of several books. For example, I authored the textbook "Light-Emitting Diodes," (1st, 2nd, 3rd, and 4th editions) initially published by Cambridge University Press, Cambridge, UK, with the later editions published on Google Books. In the LED book, I provide a comprehensive review of the state-of-art technologies for designing, packaging, fabricating, processing, and manufacturing LEDs.

12. In addition to my research, I have been teaching for more than 25 years. I have taught numerous undergraduate and advanced graduate courses in integrated optoelectronics, microelectronics technology, solid-state devices, semiconductor devices, display devices, and light-emitting diodes, all pertinent to the subject matter

in the present case. I have also advised close to 50 Ph.D. and M.S. students while at the RPI and Boston University, in areas such as LEDs, semiconductor electronics, semiconductor lasers, and solar cells.

13. I am the co-inventor of more than 35 issued U.S. patents. I was identified as one of the top 1% inventors in the field of optoelectronics, in a 2011 study conducted by Professor Erica Fuchs of Carnegie Mellon University under the support of NSF. Examples of my issued U.S. patents include:

- U.S. Patent No. 8,451,877; issued on May 28, 2013, titled "High efficiency III-Nitride light-emitting diodes."
- U.S. Patent No. 7,560,746; issued on July 14, 2009, titled "Light emitting diodes and display apparatuses using the same."
- U.S. Patent No. 8,164,727, issued on April 24, 2012, titled "Liquid crystal display with refractive index matched electrodes."

14. I have been actively involved in multiple technical societies, including the American Physical Society (APS), Institute of Electrical and Electronics Engineers (IEEE), Optical Society of America (OSA), Society for Optical Engineering (SPIE). I have served in the organizing committee of multiple technical conferences, including, for example:

- Program committee member and chair of "Display and Solid-State Lighting Devices" conference for OSA/IEEE Conference on Lasers and Electro-Optics (CLEO), 2003 – 2005
- Member of the International Advisory Committee of First International Conference on Display LEDs (ICDL), Seoul, Korea, January 31–February 2, 2007.
- Sub-Committee Chair of Track 6: Displays, Solid-State Lighting, Photovoltaics, and Energy-Efficient Photonics of Asia Communications and Photonics Conference (ACP), Shanghai, China, November 11–14, 2014. ACP is the largest and the most influential conference in Asia and the Pacific Rim for communications and photonics technologies.

15. My research has been recognized by multiple organizations, universities, and institutions. The following list includes examples of honors that I have received:

- Elected Fellow of the IEEE in 1999. According to the IEEE definition, "the grade of Fellow is one of unusual professional distinction conferred by the Board of Directors only upon a person of extraordinary qualifications and experience."

- Elected Fellow of the SPIE in 1999. According to the Society's bylaws, a Fellow "shall be distinguished through his achievements and shall have made outstanding contributions in the field of optics, or optoelectronics, or in a related scientific, technical, or engineering field."
- Elected Fellow of the OSA in 2001. OSA Fellows are elected by the OSA Board of Directors.
- Elected Fellow of the APS in 2001.
- Honored with RPI Medal as Senior Constellation Chair in 2002.
- Recipient of "Scientific American 50 Award" of 2007, as published in the January 2008 issue of Scientific American.
- Received "Rensselaer Polytechnic Institute Trustee Faculty Achievement Award" in 2002, 2008, and 2012.

16. My qualifications and accomplishments are further detailed in my CV, submitted as Exhibit 2002.

III. MATERIALS CONSIDERED

17. In writing this Declaration, I have considered my own knowledge and experience, including my work experience in the above fields; my experience in teaching those subjects; and my experience in working with others involved in those fields. I have also reviewed the Petition and the associated exhibits.

IV. LEGAL FRAMEWORK

18. I have been informed by counsel for Patent Owner that the following legal principles apply to an analysis of patentability based on 35 U.S.C. § 103 for obviousness. I have also been informed that, in an *inter partes* review proceeding such as this proceeding, to render a patent claim unpatentable, Petitioner must show by a preponderance of the evidence that the claim would have been rendered obvious by one or more properly combined prior art patents or publications.

A. Obviousness

19. I understand that to find a patent invalid for obviousness, the petitioner must prove that the differences between the claimed invention and the prior art taken as a whole would have been obvious to a person of ordinary skill in the art ("POSITA") at the time the invention was made.

20. I have been informed that to render a claim obvious, a combination of prior art references must disclose each claim element of that claim, and that obviousness is a question of law based on the underlying facts. I understand that the underlying factual inquiries are: (1) the scope and content of the prior art, (2) the differences between the prior art and the claims at issue, (3) the level of ordinary skill in the pertinent art, and (4) secondary considerations of non-obviousness.

21. I understand that secondary considerations of non-obviousness (also known as objective indicia of non-obviousness) may include: (1) a long felt but

unsolved need; (2) commercial success; (3) unexpected results; (4) industry praise; (5) licensing; and (6) copying by others. I also understand that there must be a relationship or nexus between any such secondary considerations and the claimed invention. I further understand that contemporaneous and independent invention by others is a secondary consideration supporting an obviousness determination.

22. I understand that any secondary consideration must bear a nexus to the claimed invention. Where the offered secondary consideration actually results from something other than what is both claimed and novel in the claim, there is no nexus to the merits of the claimed invention. I further understand that the patentee bears the burden of demonstrating that the relevant secondary indicia is attributable to the claimed invention, as opposed to other economic and commercial factors unrelated to the technical quality of the patented subject matter. I understand that a nexus is presumed where the secondary considerations are tied to a particular product which: (i) embodies the claimed invention and (ii) is coextensive with the claimed invention. In analyzing whether a product is coextensive with the claimed invention, I understand that there is no requirement for a perfect correspondence between the claims and the product, and that the presumption of a nexus can still apply when unclaimed features present in the product amount to nothing more than additional insignificant features.

23. I am also informed that the fact that all of the elements of a claimed invention can be found separately in more than one prior art reference is not sufficient to warrant a finding that a claimed invention is obvious. There must be a reason why it would have been obvious to modify or combine the prior art to arrive at the claimed invention. I understand that a helpful insight into this determination is whether there is a teaching, suggestion or motivation in the prior art that would lead one of ordinary skill in the art to combine the elements. When there is no suggestion for the proposed combination, or when the prior art suggests something other than the combination, a finding of obviousness is generally not warranted.

24. I understand that the prior art must be considered in its entirety, including disclosures that teach away from the claimed invention. Furthermore, if a proposed modification to a prior art reference would render the prior art invention being modified unsatisfactory for its intended purpose, then there is no suggestion or motivation to make the proposed modification.

25. I understand that the pertinent obviousness inquiry takes place at the time of the invention. Therefore, the use of hindsight in an obviousness analysis is impermissible, particularly if the hindsight is guided by the challenged patent.

26. I further understand that, in making a determination as to whether the claimed invention would have been obvious to a POSITA, the fact finder must consider certain objective factors, such as commercial success, long-felt, but

unsolved need, unexpected results, copying, and praise by others in the field. The presence of such factors—known as "secondary considerations"—is evidence of non-obviousness. I also understand that a connection, or nexus, must exist between the secondary consideration and the claimed invention.

27. Counsel has informed me, and I understand, that even where all of the claim limitations are expressly disclosed in the prior art references, there must be some showing that a person of ordinary skill in the art would have been motivated to combine such prior art references, and explanation of how the combination would be achieved, and that there would have been a reasonable expectation of successfully achieving the claimed invention from such combination.

B. Level of a Person of Ordinary Skill in the Art

28. I was asked to provide my opinion as to the level of skill of a POSITA of the '539 Patent at the priority date of the claimed invention, which counsel has told me to assume is October 5, 2010. In determining the characteristics of a hypothetical POSITA of the '539 Patent, I considered several factors, including the type of problems encountered in the art, the solutions to those problems, the rapidity with which innovations are made in the field, the sophistication of the technology, and the education level of active workers in the field. I also placed myself back in the time frame of the claimed invention and considered the colleagues with whom I had worked at that time.

29. Petitioner's declarant Dr. Doolittle contends that a POSITA in the field of the '539 patent would have "had an undergraduate degree (i.e., B.S., B.S.E. or the equivalent) in electrical engineering, materials science, physics, or a similar discipline. A [POSITA] would also have one to two years of experience in the field of LED packaging design. More education could substitute for experience, and vice versa. This person would have been capable of understanding and applying the teachings of the '539 patent and the prior-art references discussed herein." I understand that Petitioner has adopted that definition of a POSITA. Ex. 1102 ¶40; Pet. 6.

30. For purposes of this Declaration, I do not dispute the level of skill for a POSITA as set forth by Dr. Doolittle and adopted by Petitioner. I note, however, that a bachelor's degree recipient with one to two years of experience or a master's degree recipient (in electrical engineering, materials science, physics, or a similar discipline) with no experience in the field of semiconductor chip design at all, who, according to Petitioner, qualifies as a POSITA, has relatively low skills in the relevant field. A master's degree recipient with no experience in the LED lighting field would have difficulties understanding the complex issues governing LED packaging for various chip designs and lighting uses.

31. The technology is not "relatively simple" as Dr. Doolittle states. Ex. 1102 ¶39. Though LED technology has come a long way, the development of blue

LEDs took over three decades and resulted in the award of the 2014 Nobel Prize in Physics.[1] This eventually led to the invention and development of white LEDs, which is still an evolving field.

32. Based on my education, training, and professional experience in the field of the claimed invention, including teaching the requisite skills necessary for a POSITA during the relevant time period, I am familiar with the level and abilities of a POSITA at the time of the claimed invention. Additionally, I met at least these minimum qualifications to be a POSITA as of the time of the claimed invention of the '539 Patent. Specifically, by October 5, 2010, I had already obtained a Ph.D. degree in electrical engineering and accumulated at least 20 years of experience in the design and/or testing of microelectronics technology, solid-state devices, semiconductor devices, light-emitting diodes, and related technologies.

C. Claim Construction

33. I understand that the ordinary and customary meaning of a claim term is the meaning that the term would have to a POSITA at the time of the invention.

34. In the absence of an express intent on the part of the inventor to give a special meaning to the claim terms, the words are presumed to take on the ordinary

[1] *Press Release: The Nobel Prize in Physics 2014*, Nobel Prize (Oct. 7, 2014), https://www.nobelprize.org/prizes/physics/2014/press-release/.

and customary meanings in light of the relevant patent attributed to them by a POSITA.

35. I understand that it is the use of the words in the context of the written description, and as customarily used by those skilled in the relevant art, that accurately reflects both the ordinary and the customary meaning of the terms in the claims.

36. I understand that the basis for a term's ordinary and customary meaning may be derived from a variety of sources, including the words of the claims themselves, the remainder of the specification, the prosecution history, and extrinsic evidence concerning relevant scientific principles, the meaning of technical terms, and the state of the art at the time of the invention.

37. I have been instructed that dictionary definitions or definitions from technical references can be used to inform or confirm the ordinary and customary meaning of words found in a claim, but that in construing claim terms, the general meanings gleaned from reference sources, such as dictionaries, must always be compared against the use of the terms in the context of the claim itself.

38. I understand that a patent applicant is entitled to be his or her own lexicographer (in other words, provide his or her own meaning to a word or phrase) and may rebut the presumption that claim terms are to be given their plain and ordinary meaning. To do so, the applicant must clearly set forth a definition of the

term that is different from its ordinary and customary meaning. Where the applicant provides an explicit definition for a term, that definition will control interpretation of the term as it is used in the claim in which it appears. I understand that the specification can also be relied on for more than just explicit lexicography to determine the meaning of a claim term. For example, I understand that the meaning of a particular claim term may also be determined by implication, that is, according to the usage of the term in the context of the specification.

39. In my opinion, for purposes of this Declaration, I agree with Dr. Doolittle that none of the terms in the Challenged Claims are indefinite and none of the terms require additional construction beyond their plain and ordinary meaning as a POSITA would have understood them at the time of the invention (2010).

V. TECHNOLOGY BACKGROUND

40. This Section is intended to provide context for my opinions regarding the patentability of the ’539 Patent. Any images used are for demonstrative purposes only unless cited from a submitted exhibit.

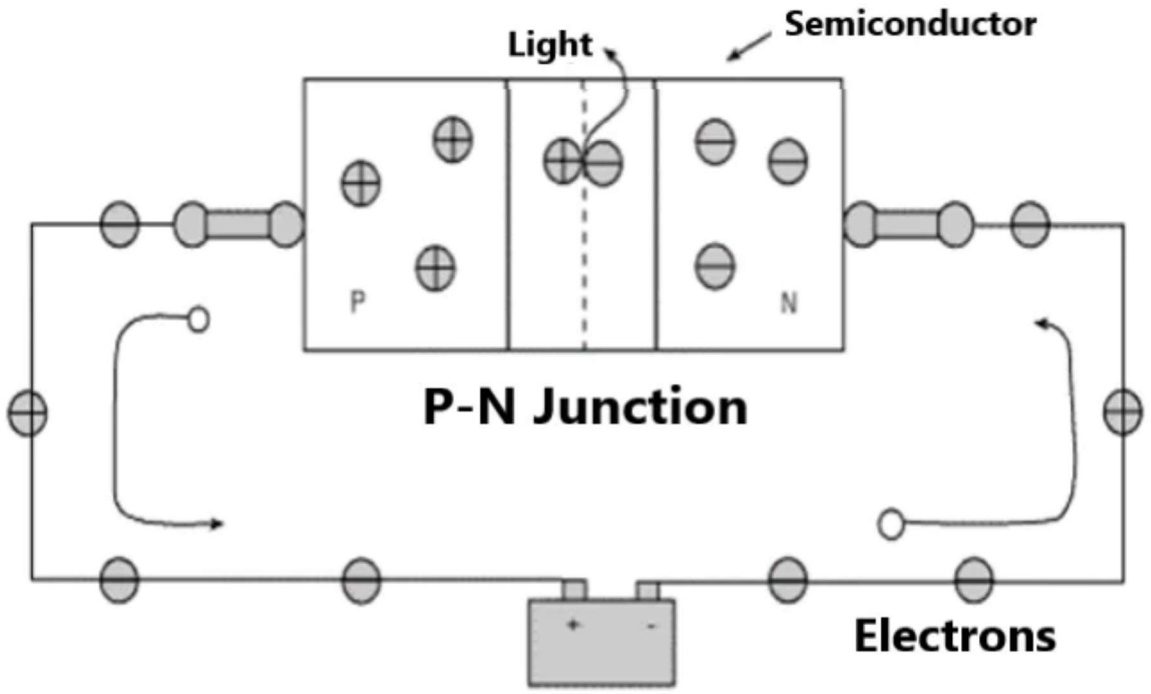
A. Light-Emitting Diodes

41. Solid-state lighting (“SSL”) utilizes light-emitting diodes (“LEDs”) made of semiconductor materials to create light in a highly efficient and durable way. Unlike traditional lighting sources such as incandescent bulbs or fluorescent tubes, which rely on heated filaments or a gas (mercury vapor) to produce light,

LEDs are made of solid materials that emit light when electricity passes through them. LEDs are widely used in everything from home and outdoor lighting, digital displays, and automotive lights. *See, e.g.*, Ex. 2014 at 1–4, 21–22, 285–86.

42. When electricity passes through the semiconductor material within an LED, it excites the electrons in the material, causing them to release photons, or particles of light. *See, e.g.*, Ex. 2014 at 35. The result is a highly efficient form of lighting that can emit a broad range of colors, brightness levels, and different color temperatures of light, depending on the material composition, semiconductor chip design, phosphors, and the LED packaging. *See generally* Ex. 2014.

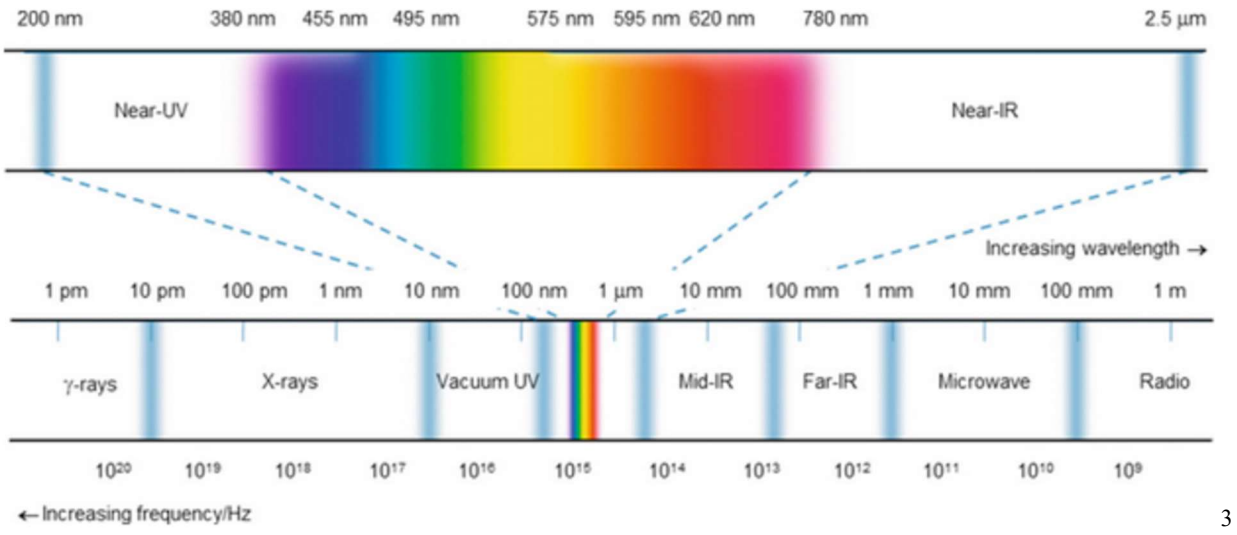
43. LEDs utilize semiconductor chips to generate light. Semiconductor chips are made up of at least two different semiconductor materials, n-type and p-type, with different conductivity characteristics. The materials create a diode, because one material has fewer free electrons (and instead more "p-type" holes in the "valence band") than the other, which has more free electrons ("n-type" electrons in the "conduction band"). *See, e.g.*, Ex. 2014 at 59–60. When an electrical current is applied, electrons from the n-type side move across a p-n junction to fill holes on the p-type side. As they do, energy in the form of light photons is released. *See, e.g.*, *id.*



[2]

This light can be emitted in the ultraviolet, visible, or infrared ranges of the electromagnetic spectrum:

[2] *LED Lamp: Technologies, Types and their Applications*, Electrical Sphere (July 4, 2024), https://electricalsphere.com/led-lamp-technologies-types-and-their-applications/.



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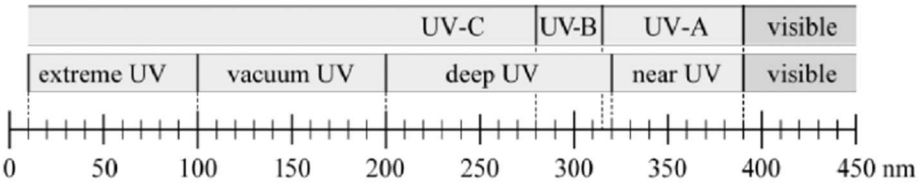


Fig. 13.1. Nomenclature of UV radiation versus wavelength (after International Congress on Light, 1932).

Ex. 2014 at 222.

44. As shown in the figures above, though scientists may have different understandings of the delineations within the ultraviolet ("UV") spectrum, the general consensus is that the UV spectrum spans approximately 10–380 nm with at least near-UV and vacuum UV regions.

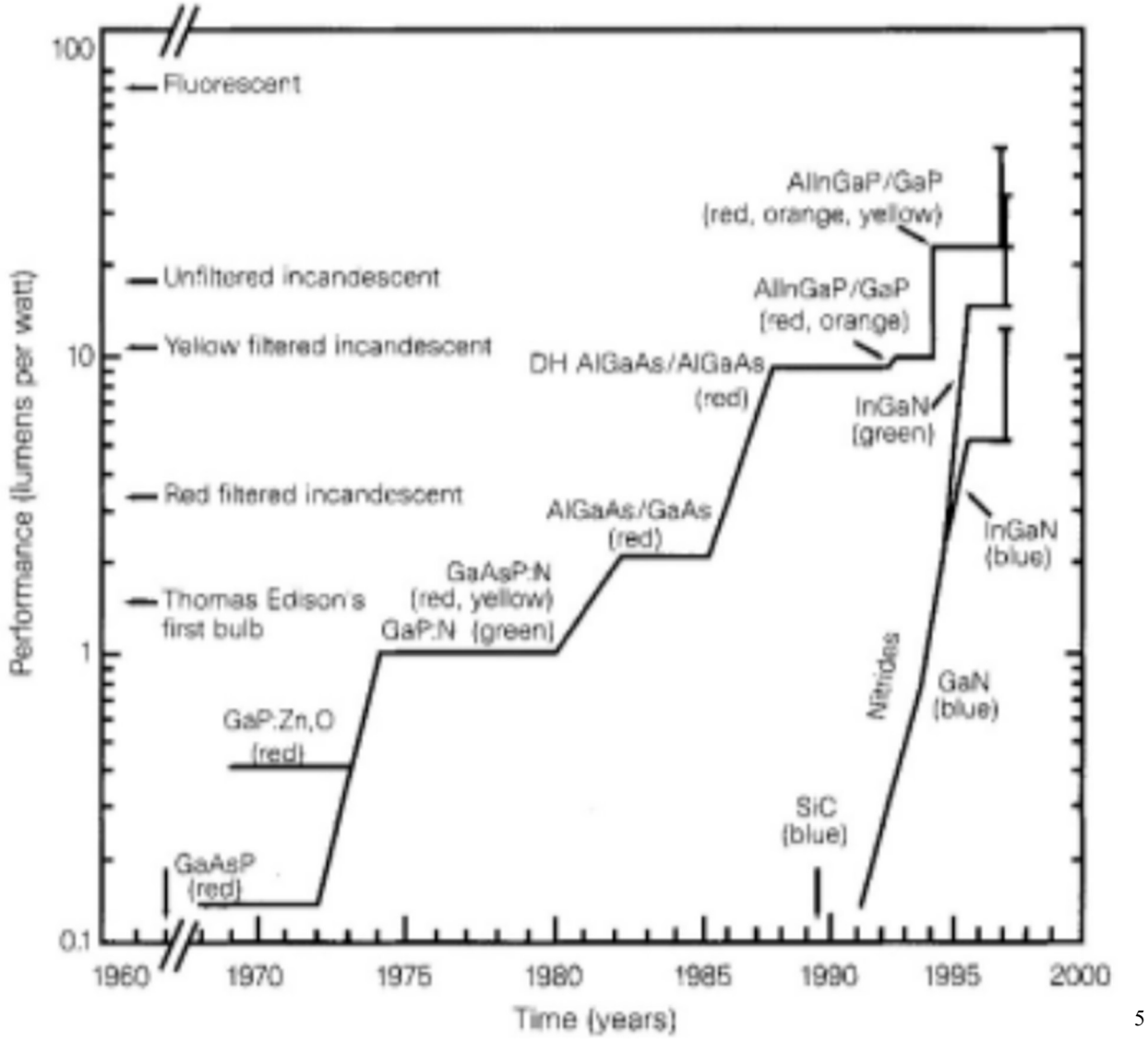
45. The visible spectrum can be divided into the three primary color regions: red ("R"), green ("G"), and blue ("B"). These three colors are referred to as the primary colors of light. Mixing of light with the three primary colors can create

[3] David L. Andrews, *Electromagnetic Radiation*, *in* ENCYCLOPEDIA OF SPECTROSCOPY AND SPECTROMETRY 427 (John C. Lindon ed., 2017).

additional colors. For example, the mixing of R and G creates yellow, the mixing of G and B creates cyan, and the mixing of B and R creates magenta. Indeed, mixing of the three primary colors can create a multitude of distinguishable colors, for example, more than 1,000 colors. The visible spectrum reaches from 380 nm at the short-wavelength end (UV or ultraviolet end) to 750 nm at the long-wavelength end (IR or infrared end). Dividing the visible spectral range into the three primary colors yields: R (red) from about 750 nm to 590 nm, G (green) from about 590 nm to 480 nm, and B from about 480 nm to 380 nm.[4] The primary colors are of particular relevance because the human eye has three types of color receptors (called "cone receptors") that have respective peak sensitivities in the R, G, and B part of the visible spectrum. *See, e.g.*, Ex. 2014 at 292–300, 313–15.

46. The material of the semiconductor light-emitting active region determines the color of light emitted from the chip. For instance, using indium gallium nitride ("InGaN" or "GaInN") creates blue and green light, while substances such as aluminum gallium indium phosphide ("AlInGaP") create red and orange light as shown below.

[4] Although the wavelength boundaries of the primary color regions are not precise, it is well established that there are three primary colors (R, G and B) and that these primary colors are associated with specific regions of the visible light spectrum. A more differentiated view may be obtained by taking into account primary as well as secondary colors of light. Secondary colors, obtained by mixing of primary colors, are numerous, at a minimum hundreds of colors.



5

This figure also illustrates the development of materials used to generate different colors. *See* Ex. 2014 at 213. It was not until the 1990s that semiconductors were developed that could emit blue light efficiently. *See id.*

[5] F.A. Ponce & D.P. Bour, *Nitride-based semiconductors for blue and green lightemitting devices*, 386 NATURE 351, 353 (1997).

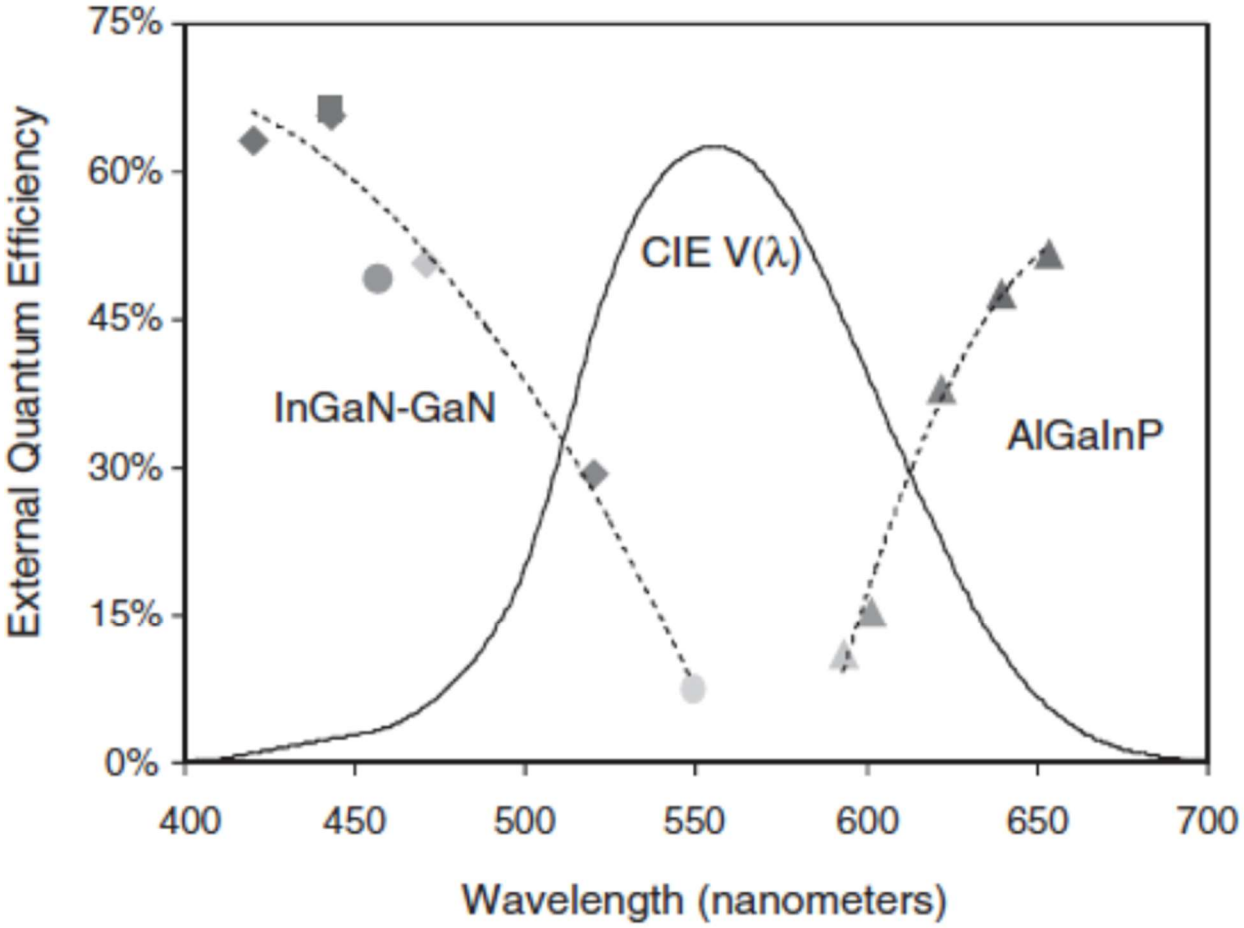
47. As Dr. Doolittle explained, the wavelength of light emitted is further determined by the energy bandgap (or just "bandgap"). *See* Ex. 1102 ¶¶44–47. This bandgap is the energy needed to move electrons from the valence band to the conduction band. Thus, not only do different materials dictate the energy (and associated voltage) required to traverse the P-N junction or bandgap, but larger bandgaps require more energy (and higher voltages) to be traversed. Because there is an inverse relationship between the energy of a photon and its wavelength, larger bandgaps produce shorter wavelengths (ultraviolet or violet light) because the photons have higher energy. In contrast, smaller bandgaps produce longer wavelengths, like orange or red light, because the photons have lower energy.

48. When designing LED chips, various factors must be taken into account, such as luminous efficacy and quantum efficiency. *See, e.g.*, Ex. 2014 at 286, 332–33.

49. Luminous efficacy is a measure of how efficiently a light source converts electrical power into visible light as perceived by a human subject. *See, e.g.*, Ex. 2014 at 284. A higher luminous efficacy indicates lower energy consumption for the same amount of visible light, which can reduce operational costs and environmental impact. Green LEDs frequently have a high luminous efficacy because human vision is highly sensitive in the green spectral range. On the

other hand, UV light sources have a luminous efficacy of zero, because human vision is insensitive in the UV spectral range (and unable to detect UV light).

50. Quantum efficiency can be divided into two types: internal and external. Internal quantum efficiency is the ratio of the number of photons generated inside an LED chip to the number of electrons injected into it. In other words, internal quantum efficiency represents how effective the LED chip's active region converts electrical energy into optical energy (light energy). External quantum efficiency is the ratio of the number of photons emitted from an LED chip to the number of electrons injected into the chip. It is the measure of the overall efficiency of an LED's ability to convert electrical energy into optical energy (light energy) that escapes the device. *See* Ex. 2014 at 86–87. A number of factors impact the quantum efficiency, including the material and desired emitted wavelength as shown below:



Ex. 2013, 70. This graph shows that, for instance, external quantum efficiency decreases with longer wavelengths when using InGaN, but increases with longer wavelengths when using AlGaInP.

B. Semiconductor Package Design

51. Semiconductor LED chips are utilized to generate light. LED chip design relates to the design of the semiconductor LED chip, that is, the semiconductor pn-junction diode that emits the primary light of the packaged white LED. LED chip technology includes the epitaxial growth of the pn-junction layers

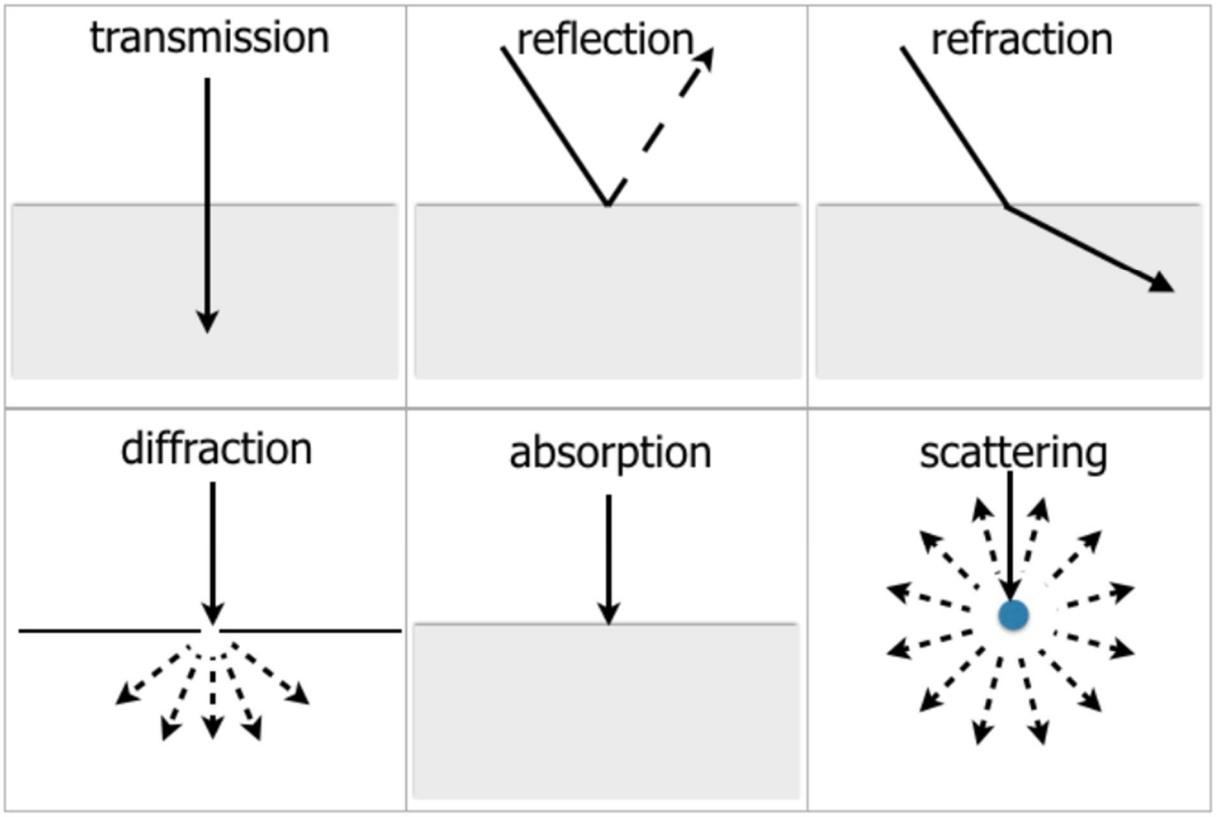
and light-emitting active layers and the processing of the LED wafer which may include thin-film deposition, etching, and photolithography processes. In contrast, LED packaging technology concerns the packaging of the finished semiconductor LED chip to yield a package that can be further used for applications such as general lighting applications. LED packaging technology includes the use of phosphors (wavelength converter materials), encapsulation (to protect the LED from environmental influences such as oxygen and moisture), optical design to attain an emission pattern that meets application-specific requirements, and environmental testing.

52. The distinctness and separateness of chip technology and packaging technology is recognized throughout the semiconductor industry. For example, Ji Zheng and Henry Lee pointed out that chip design and package design are, at a minimum, distinct technical fields. Zheng and Lee state: "At best, package design and chip design in the same corporation belong to different groups without much technical interaction. At worst, package design is outsourced to a specialized vendor preventing technical interaction."[6] This above quote reflects the distinctness of the technologies and has resulted in chip design and package design being worked on by different departments within a company or even by different companies.

[6] Ji Zheng & Henry Lee, *Chip Package-System Co-Design*, 2009 Int'l SoC Design Conf. (ISOCC) 287 (2009).

Although the Zheng and Lee statement is made in the context of silicon integrated circuit technology, it is fair to say that the distinction prevails throughout the semiconductor industry and includes imaging sensors, photo-detectors, laser emitters, integrated circuits, and last but not least, LEDs.

53. Light emitted from LED chips can interact with surrounding materials and objects in various ways, including ways that are characterized by absorption, reflection, refraction, and scattering, all of which influence the efficiency and appearance of the emitted light. Absorption occurs when a material, such as an encapsulant or housing, converts the light into heat thereby reducing the overall efficiency of the LED. Reflection can occur at the boundaries of the LED package materials, such as a substrate, with reflective materials directing light back into a desired path or causing efficiency losses if, for example, misdirected. Refraction happens when light passes through materials of differing refractive indices, such as from the LED chip into an encapsulant or lens, altering its direction and affecting beam shape. Scattering, caused by microscopic particles (such as TiO_2 particles) within a transparent material (referred to as a "binder") as well as surface textures of a material (such as a substrate), diffuse light to create a softer, more uniform light output.



[7]

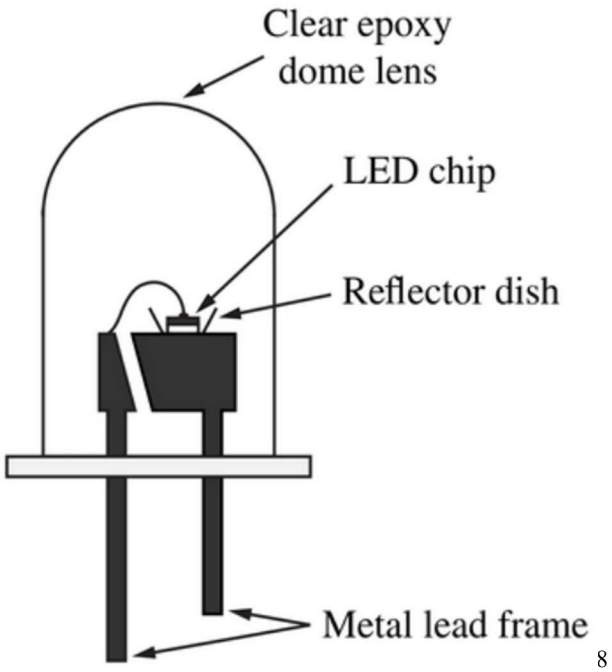
Balancing these light-matter interactions through careful material selection and device choices is essential to optimizing LED performance for various applications.

54. As discussed above, semiconductors can have differing material composition and smaller or larger bandgaps depending on the desired emission. Additionally, LEDs have been developed to have different packages that depend on whether the LED's intended purpose benefits from maximized brightness, minimized power requirements, size, cost, and thermal considerations. The type of

[7] Tony Wayne, *Light (basics and geometrical optics)*, MR. WAYNE'S CLASS, https://www.mrwaynesclass.com/lightOptics/index02.html.

chip and purpose of the LED will impact a POSITA's considerations in packaging the LED.

55. For instance, standard LEDs, as shown below, are characterized by a bulbous head, bond wires, and pins that traverse through holes in a printed circuit board. I take the liberty to refer to such packages as dual-in-line packages ("DIP").



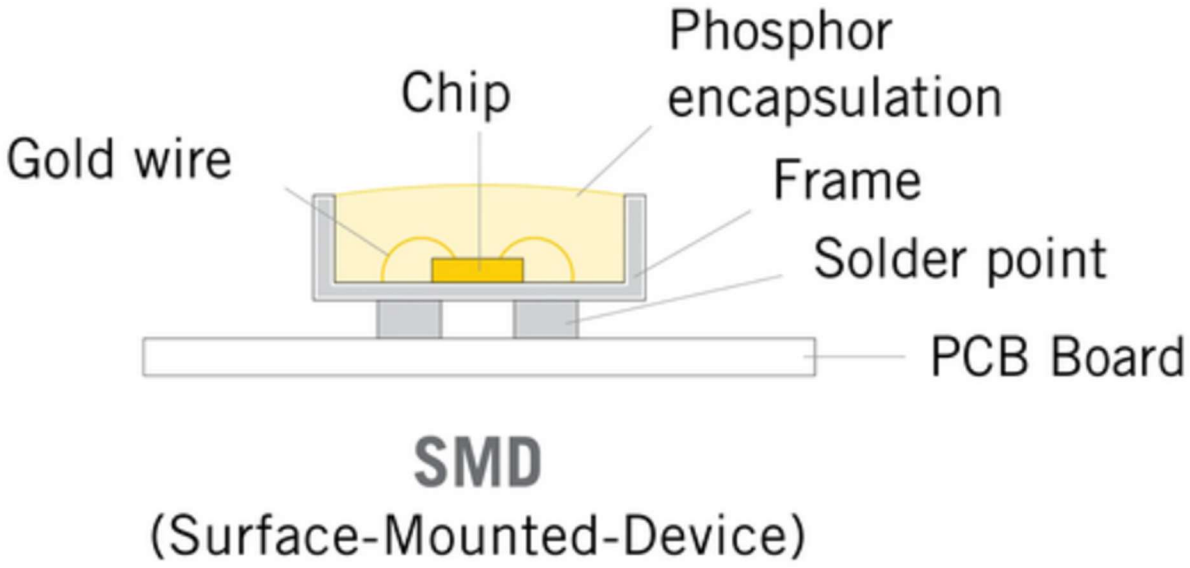
[8]

DIP LEDs are generally more expensive to manufacture due to their increased size and weight, but are considered robust, durable, and bright. They are frequently used in industrial settings (such as high-bay lighting) that require visibility at greater

[8] *Light-Emitting Diodes (LEDs)*, FOSCO, https://www.fiberoptics4sale.com/blogs/wave-optics/light-emitting-diodes-leds-1 (last accessed Nov. 10, 2024).

distances or environments where the LED will need to withstand certain stressors. *See, e.g.*, Ex. 2015, 26, 28.

56. As technology has advanced, LED packaging has reduced in size. Surface-mounted devices (or "SMD LEDs") were developed after DIP LEDs.



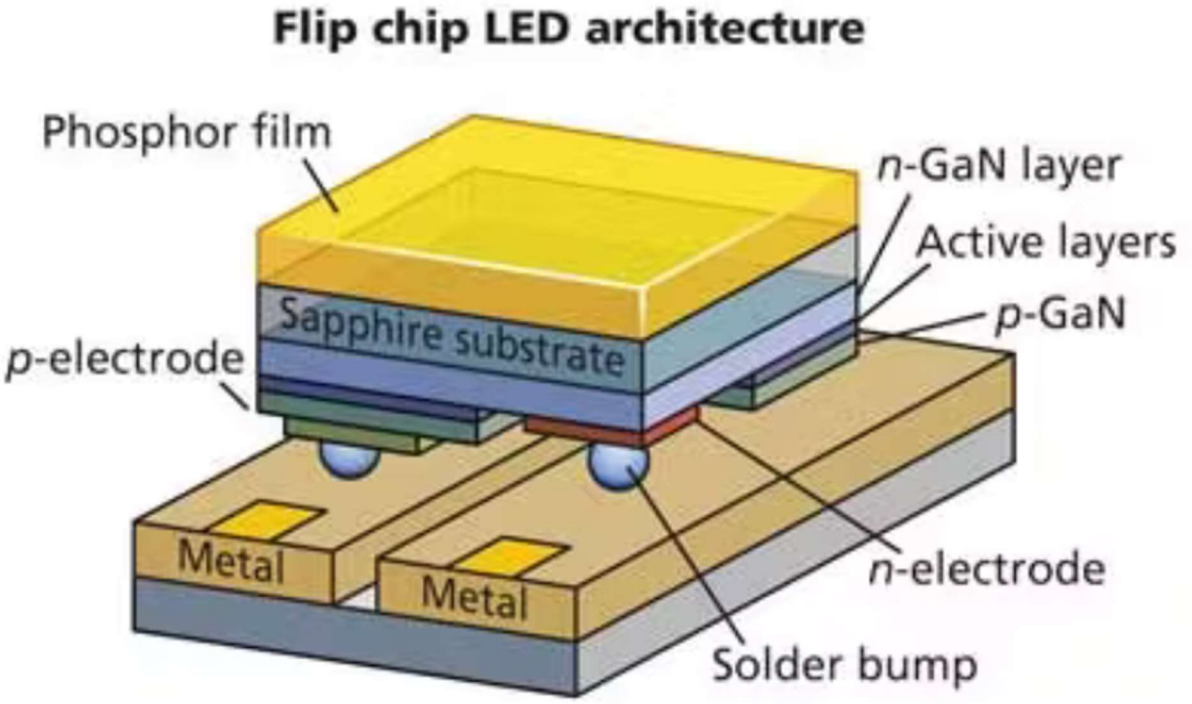
[9]

Like DIP LEDs, lead-frame SMD LEDs can have exposed wires ("bond wires") that block a small portion of the light emitting from the chip. However, SMD LEDs are smaller, have no pin-shaped leads (but rather contact pads), and are soldered directly onto the surface of circuit boards. SMD LEDs generally have a higher brightness and efficiency and have improved thermal management over DIP LEDs. Because

[9] Grant Wheeless, *What is Continuous COB LED Light?*, ARMACOST LIGHTING, https://www.armacostlighting.com/blogs/news/cob-tape-light (last accessed Nov. 10, 2024).

SMD LEDs have higher efficiency and brightness, they can be found in applications such as automobile headlights. *See, e.g.*, Ex. 2015, 28.

57. Furthermore, flip-chip LEDs were developed to be more compact than DIP LEDs. Flip-chip LEDs are a subset of SMDs and are designed to connect directly to the circuit board without needing wires (or "bond wires") to electrically connect.



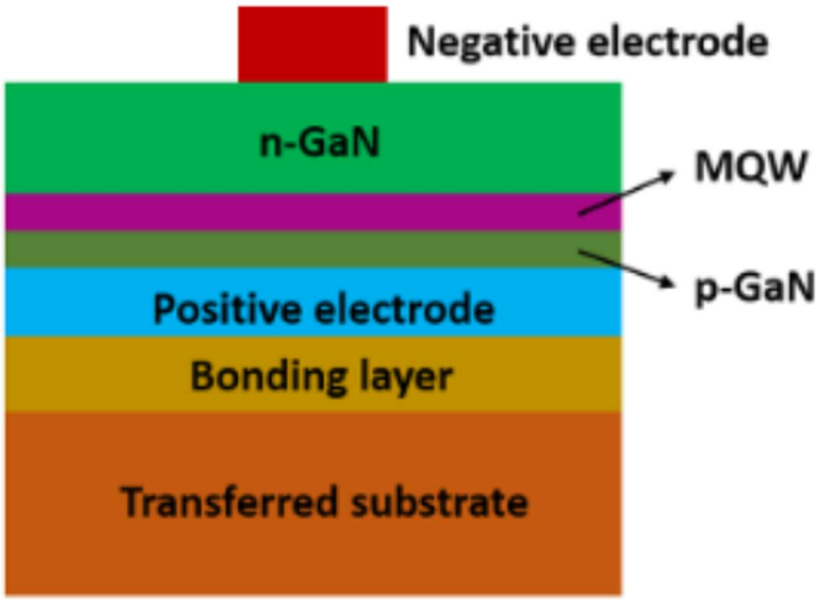
[10]

[10] Julian Carey, *New LED architectures and phosphor technologies lower costs and boost quality (MAGAZINE)*, LEDS MAGAZINE (Sept. 4, 2014), https://www.ledsmagazine.com/manufacturing-services-testing/assembly-contractmanufacturing/article/16695194/new-led-architectures-and-phosphor-technologieslower-costs-and-boost-quality-magazine.

The LED chips in flip-chip LEDs are mounted on a substrate (also referred to as "sub-mount," see image above), frequently a ceramic substrate, and do not employ a metal lead frame, as is common for the SMD LEDs as disclosed in the Shimizu-APA reference. *See* Ex. 1109. However, flip-chip LEDs are generally more efficient than lead-frame SMD LEDs due to reduced resistance in electrical and thermal pathways, and the lack of bond wires contributes to minimized light absorption and electrical losses. Further, the lack of fragile wires and increased light-emitting surface area results in increased brightness and robustness. Flip-chip LEDs are ideal for applications that require intense brightness and compact design, such as a camera flash. *See, e.g.*, Ex. 2015, 27.

58. Packaging for both flip-chip LEDs (with lateral current flow) and SMDs (with metal lead frames) requires a focus on compactness, durability, and efficient light distribution. Flip-chip designs eliminate the need for wire bonding, so packaging can be more compact with improved thermal management and higher light extraction efficiency due to fewer obstructions. Because SMD designs (as disclosed by Shimizu-APA (Ex. 1109)) additionally have fine wires to connect the chip to its substrate, packaging must provide ample space for wire placement and protection. This requires encapsulation materials to shield the delicate wires from mechanical damage and environmental factors, such as moisture and vibration. *See, e.g.*, Ex. 2015, 27.

59. Another important chip design is the vertical chip design (with vertical, top-to-bottom current flow) which is distinguished from the lateral chip design (with lateral, left-to-right current flow). In the vertical chip design, the current flows vertically through the chip, which improves electrical performance and conductivity. Unlike flip-chip LEDs with lateral current flow, vertical chips are suitable for very high current densities, which improves performance in high-power scenarios. *See, e.g.*, Ex. 2016, 3971.



[11]

[11] Jiajia Fu et al., *Degradation and corresponding failure mechanism for GaNbased LEDs*, 6 AIP Advances 055219, 055219-2 (2016), https://www.researchgate.net/profile/Lixia-Zhao-5/publication/303533555_Degradation_and_corresponding_failure_mechanism_for_GaN-based_LEDs/links/575c280a08ae414b8e4c0b6b/Degradation-andcorresponding-failure-mechanism-for-GaN-based-LEDs.pdf.

However, vertical chips (shown in image above) can require bonding wires, which can make them less durable than flip-chip LEDs with lateral current flow. Vertical chips are also more costly to manufacture, but are optimized for high-performance applications such as search lights, stadium lights, spot lights, and high-bay lights. *See, e.g.*, Ex. 2017, 165.

60. Thus, the primary focus for packaging vertical chips is on thermal management and electrical efficiency. These LEDs are designed for high-power applications, so the packaging must include substrates with excellent heat dissipation properties, such as ceramics or metal-core printed circuit boards, to handle the significant heat generation. Additionally, the packaging should provide robust electrical connections to support vertical current flow with minimal resistance, ensuring high performance and reliability. Optical design is also critical for vertical chip LEDs, as packaging must include reflective layers or advanced lens systems to maximize light extraction and achieve focused beam patterns for applications like automotive headlights or industrial lighting (such as high-bay lighting). *See, e.g.*, Ex. 2017.

61. Additionally, the type of light emitted from semiconductor chips is related to the packaging requirements. UV LEDs typically require specialized packaging to handle shorter wavelengths and higher energy photons, which can degrade conventional materials. These packages often incorporate materials with

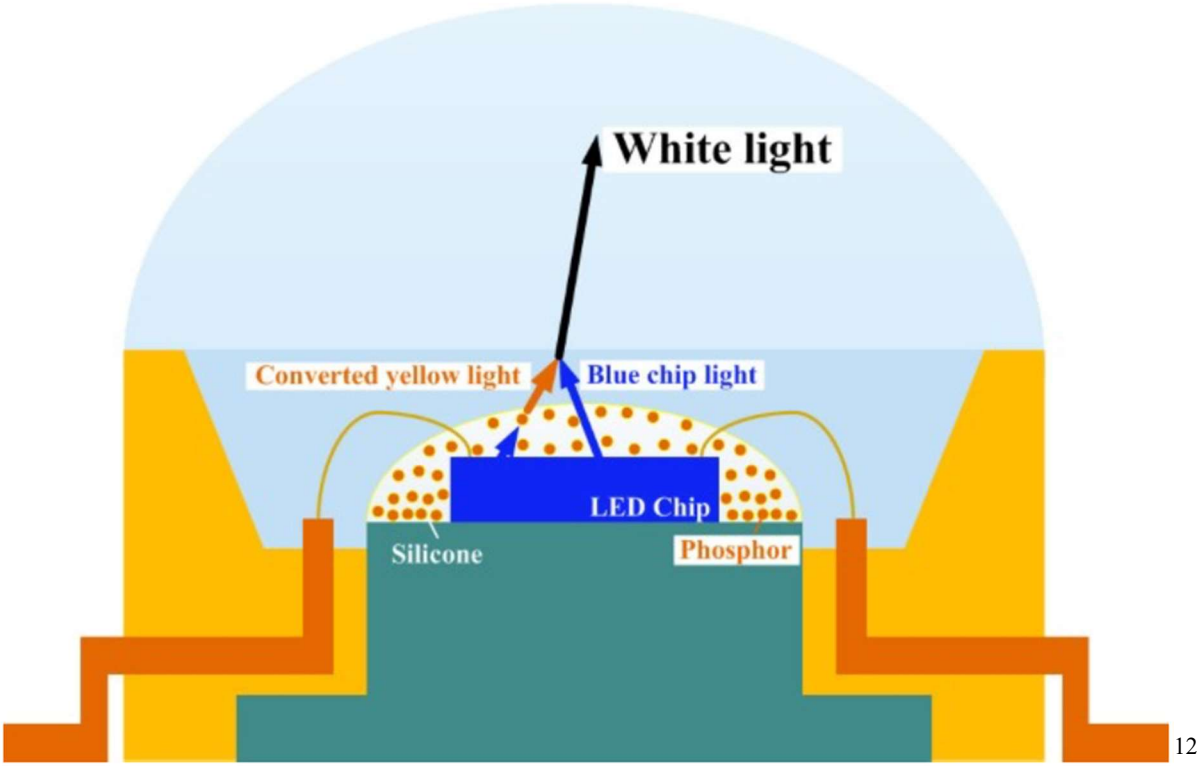
high UV resistance, such as quartz or UV-stable polymers, to ensure durability and performance. In contrast, visible light LEDs use standard epoxy or silicone encapsulants that are not UV-stabilized, as visible light wavelengths pose less risk of material degradation. Additionally, UV LEDs often incorporate more robust thermal management systems to dissipate the higher heat generated, whereas visible light LEDs may require less extensive heat sinking. UV LED packages are also more likely to include reflective coatings or optical elements optimized for UV wavelengths, while visible LEDs typically focus on maximizing visible light extraction. These differences ensure each LED type performs efficiently for its intended applications. *See generally, e.g.*, Ex. 2018.

62. Overall, different LED applications require unique combinations of performance, durability, duration of energization, and efficiency. For high-power applications, such as automotive headlights or industrial high-bay lighting, the packaging must prioritize thermal management to dissipate heat effectively and maintain high performance under continuous operation. Conversely, LEDs designed for displays or decorative purposes emphasize compactness and precise optical control, requiring packaging that supports surface-mount technology and integrates features like diffusers or phosphor coatings for uniform light output. These also include using luminescent materials that can change the color emitted by the LED package from the color emitted by the LED chip. For outdoor and/or harsh

environments, packaging must ensure durability and protection against moisture, UV radiation, and temperature fluctuations, often employing robust sealing materials and weather-resistant coatings. Meanwhile, LEDs for specialized goals, such as medical or UV sterilization purposes, need specialized packaging to enhance light output at specific wavelengths and protect against damage from high-energy emissions. Manufacturers must also optimize packaging for efficient light extraction, as photon losses at interfaces can significantly impact overall efficiency.

C. White Light LEDs

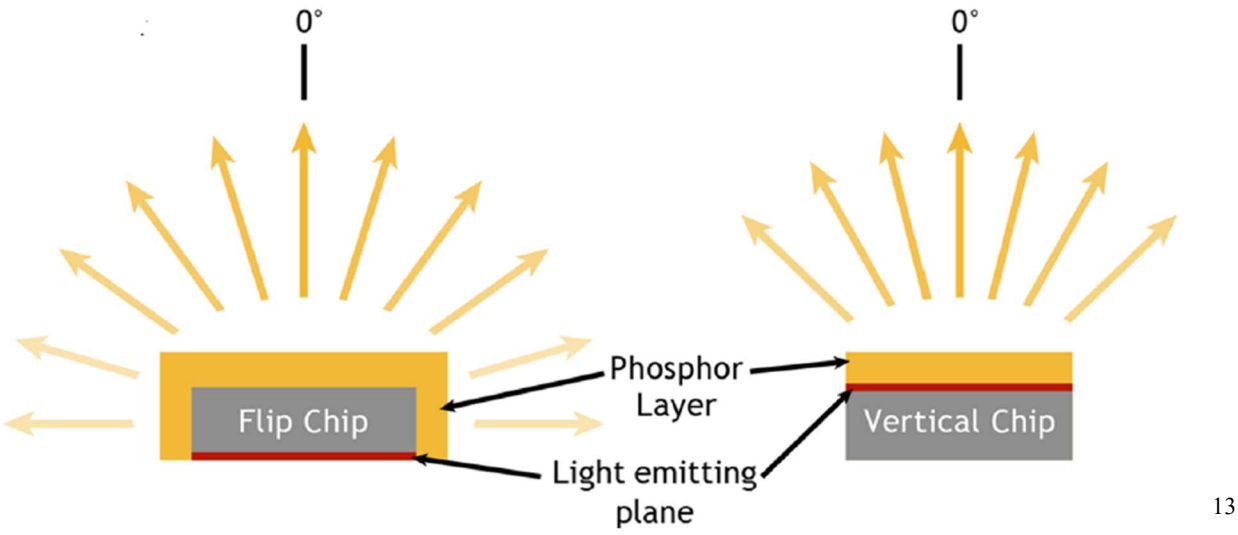
63. White LEDs have two main components: a semiconductor chip emitting blue, near UV, or UV light and a luminescent material that is excited by the chip's light and reemits the light as red, yellow, or green light. Such luminescent materials are also referred to as wavelength conversion materials. To the human eye, an appropriate combination of the three primary colors (red, green, and blue) appears white.



[12]

The luminescent material (frequently referred to as a "wavelength conversion material") is generally made up of phosphor particles suspended in a transparent binder such as a silicone binder. The thickness and composition of the phosphor can be adjusted to achieve different color temperatures and improve color rendering. As shown below, depending on the LED chip's structure, the phosphor, frequently configured as a layer, can look differently:

[12] Yiman Wang et al., *Modeling on phosphor sedimentation phenomenon during curing process of high power LED packaging*, 1 J. SOLID STATE LIGHTING 1, 2 (2014), https://journalofsolidstatelighting.springeropen.com/articles/10.1186/2196-1107-1-2.



[13]

Because the light emitting plane on a flip chip LED has a greater range of emission, the phosphor layer extends down the sides of the device, as shown in the left-side image above.

64. At the time of invention, light diffusing particles such as titanium dioxide ("TiO_2") and silicon dioxide were added to encapsulants to promote spatial color uniformity. *See, e.g.*, Ex. 2014 at 355.

D. Issues Facing White Light LEDs in 2010

65. In the early 2000s, color uniformity in white LEDs could vary with emission angle due to the differences in how UV, near UV, or blue light from the

[13] Paul Sims, *What is Vertical LED Chip Design and Why Is it Superior for Directional Lighting Devices?*, LUMINOUS (2022), https://luminusdevices.zendesk.com/hc/en-us/articles/15557156652429-What-is-Vertical-LED-Chip-Design-and-Why-Is-it-Superior-for-Directional-Lighting-Devices.

LED chip and yellow light from the phosphor layer are emitted and mixed. Because UV, near UV, and blue light tends to emit more directionally from the chip, while the phosphor emits yellow light more isotropically, light is unevenly blended at wider angles (angles off the optical axis). *See, e.g.*, Ex. 1108, 1:39–45; Ex. 2003 ¶3; Ex. 2015 at 249. Additionally, variations in the thickness or distribution of the phosphor coating can exacerbate this issue, causing color shifts with emission angle, where certain angles have a cooler or warmer white in tone.[14] *See, e.g.*, Ex. 1106 ¶4; Ex. 2003 ¶3; Ex. 2014 at 215. Optical elements, like lenses and reflectors, can further impact how the light mixes across different angles, sometimes emphasizing these color non-uniformities. *See generally, e.g.*, Ex. 2017.

66. While white LEDs were still developing, LEDs using a yellow phosphor (such as a YAG:Ce phosphor) would often appear yellow in the OFF state, which may be considered aesthetically unappealing to some consumers. This was because the phosphor material applied to the surface retains its yellowish hue, which in turn is due to its inherent yellow body color and its emission of yellow light due to the excitation from external, environmental light. *See, e.g.*, Ex. 1106, 10:5, 10:33.

67. Additionally, the cost of phosphors for LEDs was notably high, driven by the reliance on rare-earth elements like yttrium and cerium, essential for creating

[14] Bluish whites are described as "cool whites," whereas yellowish whites are described as "warm whites."

the widely used yttrium aluminum garnet doped with cerium ("YAG:Ce" or simply "YAG") phosphor. The growing demand for white LEDs in lighting and display applications coincided with supply constraints and price volatility in the rare-earth market, significantly increasing production costs. *See generally* Ex. 2019. Phosphor synthesis processes were also complex and required stringent quality control to ensure high performance and consistent color rendering, further contributing to expenses. *See, e.g.*, Ex. 2020, 247–48. As a result, manufacturers faced challenges in balancing cost with performance, prompting research into alternative phosphor materials and recycling methods to mitigate costs in subsequent years. If a phosphor has low efficiency, a higher quantity of phosphor is needed to attain a white emission color. *See generally id.* Conversely, if a phosphor has high efficiency, a lower quantity of phosphor is needed. *See generally id.*

68. At the time of the invention, mineral dispersants with a white hue such as titanium oxide, aluminum oxide, and silicon dioxide were added to obscure the color of the phosphor material. *See, e.g.*, Ex. 1109, 17:42–44.

69. In this context, I note that any new technology may initially be considered objectionable for similar aesthetic reasons. For example, trains were considered undesirable when they first appeared. Similarly, solar panels, wind power generators, and water dams have been considered undesirable by some, whereas others considered these new technologies as desirable and their environmental

impact as a non-issue. Indeed, during the relevant time frame, many considered the yellow OFF-state color as a non-issue, and just a matter of getting used to. It is well accepted that "beauty" is judged in the eye of the beholder.

70. There are numerous teachings that the yellow-tinted light emission (lower color temperature, such as 2,800 K) can be more desirable than pure-white light emission (higher color temperature, such as 5,000 K). For example, an article by Mitsunori Miki *et al.* highlights: "Kruithof reports that low color temperatures are more comfortable in lower levels of illuminance, and high color temperatures are more comfortable in higher levels of illuminance."[15] There are numerous consumers who prefer lighting sources having a yellow-tinted light over pure-white light. Even at the present time, old-style or retro-style LED light bulbs are frequently deemed attractive, including the yellowish body color of the filaments in their OFF state. The glass of some of the vintage style light bulbs is even intentionally colored in a yellowish hue (because the yellowish hue is deemed to be attractive). Examples from the Amazon website are:

- "Dimmable, Waterproof, Edison-Style Retro Look, High CRI for Accurate Color Rendering" (Source: Amazon: Sunco 10 Pack 60W

[15] Mitsunori Miki *et al.*, *Maximization of the Average Color Rendering Index of Color Temperature and Illuminance Constraints*, 2013 IEEE INT'L CONF. SYS., MAN, & CYBERNETICS 4583, 4584 (2013).

Vintage LED Edison Bulbs Equivalent 8.5W CRI92 800 Lumens, Dimmable ST64 Filament 5000K Daylight E26 Medium Base Light Bulbs High Brightness Clear Glass Waterproof UL - Amazon.com, https://www.amazon.com/Sunco-Lighting-Dimmable-Waterproof-Restauarant/dp/B07QZYG8W9?th=1) (last accessed on Dec 12, 2024)

- "Classic Vintage Design & Wide Application – Designed based on Thomas Edison's original filament bulb, the vintage retro style making this led bulb also a beautiful decorative light." (Source: Amazon: TJOY 12 Pack Vintage 8W ST58 LED Edison Light Bulbs 60W Equivalent, 800Lumens, 2700K Warm White, Dimmable, E26 Base LED Filament Bulbs, CRI80+, Antique Glass Style for Home, Bedroom, Office, Farmhouse - Amazon.com, https://www.amazon.com/TJOY-Equivalent-Dimmable-Decorative-Filament/dp/B0B5KXBSLP/) (last accessed on Dec 12, 2024)

71. To summarize, yellowish light sources with "Edison-Style Retro Look" and "vintage retro style" can be considered "beautiful," rather than undesirable.

VI. THE '539 PATENT

A. Prosecution History

72. The '539 Patent, entitled "Wavelength Conversion Component with Scattering Particles," was filed on October 13, 2011, issued on December 24, 2013,

and claims priority to Provisional Application No. 61/390,031, which was filed on October 5, 2010. Ex. 1101, codes (22), (45), (54), 1:15–20. It is my understanding that this patent was found novel and nonobvious over prior art that had similar qualities as the prior art asserted in the Petition.

73. The first non-final Office Action issued by the United States Patent and Trademark Office ("USPTO") rejected Claims 1–9, 11-15, 18-20, 22, 23, and 25-28 as being anticipated by U.S. Patent Publication 2002/0180351 ("McNulty," Ex. 2003). The remaining claims were rejected as being obvious over McNulty in view of other prior art references. *See* Ex. 1104, 122–33.

74. In response to the rejections, it is my understanding that the Applicant amended the independent claims to include the limitation "wherein the wavelength conversion component is configured such that in operation a portion of the excitation light comprising blue light is emitted through the wavelength conversion component to contribute to a final visible emission product; wherein the light scattering material scatters the blue light at least twice as much as light generated by the at least one photoluminescent material." Ex. 1104, 151–58. The Examiner issued a final Office Action in response to this amendment and rejected all then-pending claims under 35 U.S.C. § 103(a) over McNulty and maintained the previous obviousness rejections. *See* Ex. 1104, 174-85.

75. It is my understanding that in response to the final Office Action, the Applicant submitted a request for continued examination and amended each of the independent claims to add "blue light having a wavelength of greater than or equal to 440 nm." Ex. 1104, 188-90, 253-66.

76. The amendments caused the Examiner to issue a non-final Office Action that rejected Claims 1, 4-24, and 26-31 under § 103(a) as obvious over U.S. Patent Publication 2001/0000622 ("Reeh," Ex. 2004) in view of McNulty and the previous § 103(a) rejections. Ex. 1104, 312-24.

77. I understand that the Examiner granted an interview with the Applicant. *See* Ex. 1104, 392. In the Applicant's interview summary, the Applicant noted that "Applicants and Examiner agreed that the McNulty reference cannot be combined to disclose the claimed limitation 'wherein the wavelength conversion component is configured such that in operation a portion of excitation light comprising blue light having a wavelength of greater than or equal to 440 nm generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product.'" *Id.* It is my understanding that the Applicant argued that because McNulty's goal "to configure a layer of scattering material to maximize the reflection of excitation radiation back into the phosphor material in order to maximize the light output from the phosphor material," it would frustrate the purpose of McNulty to configure McNulty to "allow[] for a portion of

excitation light to be emitted through to contribute to a final visible emission product." *Id.* For this same reason, the Applicant demonstrated that McNulty teaches away from the '539 Patent application and thus was not combinable with other references. *Id.*, 392-97.

78. It is my understanding that in response to the Applicant's arguments, the Examiner entered a Notice of Allowability, which allowed all of the then-pending claims. In the Notice of Allowability, the Examiner stated that "[t]he prior art fails to teach the presently claimed invention comprising the claimed wavelength conversion component and scattering particles. The reasons for allowance are clearly set forth in Applicant's remarks." Ex. 1104, 400-07.

B. Novel Solution Presented by the '539 Patent

79. The '539 Patent "relates to solid-state light emitting devices [("LEDs")] that use a remotely positioned phosphor wavelength conversion component to generate a desired color of light." Ex. 1101, 1:24–26. The Specification explains that phosphor photoluminescent materials can be "relatively costly, and hence correspond to a significant portion of the costs for producing phosphor-based LED devices," particularly for remote phosphor LED devices, which require "a much greater amount of phosphor." *Id.*, 2:24–41. Additionally, remote phosphor LED devices "are often subject to perceptible non-uniformity in color when viewed from

different angles." *Id.*, 12:13–17. This is consistent with my understanding of the issues facing white light emitting LEDs at the time of filing. *See supra* ¶¶63–71.

80. As discussed above, when an LED device is in the ON state, "the LED chip or die generates blue light and the phosphor(s) absorbs a percentage of the blue light and re-emits yellow light or a combination of" other yellowish colors. Ex. 1101, 1:65–2:3. In the ON state, the "portion of the blue light generated by the LED that is not absorbed by the phosphor combined with the light emitted by the phosphor provides light which appears to the human eye as being nearly white in color." Ex. 1101, 2:3–6. "However, for a remote phosphor device in its OFF state, the absence of the blue light that would otherwise be produced by the LED in the ON state causes the device to have a yellowish, yellow-orange, or orange-color appearance." Ex. 1101, 2:6–10; *see also supra* ¶61. This is because in the OFF state, "light that is produced by the remote phosphor lighting apparatus is based at least in part upon external light (e.g., sunlight or room lights) that excites the phosphor material in the wavelength conversion component, and which therefore generates a yellowish, yellow-orange or orange color in the photoluminescence light." Ex. 1101, 11:5–10. This yellowish light "may be undesirable to the potential purchaser or customer that is seeking a white-appearing light" (Ex. 1101, 11:17–18) "since the device on a store shelf is in its OFF state" (*id.* 2:10–16). Thus, at the time of filing, there was "a need for an improved approach to implement LED lighting apparatuses

which addresses perceptible variations in color of emitted light with emission angle, "without requiring the large quantities of photoluminescent materials (e.g. phosphor materials) that are required in the prior approaches)." Ex. 1101, 2:47–51.

81. The '539 Patent addresses these color issues without requiring large quantities of phosphor materials by utilizing a light scattering material with average particle sizes selected such that the excitation light from the radiation source is scattered relatively more than the light generated by the phosphor. Ex. 1101, 25:57-60. Though light diffusing particles were already known in the art (*see, e.g.*, Exs. 2003, 2004), my understanding is that the purpose of the light diffusing layer in the '539 Patent is to minimize the amount of phosphor needed and thereby reducing the overall costs of the LED device, and improve the spatial uniformity of the light color with emission angle.

82. As depicted in Figure 3 below, the '539 Patent describes a wavelength conversion component 36 that comprises a light transmissive substrate 42 below a wavelength conversion layer 46 that is covered by light diffusing layer 44.

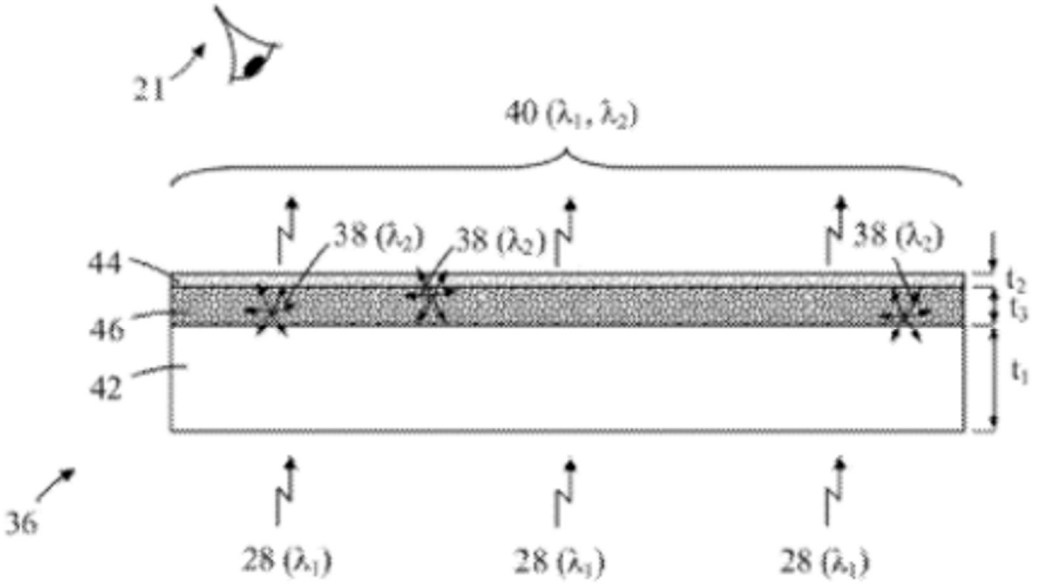


FIG. 3

Ex. 1101, Fig. 3, 10:19–23. As shown above, the light diffusing layer 44 "comprises a uniform thickness layer of particles of a light diffractive material." *Id.*, 8:19–20. When the LED is in the ON state, I understand that the blue light 28 from LED chips moves through the light transmissive substrate 42 and wavelength conversion layer 46, which will either scatter or absorb and reemit the light photons that strike particles that make up the wavelength conversion layer 46. *Id.*, 10:28–47. As a result, both the reemitted photoluminescence light 38 from wavelength conversion layer 46 and the scattered blue light 28 contribute to the overall emission product 40 that is visible to observer 21 in the form of a cool white light. *Id.*, 10:47-11:3. Additionally, the light diffusive layer 44 has a ratio of light diffractive material to binder "in a range [of] 7% to 35% and more preferable in a range of 10% to 20%." *Id.*, 3:54–57.

I understand that this range is aimed at striking a balance "between improving emission color uniformity with emission angle and the decrease in luminous efficacy" (*id.*, 13:19–21), as more light diffractive material "increases the angular emission color uniformity of the device by blending the red, blue and phosphor generated light" (*id.*, 20:49–51).

83. As the '539 Patent explains, "the use of a light diffusing layer having an appropriate particle size and concentration per unit area of the light diffractive material can substantially reduce the quantity of phosphor material" because "the light diffusing layer increases the probability that a photon will result in the generation of photoluminescence light by directing light back into the wavelength conversion layer." Ex. 1101, 3:21–28. Additionally, utilizing a light diffusing layer that directly contacts the wavelength conversion layer "can reduce the quantity of phosphor material required to generate a given color emission product, e.g., by up to 40%" (*id.*, 14:18–24; *see also id.*, 3:29–32), while also improving the color uniformity of light emitted from the LED (*see id.*, 12:19–22). Thus, "it will be much less costly to manufacture lighting apparatuses that employ such wavelength conversion components, particularly for remote phosphor lighting devices." *Id.*, 14:15–17.

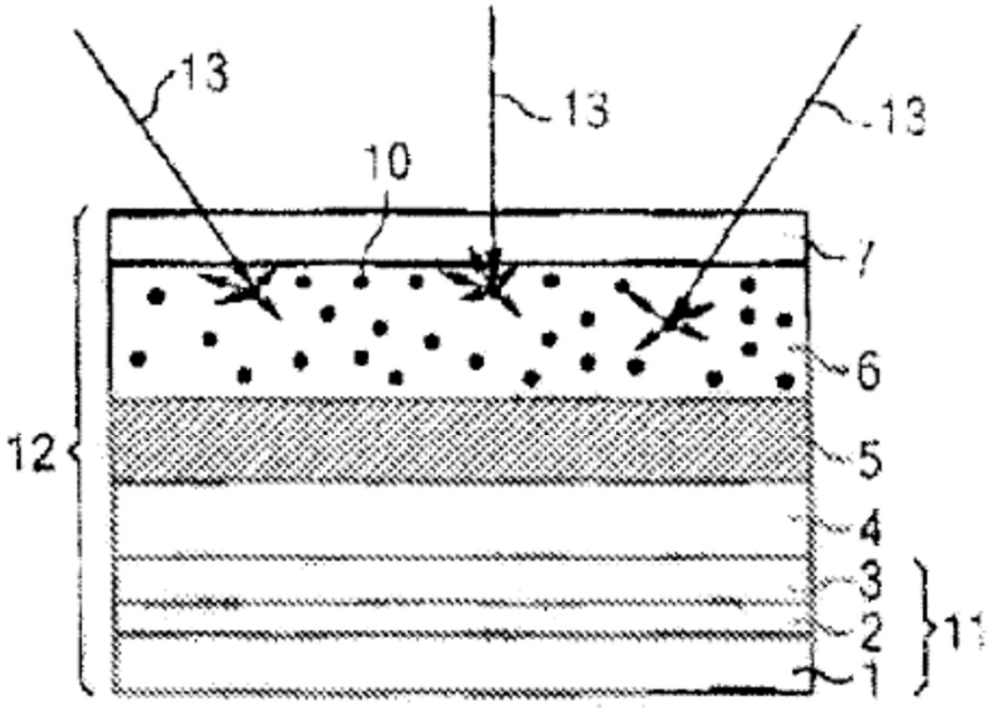
VII. OVERVIEW OF CITED REFERENCES

A. Krummacher (Exhibit 1107)

84. U.S. Patent Publication No. 2008/0079015 ("Krummacher"), entitled "Optoelectronic Component Having a Luminescence Conversion Layer" was filed on September 18, 2007, by Benjamin Krummacher and published on April 3, 2008. *See* Ex. 1107, codes (10), (22), (43), (54), (75). The application claims priority to German Patent Application No. 10 2006 046 296.3 filed on September 29, 2006. *Id.* ¶1.

85. It is my understanding that Krummacher is directed to "an improved optoelectronic component having a luminescence conversion layer, in which areas covered by the luminescence conversion layer give an improved color impression in the off state" in large area lighting units. Ex. 1107 ¶¶3, 5.

FIG 2



Id., Fig. 2. Krummacher's Figure 2 (shown above) depicts an optoelectronic component in the OFF state with an active layer 2 that emits blue light. *Id.* ¶¶31–32. The active layer 2 is covered by a layer sequence 11, which comprises additional layers 2 and 3 and a passivating layer 4 that insulates layer sequence 11 from environmental influences. *Id.* ¶33. A luminescence conversion layer 5, which is made by a conversion material (e.g., a phosphor) that converts some of the radiation emitted by active layer 2 into radiation with a longer wavelength, sits above passivating layer 4. *Id.* ¶36. Krummacher states that in one particular embodiment, "a light-scattering translucent layer 6 contains light-scattering particles 10,

which . . . serve to scatter environmental light 13 striking the optoelectronic component from the outside." *Id.* ¶39. The light-scattering translucent layer 6 contains light-scattering particles 10 with sizes, distributions, and materials that cause "the surface of light-scattering translucent layer 6 appears white." *Id.* ¶41. As a result, "the luminescence conversion layer 5 is advantageously prevented from exhibiting a yellowish hue, in the off state" "due to stimulation of the luminescence conversion materials by environmental light 13 incident from the outside." *Id.*

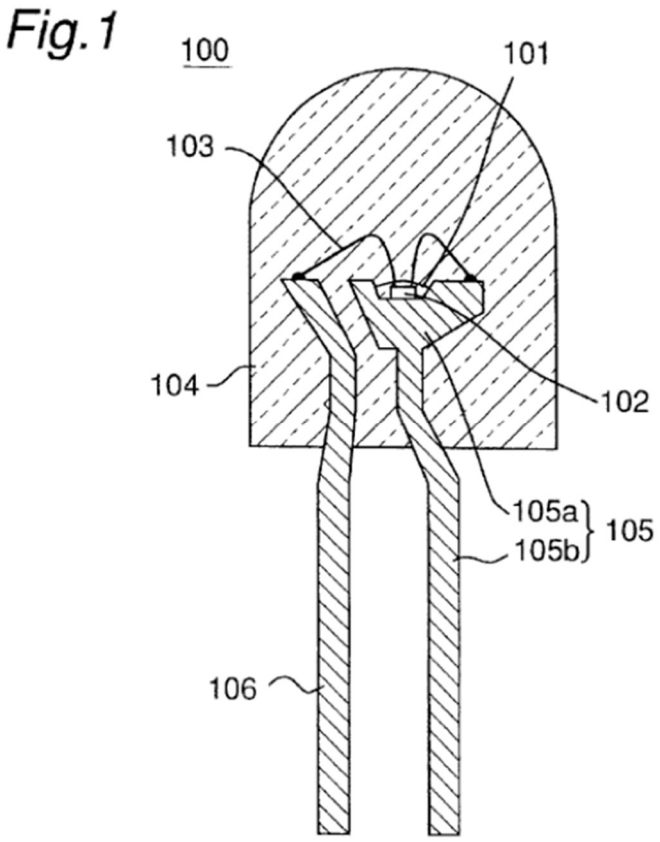
86. In my opinion, Krummacher appears to be primarily directed to LEDs in a vertical chip configuration based on the described embodiments and applications. Krummacher generally shows a vertical geometry with contacts above and below the active region. As Krummacher states: "The active layer 2 is, for example, surrounded in a layer sequence 11 by additional layers 1, 3, which serve in particular to electrically contact active layer 2." Ex. 1107 ¶33 Accordingly, the contact layers 1 and 3 are above and below the active layer 2. This configuration is to be understood as a vertical current flow geometry.

B. Shimizu (Exhibit 1110)

87. U.S. Patent No. 6,069,440 ("Shimizu"), entitled "Light Emitting Device Having a Nitride Compound Semiconductor and a Phosphor Containing a Garnet Fluorescent Material" was filed on April 28, 1999, by Yoshinori Shimizu et al. and issued on May 30, 2000. *See* Ex. 1110, codes (10), (22), (43), (54), (75). The

patent claims priority to U.S. Patent Application No. 08/902,725 filed on July 29, 1997. *Id.*, 1:6–7.

88. My understanding is that Shimizu aims to limit "the degradation of characteristics during long period of use and reduce deterioration due to light of high intensity emitted by the light emitting component as well as extraneous light . . . , thereby to provide a light emitting device which experiences extremely less color shift and less luminance decrease" in industrial lighting applications such as LED displays, back light sources, traffic signals, and trailway signals. Ex. 1110, 1:12–14, 3:54–61. As depicted below, Shimizu appears to accomplish this by utilizing a "light emitting component [102] made of a nitride compound semiconductor" that is "capable of emitting light with high luminance" in addition to a phosphor contained in a coating resin 101 and/or molding material 104 that has "excellent resistance against light so that the fluorescent properties thereof experience less change even when used over an extended period of time while being exposed to light of high intensity."



Id., Fig. 1, 3:46–54, 8:35–52. The phosphor achieves this by containing "a garnet fluorescent material comprising 1) at least one element selected from the group consisting of Y, Lu, Sc, La, Gd, and Sm, and 2) at least one element selected from the group consisting of Al, Ga and In, and being activated with cerium." *Id.*, 3:32–37. I understand that Shimizu's coating material 101 or molding material 104 may also include a dispersant such as titanium dioxide that "gives a milky white color" to aid in obscuring the color of the fluorescent material and improving the color mixing performance." *Id.*, 17:25–35. When the light emitting component 102 is installed in a cup 105a that "is filled with the fluorescent material, light emitted by

the fluorescent material is, even if isotropic, reflected by the cup in a desired direction and therefore erroneous illumination due to light from other light emitting diode mounted nearby can be prevented." 15:46–52. Shimizu also explains that erroneous illumination may include "a phenomenon as other light emitting diode mounted nearby appearing as though lighting despite not being supplied with power." *Id.*, 17:52–55. Shimizu appears to me to be primarily directed to DIP and lead-frame SMD LEDs based on the described embodiments and applications.

C. Stokes (Exhibit 1108)

89. U.S. Patent No. 6,791,259 ("Stokes"), entitled "Solid State Illumination System Containing a Light Emitting Diode, a Light Scattering Material and a Luminescent Material" was filed on August 22, 2000, by Edward Brittain Stokes et al. and issued on September 14, 2004. *See* Ex. 1108, codes (10), (22), (43), (54), (75). The patent claims priority to U.S. Patent No. 6,429,583 filed on November 30, 1998. *Id.*, 1:6–7.

90. I understand Stokes to be directed to obtaining "a significant decrease in the halo and/or penumbra effects" in LED lights used in commercial applications such as automotive, display, and safety/emergency uses. Ex. 1108, 1:19–20, 3:49–51. As Stokes explains, the halo effect occurs when there is separation between the directional blue light emitted from the LED chip and yellow light emitted from the phosphor in all directions. *Id.*, 1:39–42. Thus, Stokes notes that the light may appear

bluish-white when viewed straight on, yellow when viewed at an angle, or blue surrounded by a yellowish halo when the LED is on a flat surface depending on the angle of the viewer. *Id.*, 1:42–50. Further, Stokes describes the penumbra effect, which "is a non-uniform intensity effect" that "causes the white LED lamp emission to appear brighter at the center than at the edges" due to the directional nature of the LED emission. *Id.*, 1:51–59. The edges appear less white "due to the stray and/or reflected LED light and the phosphor emission excited by such LED light." *Id.*, 1:59–62. These effects "cause the white LED lamps to fail to meet applicable commercial quality standards required for illumination devices." *Id.*, 1:62–65. Thus, I understand that Stokes overcomes these issues by placing a layer 56 of radiation scattering material between a radiation source, such as an LED chip 53, and a luminescent material (e.g., phosphor) 55 as shown below:

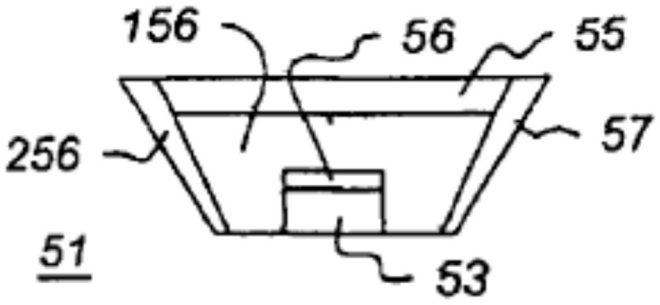


fig 7

Id., Fig. 7, 3:57–61, 7:41–46. Further, Stokes also discloses LEDs that include an encapsulation layer 156 that sits between the LED chip 53 and luminescent material 55 and an additional layer 256 of radiation scattering material on the sidewalls of a cup containing the LED. *Id.*, 7:46-52. Based on the described embodiments and applications, it is my opinion that Stokes is directed to DIP and lead-frame SMD LEDs.

D. Hussell (Exhibit 1111)

91. U.S. Patent Publication No. 2010/0124243 ("Hussell"), entitled "Semiconductor Light Emitting Apparatus Including Elongated Hollow Wavelength Conversion Tubes and Methods of Assembling Same" was filed on November 18, 2008, by Christopher P. Hussell and John Adam Edmond and published on May 20, 2010. *See* Ex. 1111, codes (10), (22), (43), (54), (75).

92. I understand Hussell to disclose a way to "integrate a semiconductor light emitting device with wavelength conversion material to provide a semiconductor light emitting apparatus" to convert light from a single-color LED to white light by orienting the LED "to emit light inside [an] elongated hollow wavelength conversion tube to impinge upon the elongated wavelength conversion tube wall and the wavelength conversion material dispersed therein" in conventional incandescent replacement applications. Ex. 1111 ¶¶3, 7, 8. As illustrated in Figure 1B of Hussell below, elongated wavelength conversion tube 110 "comprises an

elongated wavelength conversion tube wall 112 having wavelength conversion material 114 uniformly or non-uniformly dispersed therein."

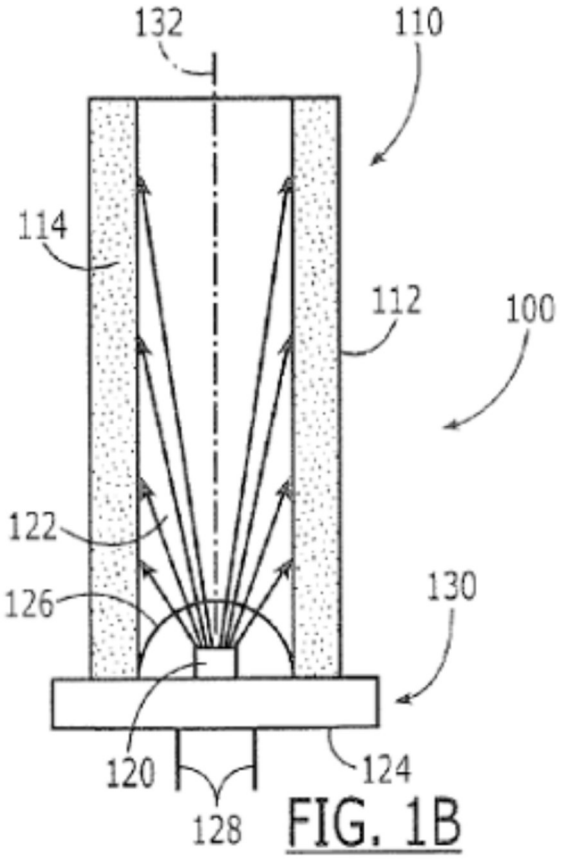


FIG. 1B

Id., Fig. 1B, ¶32. Hussell states that the wavelength conversion material 114 refers to "any material that absorbs light at one wavelength and re-emits light at a different wavelength, regardless of the delay between absorption and re-emission and regardless of the wavelengths involved," such as phosphor particles. *Id.* ¶6. The semiconductor LED 120 "is oriented to emit light 122 inside the elongated hollow wavelength conversion tube 110 to impinge upon the elongated wavelength conversion tube wall 112," where "the tube wall 112 defines a tube axis 132, and the

semiconductor light emitting device 120 is configured to emit light 122 generally symmetrically about an emission axis and is oriented such that the emission axis is generally coincident with the tube axis 132." *Id.* ¶32.

93. I note that Hussell also teaches an elongated hollow wavelength conversion tube 110 with an elongated tube wall 112 textured on the inner or outer surfaces that "may enhance scattering of light" as shown below:

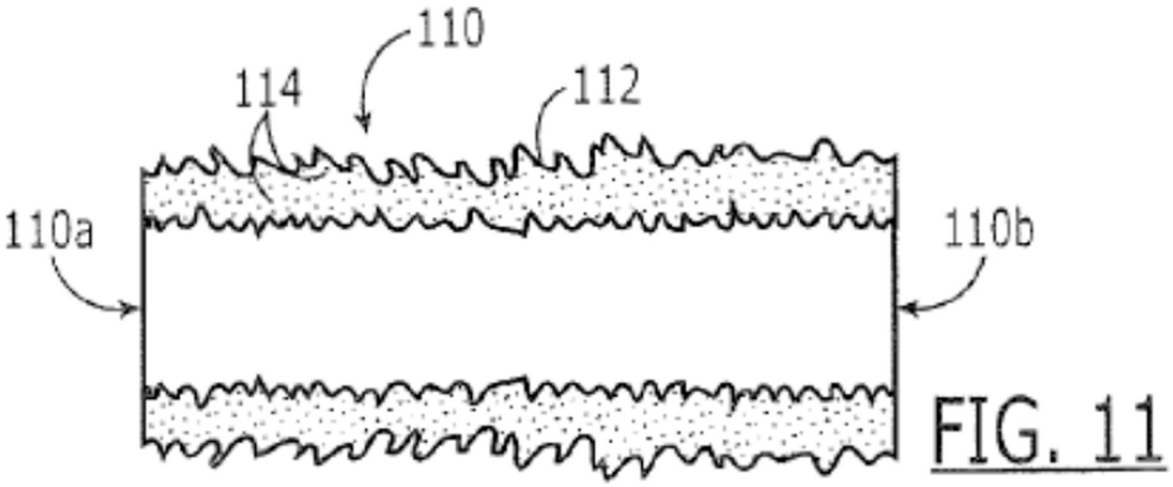


FIG. 11

Ex. 1111, Fig. 11A, ¶48.

E. Van Woudenberg (Exhibit 1120)

94. International Patent Publication No. WO 2008/044171 ("Van Woudenberg"), entitled "LED Based Luminaire and Lighting Device" was filed on October 4, 2007, by Roel Van Woudenberg et al. and published on April 17, 2008. *See* Ex. 1120, codes (10), (22), (43), (54), (75). The application claims priority to European Patent Application No. 06122131.3 filed on October 11, 2006. *Id.* at code (30).

95. I understand that Van Woudenberg is directed to a phosphor-coated LED ("pc-LED") package that "is controlled to appear neutral white in the functional OFF state of the lighting device" in "auxiliary lights in mobile phones or down-light units." Ex. 1120, Abstract, 2:9-11. Because it is a "disturbing feature" for pc-LEDs to have a "distinguished yellowish appearance" in their functional off-state (*Id.*, 1:27-28), Van Woudenberg utilizes "residual current running through the pc-LED in the functional off state of the lighting device" to cause "the tiny amount of light produced by the pc-LED [to] outshine[] the reflected ambient light" (*Id.*, 2:19-21). As a result, the functionally off pc-LED will have "a neutral white color to the human eye." *Id.*, 2:22-23. I understand Van Woudenberg to be primarily directed to DIP and SMD LEDs based on the described embodiments and applications.

VIII. OPINIONS

96. As described in more detail below, it is my opinion that none of the grounds asserted by the Petitioners render the Challenged Claims unpatentable.

A. The Prior Art Does not Render Obvious "the light scattering material has an average particle size that is selected such that the light scattering material will scatter excitation light from a radiation source relatively more than the light scattering material

will scatter light generated by the at least one photoluminescence material"

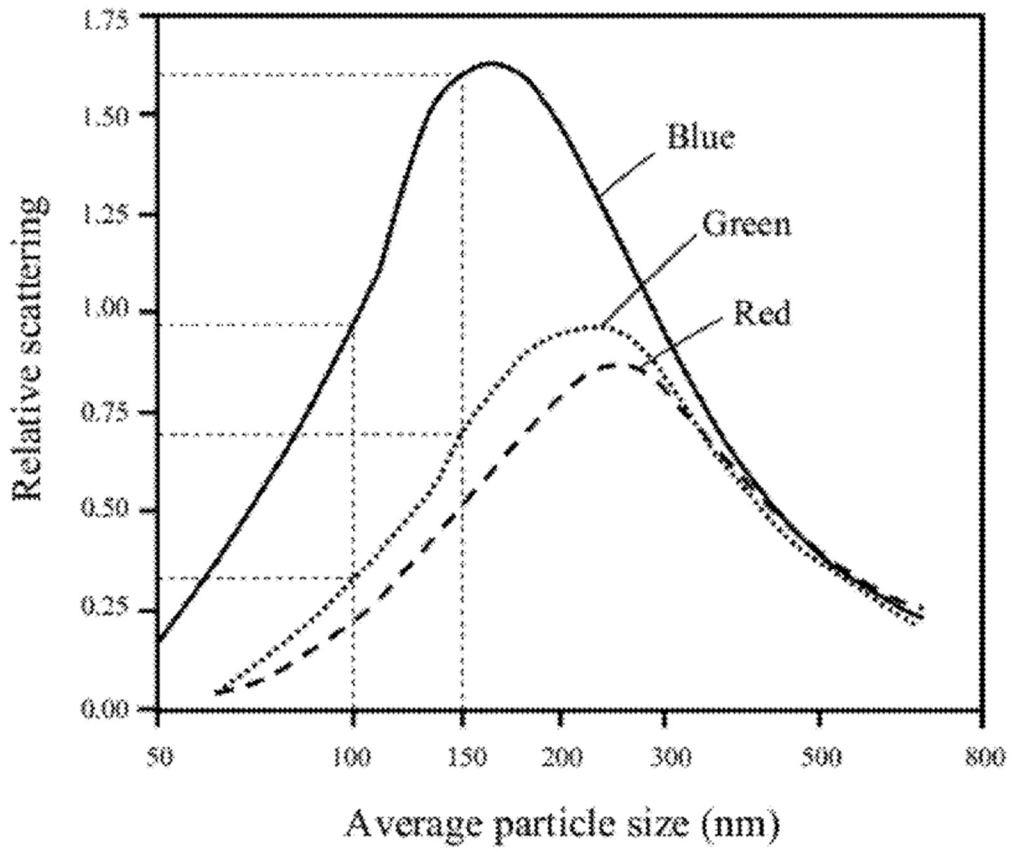
1. Ground 1 Fails in Part Because Petitioners Fail to Show that the Prior Art Teaches the Claimed "average particle size"

97. I understand that Petitioners' allege that Krummacher and/or Stokes allegedly teach the claimed "average particle size" of independent claims 1 and 18. In particular, the Petition cites to Krummacher at paragraph 39 and Stokes at lines 7:1-4, 7:17-26. Pet. at 24-28, 49. Krummacher at paragraph 39 indicates that "Particularly suitable are particles of TiO_2 or Al-O, preferably having a radius of between 50 nm inclusive and 1000 nm inclusive." Ex. 1107 ¶39. For Stokes, Petitioners only point to lines 7:1-4 ("the radiation scattering particles have a size such that the particles preferentially scatter blue or UV LED light as compared to yellow, green, red or white light from the luminescent material") and 7:17-26 (discussing advantages of a particular particle size) in support of their argument regarding disclosure of "average particle size". Pet. at 24-28, 49. Ex. 1108, 7:1-4, 7:17-26. I disagree that either reference teaches the claimed *average* particle size.

98. With respect to Krummacher, Petitioners conflate a disclosure of a broad range of particle sizes with an *average* particle size. Disclosure of one does not teach the other. Krummacher discloses particles "having a radius of between 50 nm inclusive and 1000 nm inclusive." This is a broad range of particle sizes that

does not specify any particularly beneficial sizes within that range, or the benefits that such sizes would provide. It says nothing of the *average* particle size or the distribution of particle sizes within that range, which would affect the average particle size.

99. As further recited in the claim language, the light scattering material must "scatter[] the blue light at least twice as much as light generated by the at least one photoluminescence material." Ex. 1101, cls. 1, 18. Utilizing the teachings of Figure 10 in the '539 patent, if the scattering material has a "radius of between 50 nm inclusive and 1000 nm inclusive" blue light will not be scattered preferentially. Indeed, even if we assume that this disclosure is the average particle size, it is off the charts of Figure 10. A particle's size, or diameter, is twice its radius. Accordingly, the particle diameters taught by Krummacher range between 100 nm inclusive and 2000 nm inclusive. The average of this range is ½ × (100 nm + 2000 nm) = 1050 nm, outside the range considered in Figure 10 and devoid of preferential blue light scattering.



Ex. 1101, Fig. 10. If the particles have a radius that ranges from 50 nm to 1000 nm "inclusive" there will be no preferential scattering of blue light. To scatter blue light preferentially, a much narrower distribution is required, as taught by the '539 patent. Accordingly, I disagree with petitioners that "Krummacher renders obvious this claim element." *See* Pet. at 26.

100. Furthermore, I disagree with petitioners that "Stokes *explicitly* discloses the selection of an average particle size." Pet. at 27 (emphasis added). Stokes at best suffers from the same deficiency discussed above with Krummacher. In particular, none of the cited portions of Stokes that Petitioners rely upon for this

claim element discloses any particle size. *See* Pet. at 24-28, 49. Ex. 1108, 7:1-4, 7:17-26. As such, I disagree that Stokes *explicitly* discloses this claim element.

2. Ground 2 Fails in Part Because Petitioners Fail to Show that the Prior Art Teaches the Claimed "average particle size"

101. I understand that Petitioners incorporate their analysis of Krummacher and Stokes in support of Ground 2, challenging the "average particle size" limitation of claims 18 and 28. *See* Pet. at 65-69. I understand that Petitioners have not identified any other reason that the art cited in Ground 2 teaches the claimed "average particle size." Accordingly, I incorporate my analysis provided above regarding the disclosures of Krummacher and Stokes regarding the claimed "average particle size" limitation. *See supra* ¶¶97-101.

B. A POSITA Would Not Have Any Meaningful Motivation to Combine or a Reasonable Expectation of Success

102. As described in more detail below, it is my opinion that a POSITA would not have a meaningful motivation to combine the references cited in the Petition and would not have had a reasonable expectation that combining such references would lead to success.

1. A POSITA Would Not Have Been Motivated to Combine Krummacher in view of Shimizu and Stokes

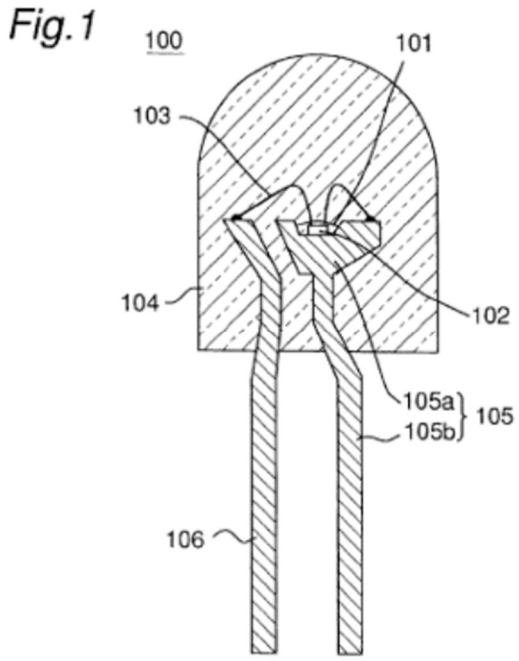
103. In my opinion, there is no motivation to combine Krummacher, Shimizu, and Stokes with a reasonable expectation of success.

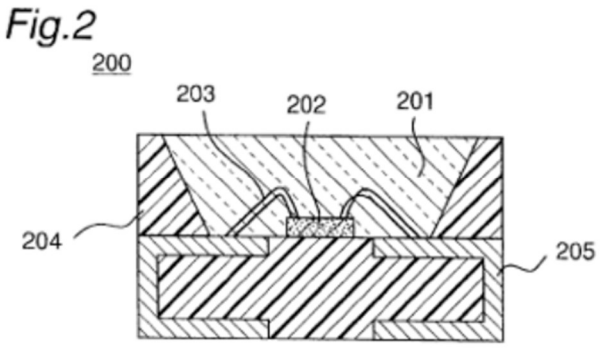
104. It is my understanding that Petitioners contend that "[a] POSA would have been motivated to use a blue-light LED chip like that disclosed by Stokes and Shimizu in a conventional white-light LED light source called for by Krummacher." Pet. 31 (citing Ex. 1102 ¶135). Because "Shimizu, in particular, is cited by both the '539 patent and the prior art as an example of a conventional white-light LED light source containing a blue-light LED," I understand Petitioners to allege "it would have been obvious to look to Shimizu and Stokes for details of the conventional white-light LED light source used in Krummacher." *Id.* However, it is my understanding that Petitioners fail to explain why a POSITA would want to import a blue light LED chip from Stokes or Shimizu into the Krummacher art. *Id.* I understand that Petitioners also claim that a POSITA would have had a reasonable expectation of success in combining these references "because they would simply be using the conventional white light LED disclosed in the prior art as directed by Krummacher." *Id.* "In other words," Petitioners state, "not only does Krummacher suggest the use of an LED like that disclosed in Stokes and Shimizu, doing so would have been the simple substitution of one known element for another to obtain predictable results and well within the skill of a POSA." *Id.* (citing Ex. 1102 ¶¶135-36). I disagree.

105. As I understand, generic assertions are not enough to establish a motivation to combine because mere demonstration that a reference may be

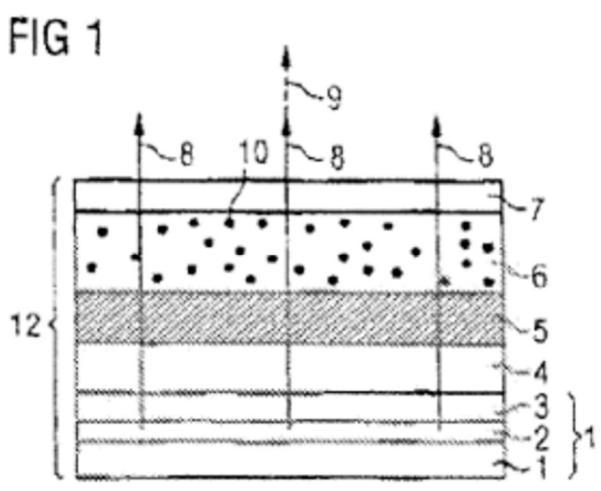
analogous art is insufficient to show motivation to combine. I do not see any evidence to support Petitioners' claims that the combination "would have been the simple substitution of one known element for another to obtain predictable results." Pet. 31.

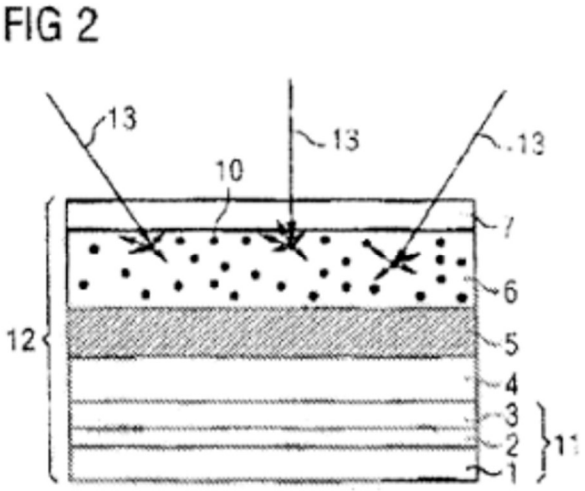
106. Additionally, I understand Krummacher, Shimizu, and Stokes to be different applications of LEDs. Krummacher appears to relate mostly to vertical chip configurations utilized for large area lighting units (*see* Ex. 1107 ¶3), Shimizu involves DIP and lead-frame SMD LEDs in industrial applications such as LED displays, back light sources, traffic signals, trailway signals, etc. (*see* Ex. 1110, 1:12–14), and Stokes involves DIP and SMD LEDs in commercial applications such as automotive, display, and safety/emergency uses (*see* Ex. 1108, 1:19–20). These require different packaging approaches (*see supra* ¶¶51–62), and I understand that Petitioners have not provided how a POSITA would incorporate the DIP or SMD LEDs of Shimizu or Stokes into Krummacher beyond "simple substitution." As discussed previously, DIP and SMD LEDs as in Shimizu utilize bond wires 103, 203 that face upward as shown here:





Ex. 1110, Figs. 1, 2. Krummacher's vertical flow chip LED is not disclosed as having wires, and does not require the housing seen in DIP and SMD LEDs:

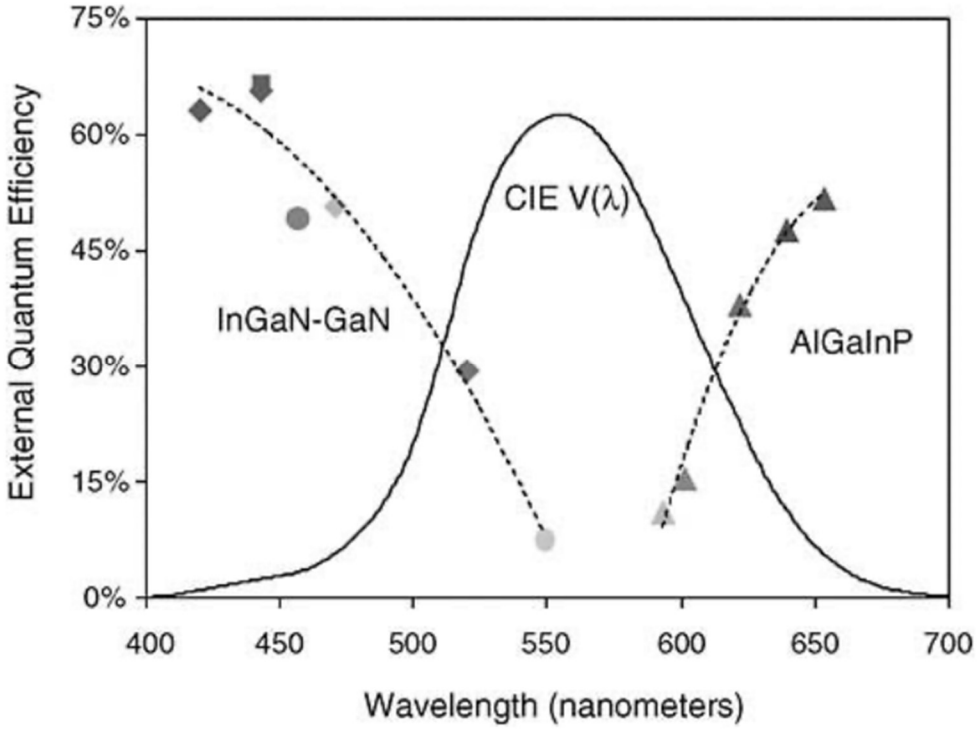




Ex. 1107, Figs. 1, 2. Because these LEDs require different packaging considerations, in my opinion, a POSITA would not find that it would be a "simple substitution" to

use Shimizu's LED with the more efficient chip in Krummacher. *See supra* ¶¶51–62.

107. Additionally, it is my opinion that nothing in the Petition, Dr. Doolittle's expert declaration, Krummacher, Shimizu, or Stokes would lead a POSITA to use wavelengths longer than 440 nm. Though blue light is generally emitted in the range of 380 to 480 nm, the quantum efficiency of blue LEDs decreases with the longer wavelengths. *See supra* ¶¶49-50; Ex. 2014 at 86–87, 222, 292–300, 313–15. As discussed above, external quantum efficiency is the number of photons that escape from the LED chip per number of electrons injected. *See supra* ¶50 (citing Ex. 2014 at 86–87). Blue light emitting Indium Gallium Nitride ("InGaN") semiconductors decrease in external quantum efficiency as emitted light wavelengths lengthen:



Ex. 2013 at 70. Inspection of the figure above shows that the external quantum efficiency continuously decreases when going from shorter wavelengths (e.g. 400 nm, efficiency about 70%) to longer wavelengths (e.g., 500 nm, efficiency about 30%). In the green spectral range (~525 nm) the quantum efficiency is very low. This fact is occasionally referred to as the "green gap."

108. For this reason, a POSITA would not have sought to implement the claimed wavelength range (i.e., greater than or equal to 440 nm). Choosing this wavelength range would actually decrease the quantum efficiency of the primary light source that is used to excite the phosphor. Thus, a POSITA would actually be deterred from implementing the claimed wavelength range.

109. In my opinion, a POSITA would generally be interested in LEDs emitting light at shorter wavelengths near to the UV-to-visible boundary where the quantum efficiency is higher because the LED is more effective at converting electrical input into light particles at this wavelength. I understand that Petitioners offer no explanation as to why a POSITA would find it obvious to use wavelengths longer than 440 nm if the quantum efficiency would decrease. It is my understanding that a rationale to combine must not rely on hindsight, but must imply a motivation to pick out those references and combine them to arrive at the claimed invention. I do not believe the Petitioners have achieved the '539 Patent by combining Krummacher with Shimizu or Stokes.

110. It is also important to note that while quantum efficiency decreases when going to longer wavelengths (*e.g.*, from 400 nm to 500 nm), the luminous efficacy increases when going to longer wavelengths (*e.g.*, from 400 nm to 500 nm). However, a POSITA would understand that quantum efficiency is more relevant because approximately 90% of the primary light photons (from the LED chip) are used to excite the phosphor and only 10% of the primary light photons (from the LED chip) are transmitted through the phosphor. *See, e.g.*, Ex. 2023, ¶45 ("The primary light (blue or UV light from the LED) must be absorbed by the phosphor with only a small percentage (typically about 10%) of the primary light escaping unabsorbed and because the secondary light emitted from the phosphor must escape the layer without further absorption, the thickness of the phosphor is important: thick enough to absorb the majority of the primary light and thin enough that some of the primary light and most of the secondary light escapes."). Because approximately 90% of the primary light is absorbed (and does not reach the human eye), the quantum efficiency and not the luminous efficacy is the relevant metric to a POSITA.

111. Thus, it is my opinion that a POSITA would not have been motivated or had a reasonable expectation of success to arrive at the present invention by combining Krummacher with Shimizu and Stokes.

2. A POSITA Would Not Have Been Motivated to Combine Hussell, with Krummacher, Stokes, or Van Woudenberg

112. In my opinion, Petitioners have not established that a POSITA would have been motivated to combine Hussell, with Krummacher, Stokes, and Van Woudenberg to arrive at the '539 Patent. It is my understanding and belief that Petitioner's arguments for combining these references are brief and conclusory. I understand that Petitioner's only argument for motivation to combine these references appear to be that "[t]he teachings in [Hussell and Van Woudenberg] also demonstrate why a person skilled in the art would be motivated to modify the 'wavelength conversion tube' in Hussell to create an off-state white appearance." Pet. 61, 62-65. I understand that this is not enough to establish a motivation to combine.

113. Additionally, as I previously opined, Hussell, Krummacher, Stokes, and Van Woudenberg are all different applications of LEDs. Hussell involves conventional incandescent replacement applications (*see* Ex. 1111 ¶3), Krummacher appears primarily directed to vertical chip configurations utilized in large area lighting units (*see* Ex. 1107 ¶2), Stokes involves DIP and SMD LEDs in commercial applications such as automotive, display, and safety/emergency uses (*see* Ex. 1108, 1:19–20), and Van Woudenberg involves "auxiliary lights in mobile phones or down-light units" (*see* Ex. 1120, Abstract). I understand that Petitioners offer nothing

meaningful to address how a POSITA would overcome these differences to apply Krummacher's light-scattering translucent layer in a vertical chip configuration to Hussell's incandescent replacement application, Stokes' DIP and SMD LEDs for commercial applications, or Van Woudenberg's auxiliary lights in DIP and SMD LEDs beyond generic "laminat[ing] or glu[ing]." Pet. 64 (quoting Ex. 1107 ¶¶42–43). As I previously opined, a POSITA would not find the packaging requirements for each structure and application to be easy to combine with a reasonable expectation of success. *See supra* ¶¶51–62.

114. Furthermore, Krummacher shows that both, a light-scattering layer containing light-scattering particles (Krummacher's first embodiment, Figure 2) and a light-scattering layer having a light-scattering surface (Krummacher's second embodiment, Figure 3) improve the OFF state white appearance. Accordingly, there is no need and no motivation to include a light-scattering layer containing light-scattering particles in Hussell who already has a light-scattering layer having a light-scattering surface.

115. As discussed above, *supra* ¶¶49-51, 108-11, the quantum efficiency of blue light LEDs decreases with longer wavelengths. Again, I understand that Petitioners do not offer any explanation as to why a POSITA would combine Krummacher with lower efficiency LEDs like Stokes or Van Woudenberg. It is my

understanding that this is using impermissible hindsight to make an obviousness argument.

116. Thus, it is my opinion that a POSITA would not have been motivated or had a reasonable expectation of success to arrive at the present invention by combining Hussell, with Krummacher, Stokes, and Van Woudenberg.

C. Secondary Considerations

117. I understand that additional "secondary considerations" may play a factor in determining whether or not claims are obvious. My understanding is that such secondary considerations may include: (1) a long felt but unsolved need; (2) commercial success; (3) unexpected results; (4) industry praise; (5) licensing; and (6) copying by others. I have seen various forms of secondary considerations that support a conclusion of non-obviousness.

118. Patent Owner's white filament products offered through third party retailers have received industry praise. For example:

- Exhibit 2029, which is a website screenshot available at https://www.homedepot.com/collection/Lighting/Feit-Electric-White-Filament-LED-Light-Bulbs/Family-325161932, indicates that "These clear glass LED bulbs with exposed white filament offer a sleek aesthetic that easily assimilates into any home décor style. Where traditional clear glass LED bulbs stand out with their yellow filaments,

these bulbs contain a discreet, white-colored core that blends in better, while still providing a smooth glow meant for chandeliers, pendants, and lamps without shades."

- Exhibit 2030, which is a website screenshot available at https://www.candlepowerforums.com/threads/feit-led-filament-bulb-with-white-filaments.481479/, indicates that "[t]he white filaments make the bulb look less obtrusive when it's off - it kind of blends into the surroundings. Interesting concept."
- Exhibit 2031, which is a screenshot of a website available at https://ir.homedepot.com/news-releases/2024/10-09-2024-130219023, indicates that Feit Electric won a Home Depot 2024 Innovation Award for its "White Filament LED Bulbs."

119. I also understand that various consumers have reacted positively to Patent Owner's white filament products. *See, e.g.*, Ex. 2032 (available at https://www.instagram.com/p/DAQ4XSqPFu6/); Ex. 2033 (available at https://www.instagram.com/p/C-0Ff05OhZV/); Ex. 2034 (available at https://www.instagram.com/p/C8wxt4GJidm/).

120. I also understand that white filament products may be sold at a higher price point than similar yellow-filament products. *Compare* Ex. 2035 (available at https://www.homedepot.com/p/Feit-Electric-60-Watt-Equivalent-ST19-Dimmable-

White-Filament-Clear-Glass-E26-Vintage-Edison-LED-Light-Bulb-Soft-White-2700K-4-Pack-ST1960927CAWFILHDRP4/324060831) *with* Ex. 2036 (available at https://www.homedepot.com/p/Feit-Electric-60-Watt-Equivalent-ST19-Dimmable-Straight-Filament-Clear-Glass-E26-Vintage-Edison-LED-Light-Bulb-Soft-White-4-Pack-ST1960-CL927CAHDRP-4/313402153).

121. Additionally, I understand that consumers have expressed a need for white filament products over the traditional yellow filament counterparts. *See* Ex. 2037 (available at https://www.reddit.com/r/Lighting/comments/hqirs0/do_white_filament_led_edison_bulbs_exist/).

122. I understand that any secondary consideration must bear a nexus to the claimed invention. It is my opinion that all of the examples referenced above are tied to the "white filament" aspect of the products, which is due in part to the claimed light scattering material in the '539 patent.

IX. CONCLUSION

123. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and 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.

Date: July 15, 2025

By:

E. Fred Schubert