

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 No. IPR2025-00698
Patent No. 8,614,539

**DECLARATION OF WILLIAM A. DOOLITTLE, PH.D.
REGARDING THE '539 PATENT**

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EXHIBIT LIST

No.	Description
EX1101	U.S. Patent No. 8,614,539
EX1102	Declaration of William A. Doolittle, Ph.D. re the '539 patent
EX1103	Curriculum Vitae of William A. Doolittle, Ph.D.
EX1104	File History for U.S. Pat. Appl. No. 13/273,215 (excl. references)
EX1105	U.S. Pat. Pub. No. 2009/0057699 ("Basin-2007")
EX1106	U.S. Pat. Pub. No. 2007/0045761 ("Basin-2005")
EX1107	U.S. Pat. Pub. No. 2008/0079015 ("Krummacher")
EX1108	U.S. Patent No. 6,791,259 ("Stokes")
EX1109	U.S. Patent No. 5,998,925 ("Shimizu-APA")
EX1110	U.S. Patent No. 6,069,440 ("Shimizu")
EX1111	U.S. Pat. Pub. No. US2010/0124243 ("Hussell")
EX1112	DuPont: Polymers, Light and the Science of TiO ₂ (2007)
EX1113	DuPont: Titanium Dioxide for Coatings (2007)
EX1114	Erik S. Thiele and Roger H. French, "Computation of Light Scattering by Anisotropic Spheres of Rutile Titania", Adv. Mater. 1998, 10, No. 15
EX1115	Erik S. Thiele and Roger H. French, "Light-Scattering Properties of Representative, Morphological Rutile Titania Particles Studied Using a Finite-Element Method", J. Am. Ceram. Soc., 81 [3] 469–79 (1998)
EX1116	Robert W. Johnson, Erik S. Thiele, And Roger H. French, "Light-scattering efficiency of white pigments: an analysis of model core-shell pigments vs. optimized rutile TiO ₂ ", TAPPI JOURNAL, November 1997, Vol. 80(11)
EX1117	William D. Ross, "Theoretical Light-Scattering Power of TiO ₂ and Microvoids", Ind. Eng. Chem., Prod. Res. Develop., Vol. 13, No. 1, 1974
EX1119	U.S. Patent No. 8,547,010 ("Jagt")
EX1120	Int'l Pat. Pub. No. WO 2008/044171 A2 ("Van Woudenberg")
EX1123	Sudhakar Madhusoodhanan and Devdatt S. Nagvekar, "UV Curable High Opacity Ink Jettable White Ink", RadTech e 5 2006

No.	Description
	Technical Proceedings (2006)
EX1124	U.S. Pat. Pub. No. 2011/0001151 (“Toquin”)

I, William A. Doolittle, Ph.D., of Atlanta, Georgia, USA, hereby declare as follows.

I. INTRODUCTION

1. I am over the age of eighteen and otherwise competent to make this declaration.

2. I have been retained by Radulescu LLP on behalf of Savant Technologies LLC d/b/a GE Lighting, Elong International USA Inc., and Xiamen Longstar Lighting Co. Ltd. to provide an analysis of the scope and content of U.S. Patent No. 8,614,539 (“the ’539 patent”) (EX1101). My analysis relates to claims 1-11, 18-20, 23-25, and 28 of the ’539 patent.

3. This declaration summarizes the opinions I have formed to date. I reserve the right to modify my opinions, if necessary, based on further review and analysis of information that I receive after the filing of this declaration, including in response to positions taken by Patent Owner or their experts that I have not yet seen.

II. EXPERIENCE AND QUALIFICATIONS

4. I have summarized in this section my educational background, career history, publications, and other relevant qualifications.

5. I am the Joseph M. Pettit Professor in the School of Electrical and Computer Engineering at Georgia Institute of Technology (“Georgia Tech”). A

complete history of my employment history, honors and awards, and scholarship can be found in my *curriculum vitae*, submitted as EX1103 with this declaration.

6. I received my B.E.E. with highest honors in Electrical Engineering in 1989 from Georgia Tech. I then received a Ph.D. in Electrical and Computer Engineering in 1996 from Georgia Tech.

7. After working as a research engineer for the university, I began my career as a professor in the year 2001, where I progressed from assistant professor, to associate professor, and finally to a full professorship in 2012. I now hold an endowed professorship at the university as the Joseph M. Petit Professor of Georgia Tech.

8. I have worked with, studied, and taught about III-Nitride materials, LEDs and phosphors in particular for more than 25 years. In addition, I have taught classes and been a world leader in research conferences on the same technologies for more than 20 years.

9. I pioneered the area of hyper doping of wide bandgap semiconductors including increasing certain conduction figures of merit known as hole concentrations to 40 times what previously had been thought as the limit. This enabled the creation of new devices that utilize quantum mechanical processes to reduce power losses and to allow new ways of interconnecting advanced power and optoelectronic devices including LEDs.

10. I have won numerous awards for my teaching and research, including the 2004 National Science Foundation CAREER Award to study the integration of single crystal ferroelectrics with wide bandgap semiconductors through epitaxial processes. The research involved the epitaxial growth of III-V thin film semiconductor layers, and in particular III-Nitride structures and devices. I have also won Multidisciplinary University Research Initiative awards for Epitaxial Multifunctional Materials and Applications, Laboratory Instrumentation Design Research for Scalable Next Generation Epitaxy, and Cross Disciplinary Electronic Research Enabling Biologically Realistic Autonomous Learning, and numerous teaching awards.

11. From 2003-2009, I was the first assistant professor to win a MURI award, one of the most prestigious grants in the semiconductor field. In fact, I was lead PI on two Multidisciplinary University Research Initiatives (MURI) programs as an assistant professor focusing on the development of next generation epitaxial systems for three-dimensional epitaxy and on the development and exploitation of epitaxial multifunctional oxides. This latter MURI was an extension of my NSF CAREER award and led to a new branch of science in multifunctional materials. I was also awarded and am currently the lead PI on a third MURI program aimed at using quantum phenomena to build nanoscale devices that operate in analogy to various brain functions. I am also currently co-principal investigator on a 4th

MURI looking at the nanoscale engineering of thermal interfaces so as to improve heat dissipation in III- Nitride power electronics while maintaining high crystalline quality.

12. I am a co-inventor of 12 US patents and three foreign patents including semiconductor toolsets, epitaxy tools, device structures including a patented (US Patent 7,888,669 B2, “Nitride/Zinc Oxide Based Light-Emitting Diodes.” February 15, 2011) white light emitting LED that uses a self-luminescent substrate as an alternative to traditional phosphors for the conversion of blue/UV light to white light. As such I have detailed understanding of light emitting device designs, materials all mechanisms for luminescence including but not limited to photoluminescence, electroluminescence, fluorescence and phosphorescence.

13. I have been recognized multiple times by my international peers as a leader in the field having been asked to Chair (the lead role) the two biggest conferences in the III-Nitride area (International Workshop on Nitride Semiconductors and the International Conference on Nitride Semiconductors) in 2016 and 2019. Additionally, I have been program chair (responsible for selecting from thousands of submissions the most cutting-edge papers for inclusion in the conference) for these conferences several times. My leadership roles in these meetings provides me with a broad understanding as to what is the state of the art in the academic, industrial and commercial fields of solid state lighting and III-

Nitride semiconductor technology. My longevity in the field provides me with a historical record of what was the state of the art at various times.

14. I am currently director of the Advanced Semiconductor Technology Facility with an estimated equipment capitalization of \$6 million, and funded research since year 2000 totaling almost \$42 million.

15. To date, I have advised and graduated two dozen Ph.D. students, 12 master's students and 45 undergraduate students and have taught over 1000 undergraduates and over 175 graduate students in all aspects of microelectronics, optoelectronics and semiconductor science and technology.

16. I have published over 186 refereed journal and conference papers and conference proceedings in the subject matter areas of compound semiconductor materials and devices for detectors. These works have been published in journals including Advanced Materials, Journal of Crystal Growth, Journal of Applied Physics, IEEE Journal of Photovoltaics, Electronic Materials Letters, and Current Topics in Solid State Physics, among many others.

17. I am the founder of two companies, Innovative Advanced Materials Inc. and Innovative Advanced Technologies. Both companies focus on commercialization of state-of-the-art epitaxial growth systems that bridge the benefits of the two most popular growth methodologies, metal-organic chemical vapor deposition (MOCVD) and molecular beam epitaxy (MBE).

18. I have been awarded numerous grants and have published numerous papers that examine III-Nitride light-emitting diodes (LEDs) (including ultraviolet (UV) LEDs), solar cells, photodetectors and various transistors including high electron mobility transistors (HEMTs) and heterojunction bipolar transistors (HBTs) as well as the fundamental physics of III-Nitride epitaxial growth.

19. I have given over 150 talks and seminars in the U.S. and abroad, including over 35 invited and keynote addresses. I am also a Senior Member of the Institute of Electrical Electronic Engineering (IEEE). I have twice (2016 and 2019) been selected by a diverse international advisory committee made up of some of the most prominent scientists in the III-Nitride semiconductor community to lead (Chair) the two largest conferences in the field: the International Workshop on Nitride Semiconductors (IWN 2016) and the International Conference on Nitride Semiconductors (ICNS 2019). Additionally, I have served as a program chair selecting the best contributions and organizing lectures for each of these meetings in 2010/2024 (IWN) and 2013/2017 (ICNS). In these capacities, I have not only been recognized as an international leader in the field but also as an expert in what the entire III-Nitride community is doing.

20. Based on the above education and experience, I believe that I have a detailed understanding of the state of the art during the relevant period, as well as a

sound basis for opining how persons of skill in the art at that time would understand the technical issues in this case.

III. STATUS AS AN INDEPENDENT EXPERT WITNESS

21. As noted above, I have been retained in this matter by Radulescu LLP on behalf of Savant Technologies LLC d/b/a GE Lighting and LEDVANCE LLC (“Petitioners”) to provide analysis on the scope and content of the ’539 patent relative to the state of the art at the time of the earliest application underlying the ’539 patent, which I understand to be on or about October 5, 2010. My analysis relates to claims 1-11, 18-20, 23-25, and 28 of the ’539 patent.

22. I am being compensated at the rate of \$450 per hour (plus any expenses) for my work and testimony. My fee is not contingent on the outcome of any matter or on any of the technical positions I explain in this declaration. I have no financial interest in Petitioners.

23. I have been informed that Feit Electric Company, Inc. is the owner of the ’539 patent. I have no financial interest in Patent Owner or the ’539 patent nor to my recollection have I ever had any contact with the Patent Owner or the listed inventors of the ’539 patent.

IV. MATERIALS CONSIDERED AND BASIS OF OPINIONS

24. My opinions are based on more than 30 years of studying, teaching about, and directly working with light emitting diodes. My opinions are also based

on investigation and study of the relevant materials, including the patent at issue and its file history, and the prior art. In the course of forming my opinions I have reviewed all the exhibits of record.

25. I may rely upon these materials and/or additional materials to rebut arguments raised by the Patent Owner. Further, I may also consider additional documents and information in forming any necessary opinions – including documents that may not yet have been provided to me.

26. My analysis of the materials relevant to this proceeding is ongoing and I will continue to review any new material as it is provided. This declaration presents only those opinions I have formed to date. I reserve the right to revise, supplement, and/or amend my opinions stated herein based on new information and on my continuing analysis of the materials already provided.

V. LEGAL STANDARDS

A. Invalidity

27. I have been advised by counsel on the law regarding invalidity. I understand that for the purposes of this proceeding a patent claim may be found invalid as anticipated or obvious.

28. I have been advised that a patent claim can be invalid if it is anticipated in view of the prior art. I understand that anticipation of a claim

requires that every element of a claim be disclosed expressly or inherently in a single prior art reference, arranged as in the claim.

29. I have been informed that a patent claim is invalid as “obvious” in light of one or more prior art references if it would have been obvious to a POSA, taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called “secondary considerations” of non-obviousness, which include: (i) “long felt need” for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) “copying” of the claimed invention by others.

30. The '539 patent claims priority to an application filed as early as October 5, 2010. For purposes of my analysis here, I have applied a date of October 5, 2010 as the date of the alleged invention in my obviousness analysis, although in many cases the same analysis would hold true even if the date of the alleged invention occurred earlier than October 5, 2010 (especially given the earlier publication or filing dates of the prior art discussed herein).

31. I have been informed that a claim can be obvious in light of a single prior art reference or multiple prior art references. To be obvious in light of a single prior art reference or multiple prior art references, there must be a reason that would have prompted a POSA to modify the single prior art reference, or

combine two or more references, in a manner that provides the elements of the claimed invention. This reason may come from a teaching, suggestion, or motivation to combine, or may come from the reference(s) themselves, the knowledge or “common sense” of a POSA, or from the nature of the problem to be solved, and this reason may be explicit or implicit from the prior art as a whole. I have been informed that, under the law, the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I also understand it is improper to rely on hindsight in making the obviousness determination.

B. Claim Construction

32. I understand that, for purposes of my analysis in this proceeding, the terms appearing in the patent claims should be interpreted according to their “ordinary and customary meaning.” In determining the ordinary and customary meaning, the words of a claim are first given their plain meaning that those words would have had to a POSA. I understand that the structure of the claims, the specification, and the file history also may be used to better construe a claim insofar as the plain meaning of the claims cannot be understood. Moreover, treatises and dictionaries may be used, albeit under limited circumstances, to determine the meaning attributed by a person of ordinary skill in the art to a claim term at the time of filing. I have followed this approach in my analysis, and for all

of the claim terms considered in this declaration, I have applied the plain and ordinary meaning of those terms unless otherwise specifically indicated.

33. I also understand that the words of the claims should be interpreted as they would have been interpreted by a POSA at the time the alleged invention was made.

VI. DESCRIPTION OF THE RELEVANT FIELD AND TIMEFRAME

34. I have carefully reviewed the '539 patent. The information that I considered in arriving at my opinions is listed in the Exhibit List above.

35. Based on my review of these materials, I understand that the relevant field for purposes of the '539 patent is solid-state light emitting devices. (EX1101, 1:24-26.)

36. I understand the relevant timeframe for my analysis is the time preceding October 5, 2010, which is the date of the earliest filing to which the '539 patent claims priority. (EX1101, [60].)

37. As described above, I have extensive experience in the relevant field, including experience relating to the characteristics and output of light emitting devices, including the use of phosphor wavelength conversion layers and TiO₂ light diffusing layers. Based on my experience, I have an established understanding of the relevant field in the relevant timeframe.

VII. PERSON OF ORDINARY SKILL (“POSA”)

38. I have been informed that “a person of ordinary skill in the relevant field” is a hypothetical person to whom an expert in the relevant field could assign a routine task with reasonable confidence that the task would have been successfully carried out. I have been informed that evidence of the level of ordinary skill in the art can be determined based on information about the field including: the types of problems encountered, known solutions, the speed of innovation, sophistication, and the educational level of active workers. I also understand that the ’539 patent itself and its description are evidence of the level of skill in the art. I have considered this information along with my own background working with students and other professionals in the field to reach my conclusion.

39. Important to my analysis is the specification of the ’539 patent, which implies that the technology is relatively simple to a person of skill in the art. Many of the materials used are referred to generically, rather than by providing specific examples. Similarly, the process steps and structures are identified, at most, at a high level. Instead of providing details, the ’539 patent leaves the reader to fill in those details based on cited references and his or her knowledge and experience. I agree with the ’539 patent’s implication that the technology is simple, and that the specific implementation details for a white-light LED light source would have been within the ordinary level of skill in the art at the relevant time.

40. Therefore, it is my opinion that the person of ordinary skill (which I may refer to as a POSA) in the art at the relevant time 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 POSA 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.

41. In my opinion, the level of skill is informed by the relative detail provided in the '539 patent and the references relied on in the petition. That is, the applicants for the '539 patent did not invent white-light LED light sources or the blue-light LED chips that made them possible. The '539 patent acknowledges those as the invention of others, explaining that “[w]hite light emitting LEDs (“white LEDs”) [light sources] are known” and citing to Shimizu-APA for teaching such light sources. (EX1101, 1:30-50.) The '539 patent further acknowledges that “[d]ue to their long operating life expectancy (>50,000 hours) and high luminous efficacy (70 lumens per watt and higher) high brightness white LEDs are increasingly being used to replace conventional fluorescent, compact fluorescent and incandescent light sources.” (EX1101, 1:51-55.) Nor did the applicants invent the use of a light diffusing layer containing TiO₂ particles.

Indeed, the use of a light diffusing layer to improve the appearance of a white light LED light source was well within the level of ordinary skill of a POSA.

42. Based on my experience, I have an understanding of the capabilities of a person of ordinary skill in the relevant field. I have supervised, directed, and instructed many such persons over the course of my career and was doing so in the fall of 2012.

VIII. TECHNICAL BACKGROUND

43. This technical background is meant as a primer for the reader.

A. Background of LEDs and Light Diffusing Materials

Semiconductors as Light Emitting Components and Light Diffusing Components

44. Semiconductor materials are used both to emit light and to scatter light in LEDs. Semiconductors have a property called an energy bandgap (often just stated as “the bandgap”) related to the energy required to break an electron off the atoms, allowing the electrons to freely conduct throughout the material. The bandgap affects both the color of light emitted from a semiconductor and the range of colors of light that freely transmit through the semiconductor.

45. LEDs emit light having a particular color based on the bandgap of the semiconductor that the LED is made of as defined by the equation $E_g = 1.24/\lambda$ where E_g = the bandgap in eV and λ is the wavelength of light emitted in microns. Selection of the semiconductor used determines the light that the LED emits.

46. Likewise, which color (wavelengths) of light passing through a semiconductor that is absorbed or transmitted is largely based on the energy bandgap. Light with energy greater than the bandgap (shorter wavelengths) is strongly absorbed whereas light with energy less than the bandgap (longer wavelengths) is very weakly absorbed. Because visible light is roughly from 400 nm to 700 nm as illustrated below, or corresponding to energies from ~ 3.1 to 1.8 eV, the 3.0 to 3.2 eV bandgap TiO₂ semiconductor particles are transparent to all visible colors but absorb UV light. This makes use of TiO₂ particles common in consumer products from paints to sunscreen ointments (*see, e.g., EX1103*). Thus, as discussed later, the optical properties of the TiO₂ containing layers are primarily due to the small particle size and not the fundamental properties of the semiconductor (except its optical index of refraction).

VISIBLE SPECTRUM

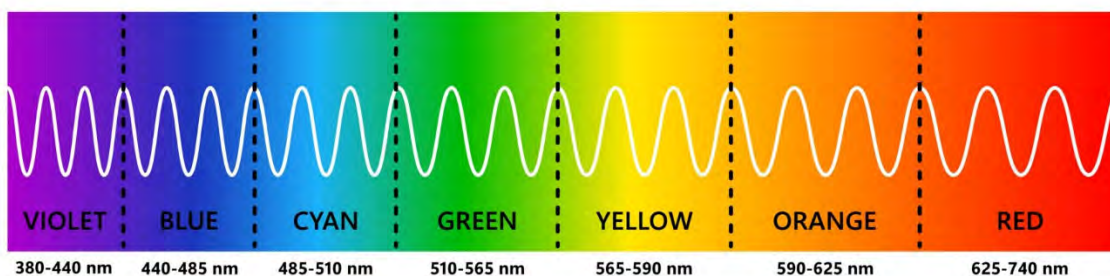


Image Credit: <https://perma.cc/L6MZ-K3SX>

47. LEDs that emit red light were developed in the 1960s. Red light has the lowest energy of wavelengths in the visible light range. Over the next 30 years, LEDs that emit red, orange, and yellow light using gallium arsenide (GaAs) and gallium phosphide (GaP) based semiconductors and their indium related derivatives were developed. However, blue LEDs and phosphor-converted LEDs required wide-bandgap materials that were not developed until much later.

48. The first “candela-class” blue-light emitting LED was described in the literature in 1994. The term “candela-class” refers to a device bright enough to be capable of being used for illumination. A candela is a unit of measure that historically referred to the luminous intensity of a standard candle. This LED used gallium nitride (GaN)-based semiconductors, which encompass indium gallium nitride and aluminum gallium nitride. Since 1994, GaN-based LEDs have been made brighter and made to emit wavelengths varying from ultraviolet (UV) to green.

49. Colored LEDs have been used for decades for signaling or large displays. Displays use multiple red, green, and blue LEDs arranged close together to form individual pixels including pixel combinations that appear white. But after the development of blue and UV GaN-based LEDs, these newer singular LEDs were combined with phosphors, which made generating white light for general illumination using LEDs feasible.

Phosphors

50. Phosphors are materials that are primarily used to convert light from one wavelength to another. Phosphors have existed for many decades and have been thoroughly developed for use in fluorescent lights, later applied to use with LEDs. If you have ever mistakenly broken a fluorescent tube light, you may have seen the white powder coating on the inside of the bulb. This is one or more of several colors of phosphors used to convert the UV light from an arc running throughout the tube to white light humans perceive. Phosphors absorb light (UV or blue light) from one narrow band of wavelengths and emit light at another band of wavelengths longer than the absorption wavelengths.

51. The process of converting light from one wavelength to a longer wavelength loses some energy, even with ideal phosphors. Because the shorter wavelengths carry more energy, the process of converting light from a “primary” shorter wavelength to “secondary” light with a longer wavelength entails losing some energy efficiency. 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.

52. Phosphors can be used to emit white light from blue emitting LEDs by absorbing a portion of the blue light and converting it to lower-energy red, green, or yellow light. The combination of blue light from the LED and light from the phosphors appears white. Because humans perceive blue + yellow light as white light, this is a particularly useful combination (blue LED + yellow phosphor) resulting in an inexpensive and energy efficient white light source. UV LEDs operate similarly, except they generally absorb all the light from the LED and emit blue, red, yellow, and/or green such that the combination appears white.

Specular Versus Diffuse Reflection

53. It is widely known that red colored surfaces absorb all colors except those of red wavelengths, reflecting red colors to an observer. Likewise white colors reflect all colors, absorbing no visible light. But the light being reflected comes from a source, whether the sun, an artificial light source, or reflected from the walls of a room. Inherently this light contains spatial information which appears to a human as an image that if exposed to a simple reflecting mirror (specular reflecting mirror as shown below) would return this spatial information (image) to the observer. In other words, the light observed from a specular mirror would retain the image of its original source such as one's own reflection. To

obtain a truly white, red, or other color appearance, the object must randomize all spatial information, making the reflected light absent of any room or source image.

54. Red surfaces randomize the reflected red light to lose the spatial information (images). Likewise white surfaces must randomize the reflected light for all colors of light, reflecting all colors but scattering the light enough that the original image (light source or room image) is lost. This randomizing medium is called a “diffuse medium” (see figure below) and thus, “diffusive mediums” are synonymous with “scattering mediums.” The figure below describes specular (reflections retaining the image spatial information) and diffusive (reflections destroying the image spatial information) surfaces. But such surfaces are subject to environmental changes like aging, corrosion etc. that could affect the light properties. As is described below, there is a better way to create diffusive/scattering mediums using particles that are not exposed to atmosphere or degradation sources.

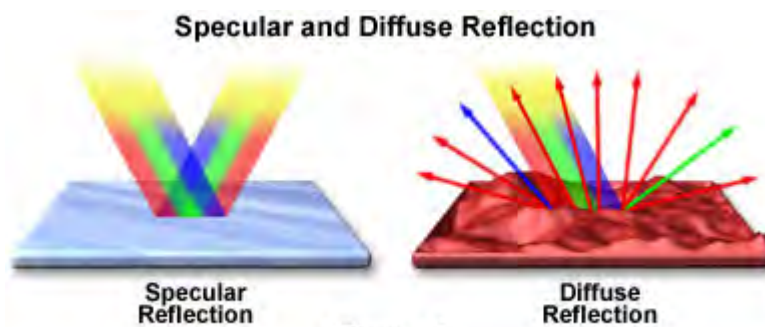


Figure 1
Image Credit: <https://perma.cc/T3KW-UBHQ>

Embedded Particle Based Light Diffusing/Scattering

55. Here we first consider the light coming from the room when the LED is powered off. Reflective, scattering and diffusing particles like titanium dioxide (TiO_2) have been known to affect light for many generations and are commonly embedded in other transparent materials. Consider the ability of TiO_2 particles embedded in other transparent materials to “cover” the color/appearance of underlying materials (for example a yellow phosphor) on which it is deposited resulting in a white appearance: TiO_2 is well known to be a coloring pigment in white paint. Dupont states “Titanium dioxide (TiO_2) is the most important white pigment used in the coatings industry. It is widely used because it efficiently scatters visible light, thereby imparting whiteness, brightness and opacity when incorporated into a coating.” (EX1113, p.4.)

56. But since TiO_2 is a wide bandgap semiconductor comparable to GaN in optical properties, its optical scattering, diffusing, and reflecting properties largely result from the small particle size and not its fundamental properties (other than refractive index). That is, “titanium dioxide (TiO_2) and other white pigments opacify paint films primarily by diffusely reflecting light. This reflection occurs because the white pigment scatters or bends light strongly. If there is enough white pigment in a paint film, almost all visible light striking it ... will be reflected, and the film will appear opaque, white, and bright... The primary control of opacity

and brightness in white paint films depends on scattering of light. Scattering of light means bending of light, and in coatings, light can be bent by surface reflection, by refraction and by diffraction.” (EX1113, p.5.)

57. TiO_2 particles embedded in a transparent material (TM) appear white because of multiple scattering events, not on a surface, but inside the TiO_2 -TM layer that results in broad wavelength reflection. First considering how TiO_2 particles scatter light, the figure below shows how light can be refracted using a small transparent particle. TiO_2 is a semiconductor with a bandgap large enough to allow visible light to pass through it, making TiO_2 transparent. Light following various paths represented by the lines below are strongly redirected exiting the particle in different directions than it entered. This effect is known as “refraction based light scattering” and has been known for many decades.

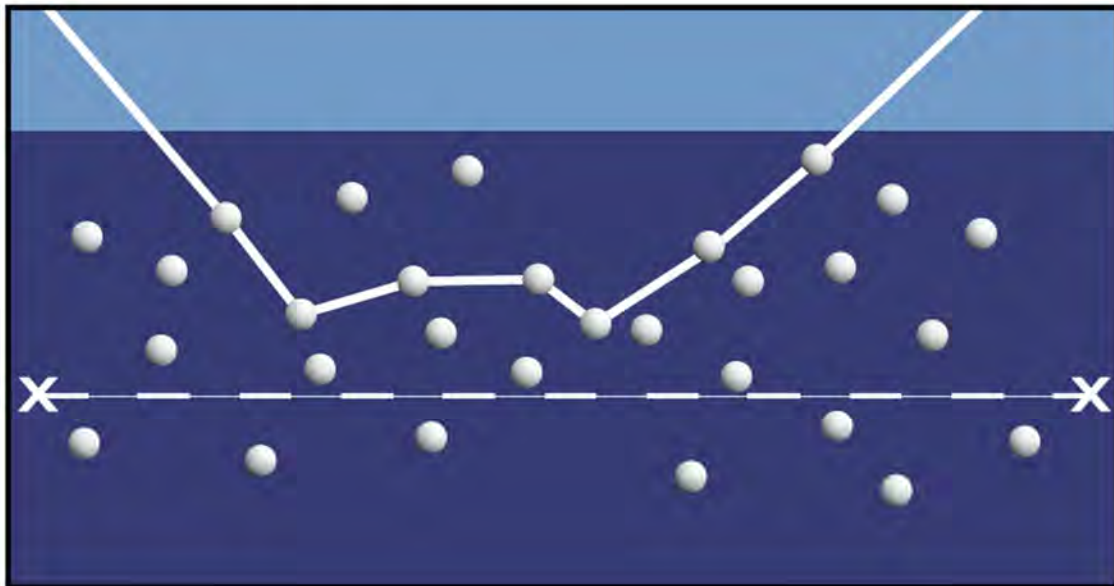


Higher Refractive Index

(EX1113, p.5.)

58. When multiple such scattering events occur as in a film containing many TiO_2 particles as shown below, the entering light undergoes multiple random scattering events and eventually escapes the scattering/diffusing layer implementing a randomized reflector. Random (multiple scattering) reflectors are different than the commonly thought of mirror reflectors in that unlike a specular mirror reflector that preserves both the color content (white light) and the image impinging on the mirror, a randomized diffusive reflector reflects no image but does preserve the white color of the impinging light. Since the incoming room light contains multiple colors (i.e. white light) the exiting scattered/diffused light also appears white but without any image – creating a white appearance.

Figure 3. Path of Light in White Paint Films.



High R.I. Pigment

(EX1113, p.6.)

Transmitted LED Primary Light in Particle Dispersed Mediums

59. The prior section described how random scattering of room light could result in a white reflective surface that covers (is opaque) underlying layers (like a yellow phosphor) giving a white appearance. But the same random scattering process and a different process known as diffraction can affect a powered-on LED emitted light that is transmitted through a TiO_2 -TM layer as well.

60. For general illumination applications, consumers prefer a light source with as little as possible angular dependence. But as shown below, a typical LED has a direction varied light emission. For example in the simplistic LED with clear and diffuse (scattering) lenses below, the 100% light intensity (brightest emission) is improved by adding a light scattering (diffuse) cover lens.

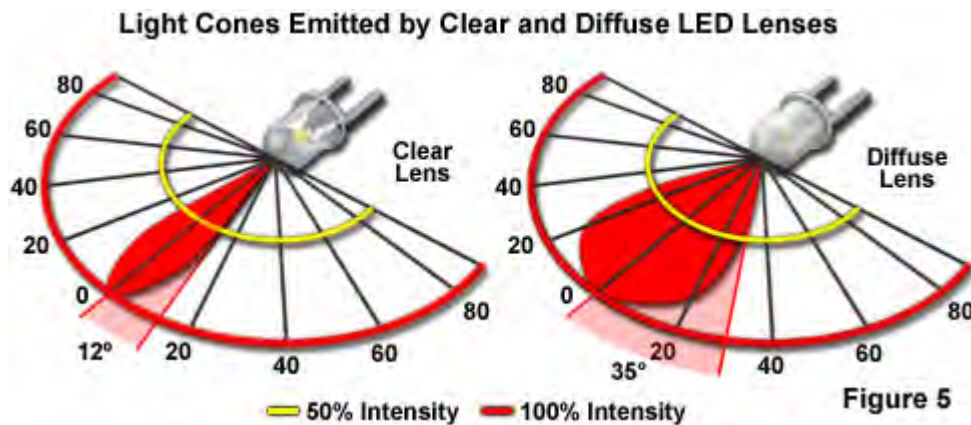


Image Credit: <https://perma.cc/2MJL-D66U>

61. Similarly, by adding light scattering particles, like TiO_2 , the exiting LED light can be homogenized to provide a wider emission angle. This can be

done by both refraction as described previously for room light reflection to obtain a white appearance and by diffraction.

62. First consider that since the refractive scattering by the TiO₂ particles is random, some light is scattered out of the device providing the blue content of the white light but with a wider emission angle than inherent to the LED chip itself. But there also exists a different mechanism for scattering outgoing blue light from the LED – diffraction. Dupont describes the phenomena of diffraction in the following way on page 6 of EX 1013:

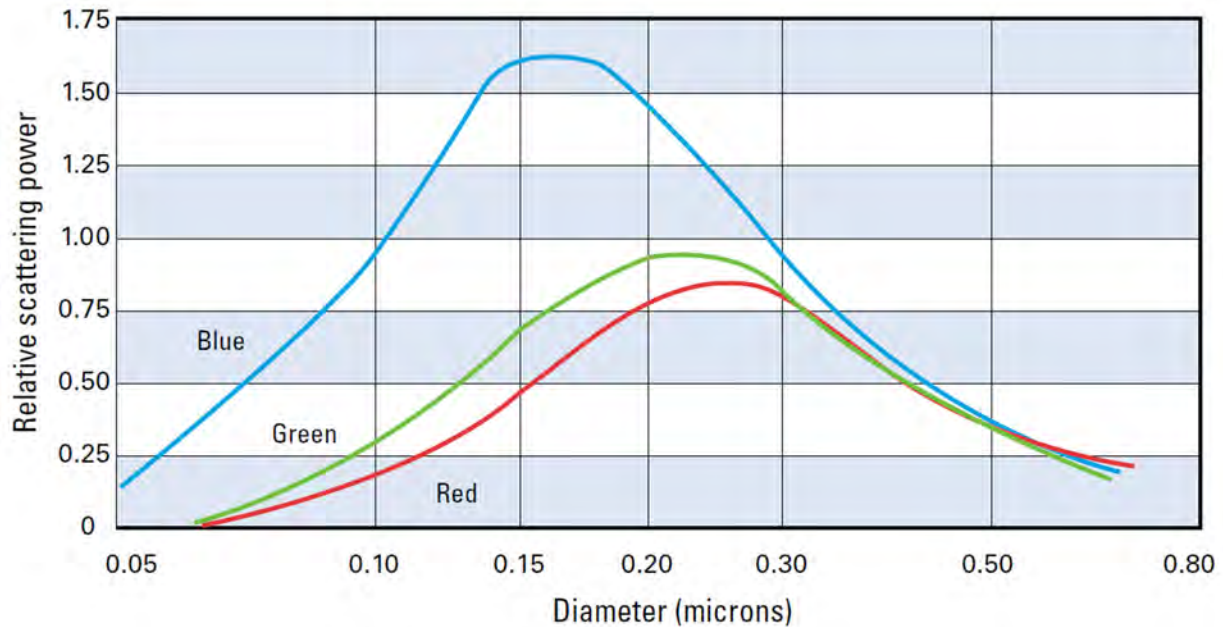
“The phenomenon of diffraction can be approached by consideration of one characteristic of wave motion. When a wave passes an obstruction, it tends to bend from its original path. As an example, waves of water passing a vertical piling will bend in behind the piling. The same is true of light waves as they pass near an object, they tend to bend behind the object. With large objects the amount of bending is generally insignificant to the eye, but when the object’s dimensions approach the wavelength of incident light, bending (diffraction) becomes appreciable. When the size of the TiO₂ particles approaches half the wavelength of incident light, the particles can bend four to five times as much light as actually falls on the particle because a large amount of the light is diffracted when it passes close to the particles. In other words, the scattering cross section can be four to five times the geometric cross

section of the particles.”

63. So, it has been well known that diffraction can occur when light interacts with small particles of TiO_2 (and similar materials) of size comparable to the wavelength of the light. This wavelength-particle size relationship leads to a color variation in the effectiveness of light scattering via the diffraction mechanism. This makes small wavelength light like the primary blue light from a directional LED scatter more than larger wavelength secondary light from a yellow, green, or red phosphor. But since the secondary light is already randomly oriented due to the random orientation of the phosphor particles, the mixture of randomized (diffraction + refraction scattered) blue light and randomized yellow phosphor light (random origination + refraction scattered) results in a more uniform illumination intensity with angle of viewing.

64. Thus, the most directional light, the LED light, can undergo “additional” diffraction to randomize its escape angle. To do this, one must select the correct particle size to affect the blue light more so than other colors. But this is also known. For example, Dupont shows in EX1113 (page 8) that at 150 nm (0.15 microns), the light scattering power of TiO_2 for blue light is substantially stronger than that of green or red light as shown in the figure below: “at 0.15 microns, the diameter corresponding to maximum scattering of blue light, light scattering in the red and green regions drops markedly.”

Figure 7. Relative Light Scattering Power versus Rutile Particle Size.



(EX1113, p.8.)

B. Blue-light LED chips led to white-light LED light sources

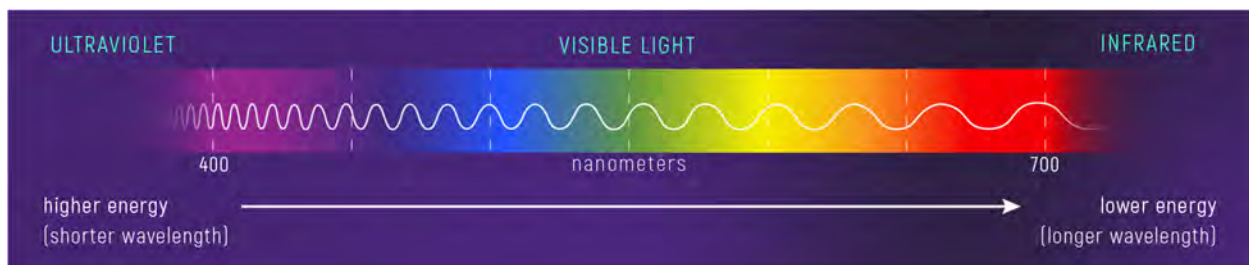
65. As reflected in the Background of the '539 patent and as discussed above, it was the development of high-efficiency blue-light LED chips that allowed for white-light LED light sources for replacing fluorescent and incandescent light sources. (EX1101, 1:30-46.) The '539 patent cites Shimizu as an example of such a white-light LED light source. (*Id.*) As the '539 patent states:

Typically, the LED chip or die generates blue light and the phosphor(s) absorbs a percentage of the blue light and re-emits yellow light The portion of the blue light generated by the LED that is not absorbed by the phosphor material combined with the light emitted by the phosphor provides light which appears to the eye as being nearly

white in color.

66. The principle of operation of white-light LED light sources was straightforward once blue-light LED chips were available. As described in Shimizu and elsewhere, LED chips convert electricity to light very efficiently, but they emit monochromatic light in a relatively narrow range. LED chips have long been known to emit red or green light. Technology for making LED chips that emit blue light was eventually commercially developed in the 1990s. But LED chips do not emit the broad spectrum of light that is perceived as white light.

67. Phosphors are used to convert the wavelength of light by absorbing light at one wavelength and emitting it at another. Because blue light is at the higher frequency (smaller wavelength) end of the visible light spectrum, it is also higher energy than other visible light. Thus, there are phosphors that will convert higher energy blue light to a lower energy complementary light like yellow light.



NASA, ESA, STScI (available at <https://perma.cc/QM4N-WPKS>)

68. The light output by a typical white-light LED light source is the sum of the yellow light emitted by the phosphors and the unabsorbed light emitted by the LED chip. Shimizu demonstrates this using a series of charts. Figures 19A-C

have been annotated below to indicate 440 nm (as specified in the claims of the '539 patent) and shade the visible blue light range above 440 nm.

69. Figure 19A shows the relative intensity of the yellow light emitted by the phosphors. Figure 19B shows the relative intensity of the blue light emitted by the blue light LED chip, which is a has a peak at 450 nm. Finally, Figure 19C shows the relative intensity of the white light that is the sum of the emitted blue and yellow light, reflecting the contribution at 450nm of the blue light emitted by the LED chip and not absorbed by the phosphors.

Fig.19A

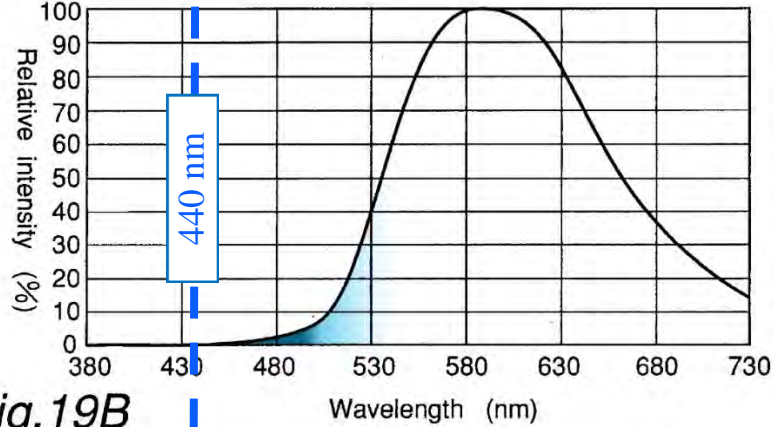


Fig.19B

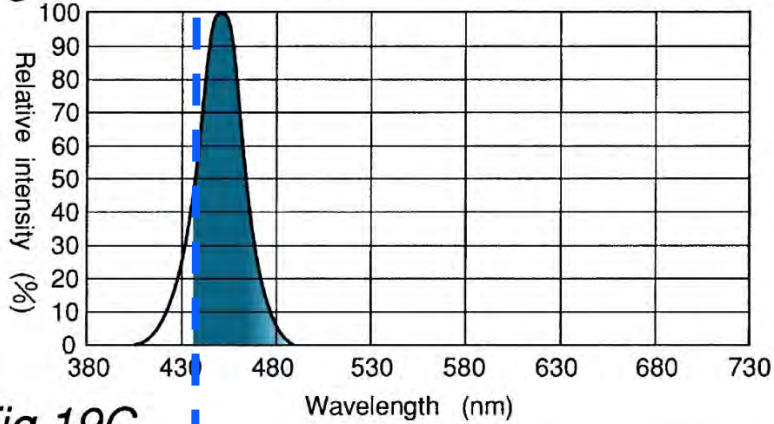
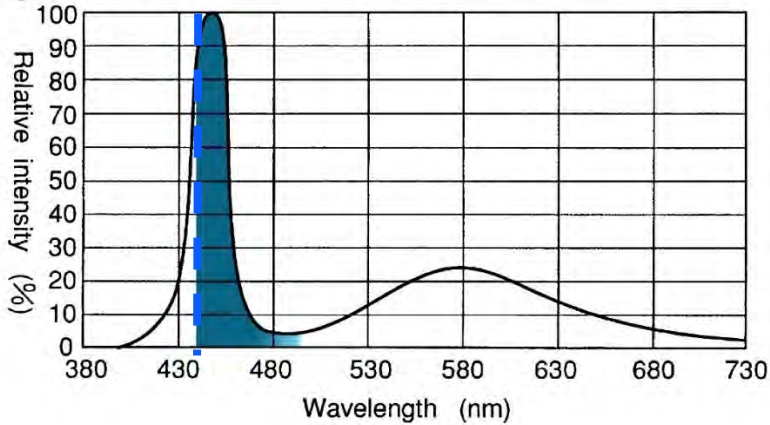


Fig.19C



C. White-light LED light sources were improved with a TiO₂-containing light diffusing layer

70. It was well-known to use a light diffusing layer, such as a layer containing TiO₂ particles, with LED light sources to diffuse light, as discussed

above and disclosed in numerous references, including those cited during prosecution. TiO_2 itself is a commodity chemical, the standard white pigment (“titanium white”), and the most important white pigment in the world.

71. Because the phosphors described above absorb blue light and emit yellow light, they will absorb ambient blue light and emit a small amount of yellow light even when the LED light source is off. This gives the phosphors a yellowish appearance. And that gives the white-light LED a yellowish color when powered off.

72. Once white-light LED light sources were developed, it was obvious to use a light diffusing layer containing TiO_2 particles to, among other things, make the white LED light sources appear whiter when turned off. This is reflected in the number of prior art references that did so, as discussed with respect to the asserted references below.

73. Indeed, data that the '539 patent presents without attribution can also be found in the prior art, because prior artists used the same data for the same purpose and properly attributed the data to DuPont, the TiO_2 particle manufacturer. DuPont had provided the copyrighted data with educational and marketing materials for its customers, customers like the prior artisans. Additionally, Dupont had sponsored and widely published scientific papers stretching back to the 1970's with detailed analysis in the 1990's explaining the physical mechanisms, light

diffusion/scattering, of the TiO₂ (Titania) particles making their form and purpose well known decades before the priority date of the '539 patent (EX1114, EX1115, EX1116, EX1117.) In these references and the Dupont marketing data (EX1112, EX1113), TiO₂ is interchangeably referred to as TiO₂, Titania, and Titanium Oxide and the specific crystalline form of TiO₂ best suited for the scattering mechanism, rutile, was identified and known.

74. Accordingly, it was well-known to use a TiO₂-containing light diffusion layer with a white light LED light source, as claimed by the '539 patent.

D. Sub-micron particles of TiO₂ were known to preferentially scatter blue light

75. The prior art also disclosed the use of sub-micron TiO₂ particles to scatter relatively more blue light than light generated by the at least one photoluminescence material, including TiO₂ particles that were believed to scatter blue light at least twice as much as light generated by the at least one photoluminescence material.

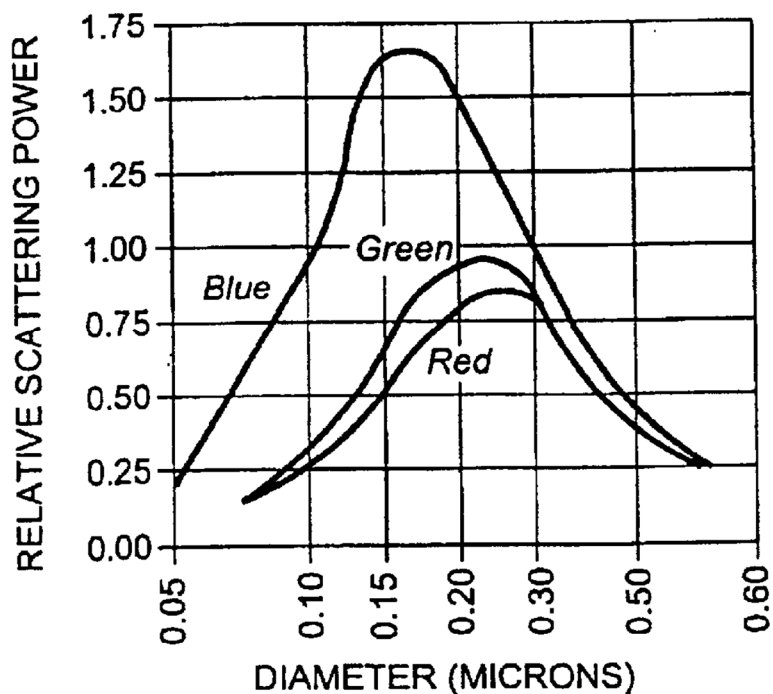
76. In May 1997, two DuPont researchers, Erik S. Thiele and Roger H. French, presented the paper "Light-Scattering Properties of Representative, Morphological Rutile Titania Particles Studied Using a Finite-Element Method." (EX1115.) Until then, the light-scattering properties of TiO₂ particles had been modeled using Mie theory, which was overly simplistic and had significant limitations. (*Id.*, p.469)

77. Accordingly, the paper proposed a finite-element method to theoretically determine the light-scattering properties of certain types of TiO₂ particles. (*Id.*) Among other things, this finite-element method depended on the “wavelength of interest.” (*See, e.g., id.*, p.471 (“The wavelength of interest for tint strength tests of paint films is 560 nm, the center of the visible spectrum. This wavelength is used in the computations performed throughout this study.”).) In other words, it could be used to model the light-scattering properties of certain types of TiO₂ for selected wavelengths of light.

78. U.S. Patent No. 6,791,259 to Stokes was filed on August 22, 2000, issued on September 14, 2004, and was assigned to the General Electric Company (EX1108). Stokes provides a figure labeled “prior art”¹ (fig. 6, shown below) that uses the DuPont finite-element method to “illustrate[] the relationship between the particle diameter and the wavelength of the scattered light for Ti-Pure[®] rutile TiO₂ particles made by DuPont.” (*Id.*, 7:7-9.)

¹ It is unclear if the figure was provided by DuPont originally or if it was created by the General Electric engineers using the DuPont model. Based on similarity to later marketing materials, it appears to be derived from early DuPont marketing materials.

79. Stokes applies this information to a white-light LED light source to suggest preferentially scattering “blue radiation (i.e., such as that emitted by a blue emitting LED)” as compared to “green or red (or for that matter yellow) radiation (i.e., such as that emitted by the phosphor or dye).” (*Id.*, 7:1-26.) In particular, Stokes explains that selecting an appropriate particle size “enhances the scattering of the radiation source radiation while it decreases the amount of scattering of the luminescent material radiation” such that “the lamp radiation output is rendered more uniform because a greater amount of radiation source radiation is scattered toward the luminescent material[.]” (*Id.*, 7:10-26.)



Stokes (EX1108), Figure 6

80. Research papers were also published during the relevant time period containing a similar graph. For example, a paper (EX1123) was presented at the RadTech e|5 2006 conference containing the following figure.

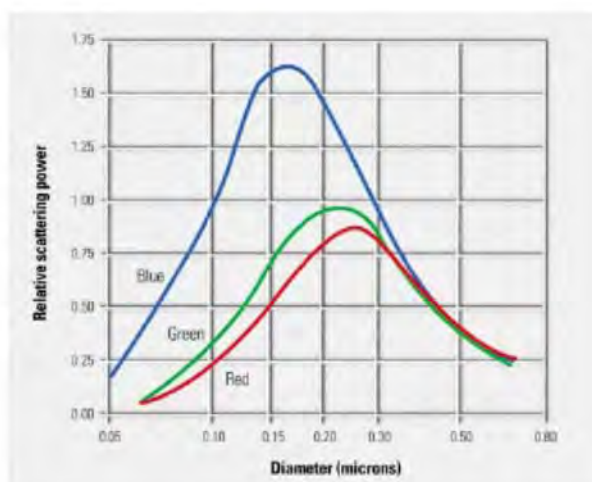
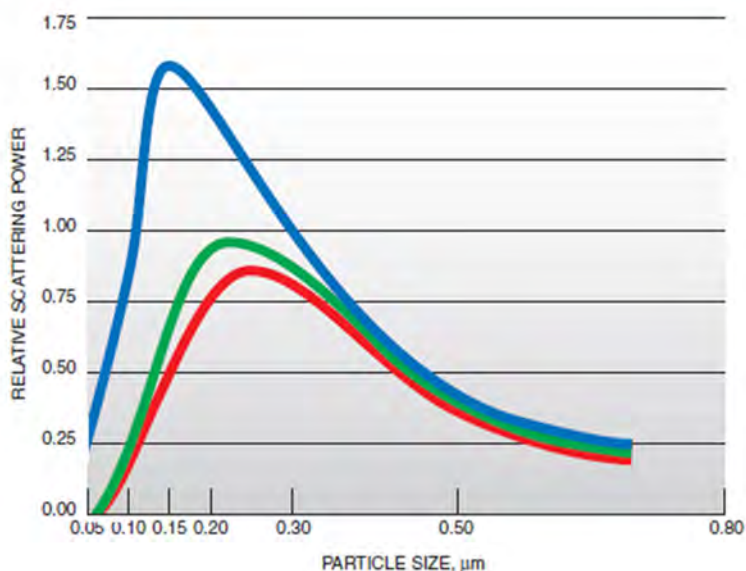


Figure 5. Relationship between TiO₂ particle size and light scattering (Courtesy: Dupont Titanium Technologies).

81. Noting that Stokes cites the DuPont web page as it appeared in 2000 (“DuPont Ti-Pure Titanium Dioxide Web Page,” DuPont Home Page, visited Aug. 3, 2000) and other references credit DuPont, a graph similar to Figure 6 of Stokes was widely distributed in DuPont marketing materials for TiO₂ that were published in 2007. As the marketing materials explain, the graph is “derived from theoretical considerations in highly dilute systems [and] show[s] the relative scattering power of rutile² TiO₂ for blue, green and red light as a function of particle size.” (EX1112, p.4; EX1113, p. 8.)

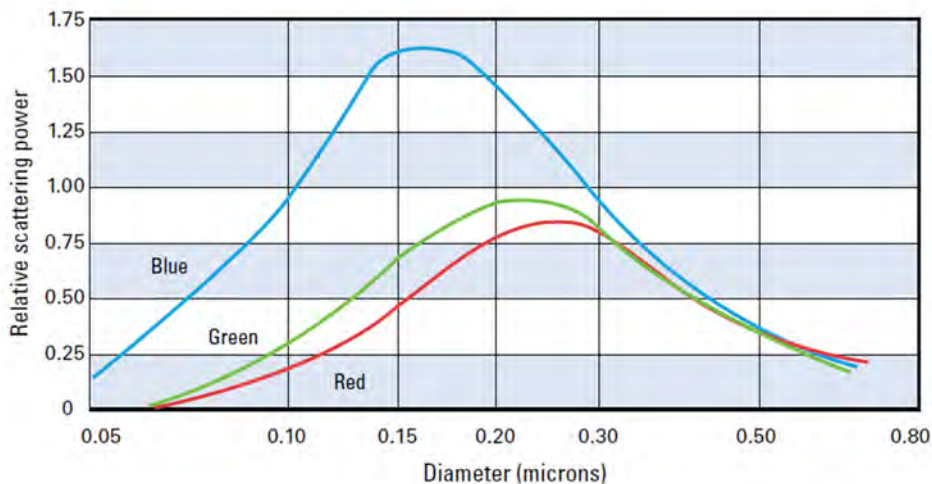
² Titanium dioxide comes in various forms (in other words, polymorph forms having the same chemical formula: TiO₂). The “rutile” form is the most common

Figure 4. Relative Light Scattering Power vs. Rutile Particle Size



DuPont: Polymers, Light and the Science of TiO₂ (2007) (EX1112), p.4

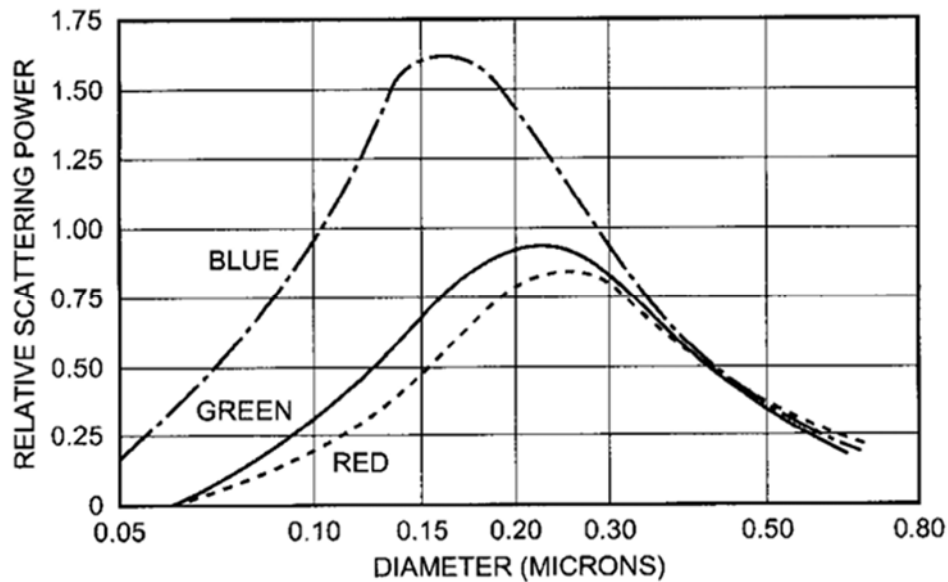
Figure 7. Relative Light Scattering Power versus Rutile Particle Size.



DuPont: Titanium Dioxide for Coatings (2007) (EX1113), p.8

natural form, is the form used for white pigments, and is thus the form studied by Dupont in their early theoretical work cited above.

82. U.S. Patent Application No. 12/498,253 to Toquin was filed on July 6, 2009, published as Pub. No. 2011/0001151 on January 6, 2011, and was assigned to Cree, Inc. (EX1124). Toquin provides a similar figure “showing the relative light scattering power vers[us] the scattering particle size for TiO₂ scattering particles commercially available from different sources, such as from Dupont, Inc.” (EX1124, ¶[0080].)



Toquin (EX1124), Figure 4

83. These prior art figures are all similar and all either reference DuPont or were published by DuPont. Figure 10 of the '539 patent also bears a striking similarity to these prior art figures. In addition to graphing the same theoretical model, the figures all share certain unusual design decisions, such as using: the

same nonlinear or nonstandard scale for the x-axis (particle size) of the graph;³ the same vertical axis scale, 0 to 1.75; and the same data range, from 0.05 microns (50nm) to around 0.65 microns (650 nm).

E. Summary of the '539 Patent

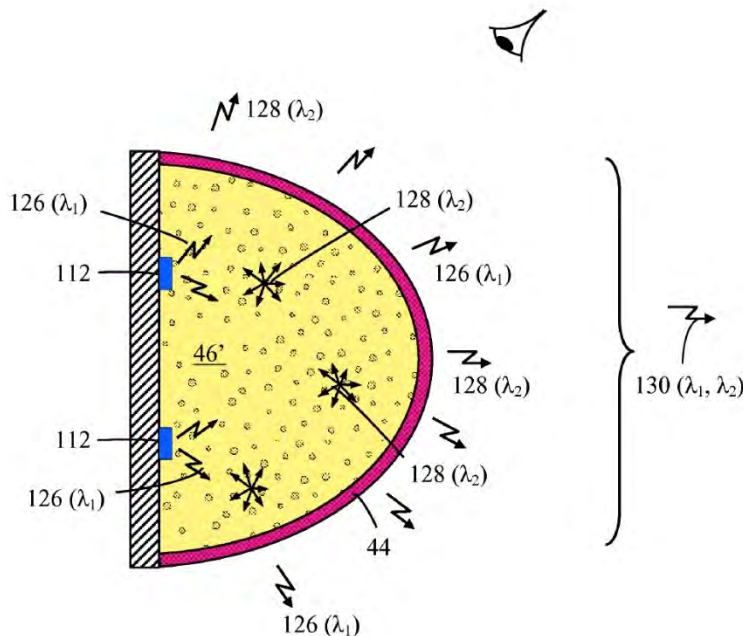


FIG. 18

84. The '539 patent is entitled “Wavelength Conversion Component with Scattering Particles.” The disclosed wavelength conversion component with a

³ The graph in EX1112 has a linear x-axis while the graphs in EX1113, EX1123, Stokes, Toquin, and the '539 patent each have a logarithmic x-axis.

diffusing layer is configured to be used with a blue-light LED and other components to create a white-light LED light source.

85. The '539 patent claims broadly cover a white-light LED light source with a light scattering material containing sub-micron TiO₂ particles, e.g.:

1. A wavelength conversion component for a light emitting device comprising:

at least one photoluminescence material; and

a light scattering material, wherein 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;

wherein the wavelength conversion component is configured such that in operation a portion of the excitation light comprising blue light having a wavelength of greater than or equal to 440 nm 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 photoluminescence material.

86. The addition of a "light diffusing layer" is the only claim requirement that is not admitted prior art. The others are all fundamental to any white-light LED light source made with a blue-light LED chip, as disclosed by, for example,

Shimizu. Shimizu is both cited in the '539 patent as well as incorporated by reference in Stokes.⁴

87. The prior art Krummacher and Stokes disclose white-light LED light sources including a “light diffusing layer” containing TiO₂ particles.

F. Prosecution History of the '539 Patent

88. The '539 patent issued from U.S. Pat. Appl. No. 13/273,212. (EX1104.) It claims priority to U.S. Provisional Pat. Appl. Nos. 61/390,091, filed October 5, 2010, and 61/427,411, filed December 27, 2010.

89. During prosecution, the only prior art reference applied by the Examiner against the independent claims for the “light diffusing layer” was U.S. Pat. Pub. No. 2002/0180351 to McNulty. The applicants distinguished McNulty on the basis that it (1) was not configured like a white light LED light source (EX1104, pp.161-65), and (2) indeed, taught an ultraviolet (i.e., not visible light) LED chip unsuitable for a white-light LED light source (EX1104, pp.259-62).

90. With respect to the *first* distinction, the applicants amended the claims to require the configuration used by white-light LED light sources, which as discussed below, mix blue light emitted directly from a blue-light LED chip with

⁴ U.S. Patent No. 5,998,925 (“Shimizu-APA,” EX1109) is cited by the '539 patent. U.S. Patent No. 6,069,440 (EX1110) is incorporated by reference in Stokes.

yellow light emitted by phosphors which are excited by the blue light (and appear yellow when the light source is off). (EX1104, p.151.) The relevant requirements with respect to claim 1 are underlined once below. With respect to the *second* distinction, the applicants amended the claims to specifically require the blue light generated by a blue-light LED chip (as would be used in a white-light LED light source). (EX1104, p.253.) That amendment is underlined twice below.

1. A wavelength conversion component for a light emitting device comprising:
at least one photoluminescence material; and
a light scattering material, wherein 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;
wherein the wavelength conversion component is configured such that in operation a portion of the excitation light comprising blue light having a wavelength of greater than or equal to 440 nm 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 photoluminescence material.

91. The applicants convinced the Examiner that it would not have been obvious to use a light diffusing layer with a phosphor-converted white-light-emitting LEDs utilizing blue LEDs. (EX1104, p.406 (citing pp.395-96).) The applicants never informed the Examiner that the use of a TiO₂-containing light diffusing layer with a white-light LED light source was disclosed in the prior art.

IX. OPINIONS ON CLAIM CONSTRUCTION

92. I understand that claim construction is considered an issue of law that will be resolved by the Board. This section explains my opinion regarding how a person having ordinary skill in the art would have understood the claim terms identified below after reviewing the '539 patent and file history.

93. As discussed above, the prosecution history of the '539 patent confirms that the claim term “blue light having a wavelength of greater than or equal to 440 nm generated by the light emitting device” was intended to encompass the blue light emitted by a blue-light LED chip and exclude the ultraviolet light emitted by a UV LED chip. (EX1104, p.194, 200-03.)

94. The specification of the '539 patent confirms that TiO₂ particles are light scattering particles within the meaning of the claims. (*E.g.*, EX1101, 8:19-21 (“The diffusing layer 44 comprises a uniform thickness layer of particles of a light diffractive material, preferably titanium dioxide (TiO₂).”).) *See also* EX1101, 6:28-31 (“Additionally the wavelength conversion component comprises a light

diffusing layer comprising particles of a light diffractive material (also referred to herein as ‘light scattering’).”

95. The specification also confirms that phosphor materials are photoluminescent materials within the meaning of the claims. (*E.g.*, EX1101, 1:36 (“photoluminescent materials (e.g., phosphor materials)”)).

X. SUMMARY OF INVALIDITY POSITIONS

96. I understand that Petitioners are requesting review of claims 1-11, 18-20, 23-25, 28 of the ’539 patent under the following grounds:

Ground	Claims	Description
1	1-11, 18-20, 23-25	Obvious over Krummacher in view of Stokes and Shimizu
4	18, 28	Obvious over Hussell in view of Krummacher, Stokes, and Van Woudenberg

97. It is my opinion that the identified prior art renders the challenged claims obvious.

XI. PRIOR ART REFERENCES

A. Krummacher (Pub. No. US2008/0079015; EX1107)

FIG 1

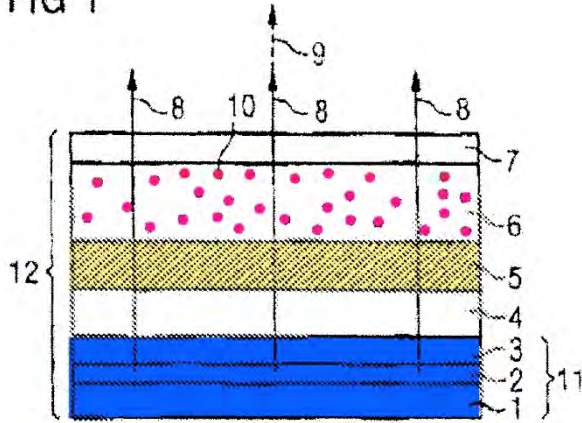
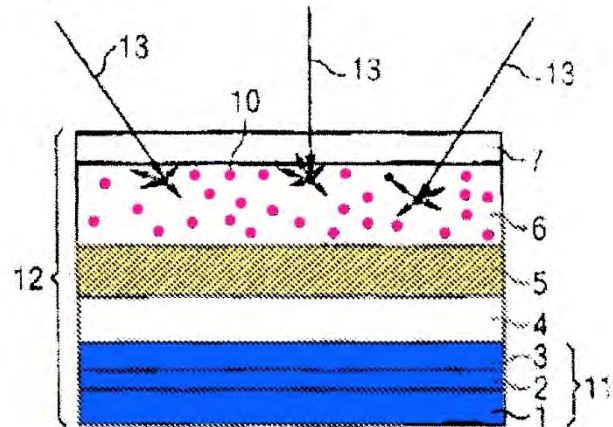


FIG 2



98. U.S. Patent Publication No. US 2008/0079015 A1 entitled “Optoelectronic Component Having a Luminescence Conversion Layer” to Krummacher was filed on September 18, 2007 and published on April 3, 2008. (EX1107.) Krummacher is prior art under pre-AIA 35 U.S.C. § 102(b).

99. As shown in the annotated figures above, Krummacher also discloses a white-light LED light source with a blue-light LED chip (11) with an encapsulant layer (4), a phosphor-containing wavelength conversion layer (5), a particle-containing light diffusing layer (6), followed by a cladding layer (7). Figure 1 shows the white-light LED light source in the ON state, where the blue light from the LED chip (11) combines with the yellow light from the phosphor layer (5) to create a white-light LED light source. Figure 2 shows that the light-diffusing layer

(6) (containing, for example, TiO_2 particles) obscures any yellow light from the phosphor layer (5) when the light source is in the OFF state.

100. Krummacher was not before the Examiner during prosecution of the '539 patent.

B. Stokes (Pat. No. 6,791,259; EX1108)

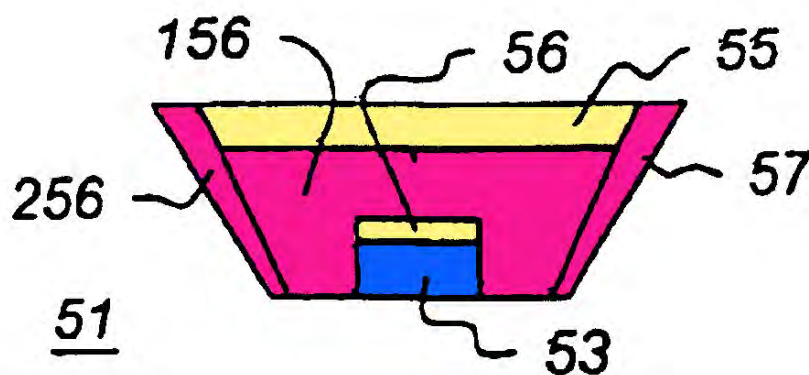


fig 7

101. U.S. Patent No. 6,791,259 entitled “Solid State Illumination System Containing a Light Emitting Diode, a Light Scattering Material and a Luminescent Material” to Stokes was filed on August 22, 2000 and issued on September 14, 2004. (EX1108.) Stokes is prior art under pre-AIA 35 U.S.C. § 102(b).

102. Stokes also discloses a white-light LED light source with light diffusing layers containing TiO_2 particles (56, 156, and 256 in the annotated image

above). Significantly the “prior art” Figure 6 of Stokes (shown below) is essentially the same as Figure 10 of the ’539 patent. Stokes attributes the data to DuPont, and the data relates to the relative scattering of different size TiO₂ particles on red, green, and blue light. (EX1108, 7:7-26, [56] (citing “DuPont Ti-Pure Titanium Dioxide Web Page,” visited Aug. 3, 2000).)

103. Stokes was not before the Examiner during prosecution of the ’539 patent. The applicants did not inform the Examiner that at least Figure 10 of the ’539 patent was in the prior art.

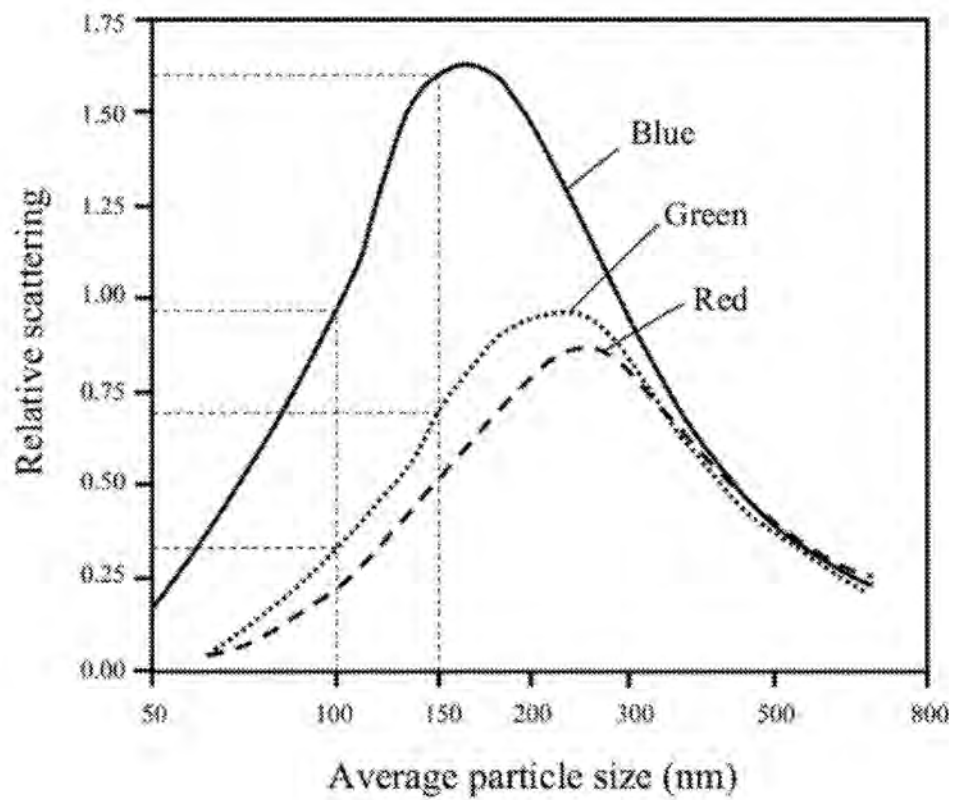


FIG. 10

'539 patent (EX1101).

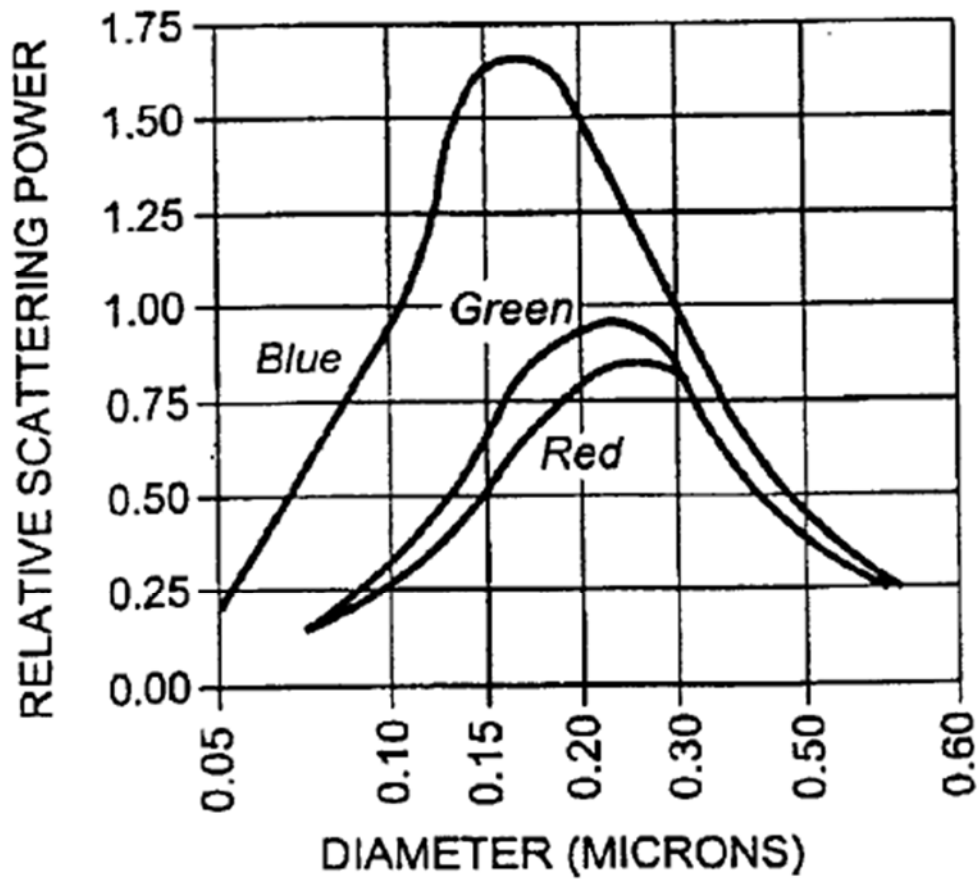
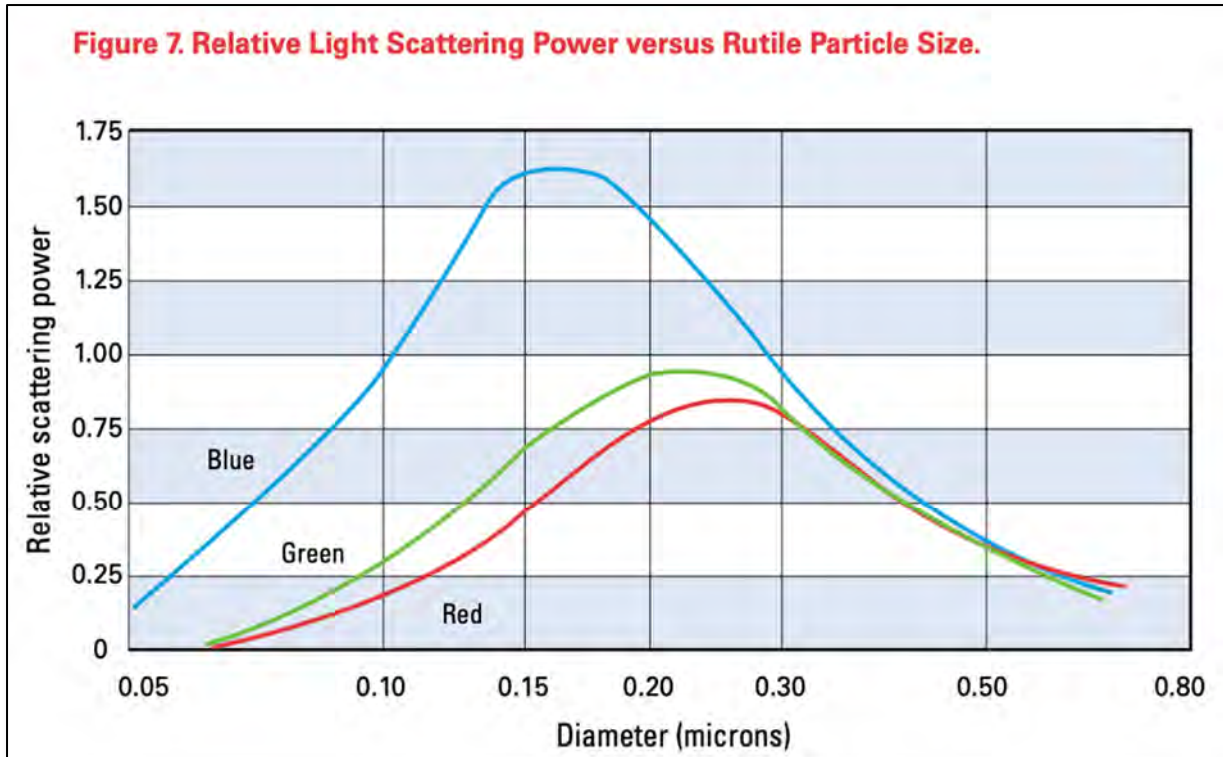


fig. 6
(PRIOR ART)

25

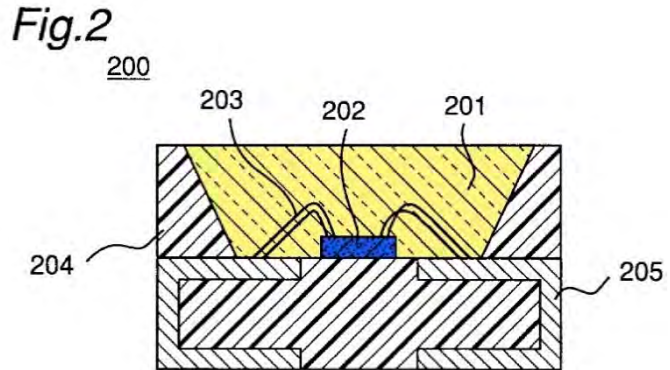
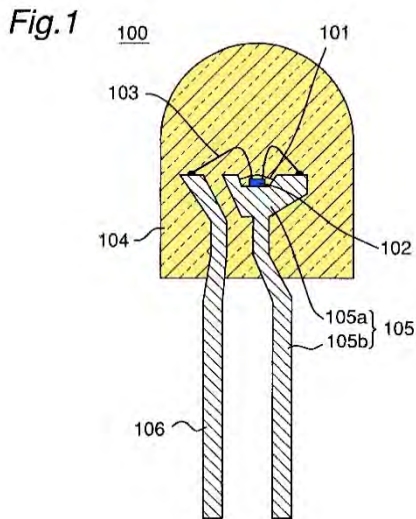
Stokes (EX1108).



DuPont™ Ti-Pure® titanium dioxide Brochure, Copyright 2007⁵(EX1113) at 8.

⁵ As stated in the 2007 brochure, the curves shown in these figures are not based on experimental data but are theoretical: “Curves in Figure 7 derived from theoretical considerations in highly dilute systems show the relative scattering power of rutile TiO₂ for blue, green and red light as a function of particle size.” (EX1113, p.8.)

C. Shimizu (Pat. No. 6,069,440; EX1110) and Shimizu-APA (Pat. No. 5,998,925; EX1109)



104. Both entitled “Light Emitting Device Having a Nitride Compound Semiconductor and a Phosphor Containing a Garnet Fluorescent Material,” U.S. Patents Nos. 5,998,925 (“Shimizu-APA”) and 6,069,440 (“Shimizu”) issued from divisional applications and share a common disclosure. Shimizu-APA is cited by the ’539 patent as admitted prior art. Shimizu is incorporated by reference into Stokes.

105. Shimizu discloses a prior art white-light LED light source. It includes a detailed discussion of the components of the white light emitted by a white light LED light source, as referenced above.

106. Shimizu is also anticipatory, as it discloses using a diffusing layer to improve the OFF-state color of a white-light LED light source, e.g.:

According to the present invention, adding the dispersant

and/or a coloration agent in the molding material has the effects of masking the color of the fluorescent material obscured and improving the color mixing performance. That is, the fluorescent material absorbs blue component of extraneous light and emits light thereby to give such an appearance as though colored in yellow. However, the **dispersant** contained in the molding material gives **milky white color** to the molding material and the coloration agent renders a desired color. **Thus the color of the fluorescent material will not be recognized by the observer.**

(EX1110, 17:35-45.)

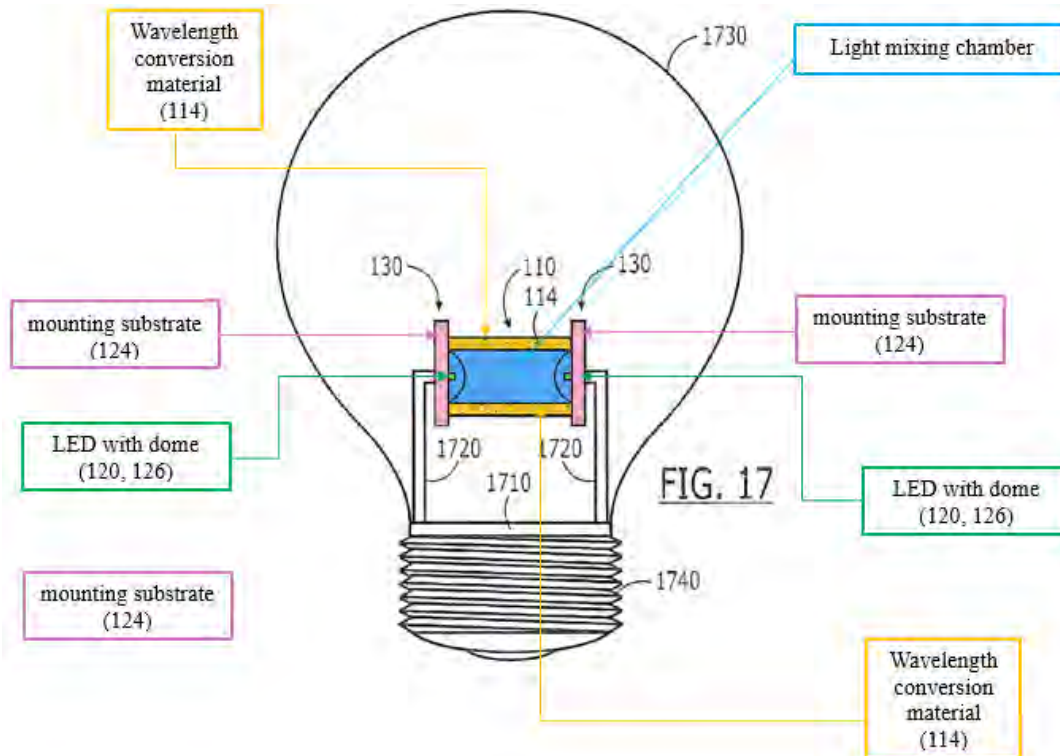
107. The applicants did not inform the Examiner that Shimizu disclosed a white-light LED light source with the claimed light diffusing layer.

D. Hussell (Pub. No. US2010/0124243; EX1121)

108. U.S. Patent Publication No. US2010/0124243 to Hussell et al (“Hussell”), filed on November 18, 2008 and published on May 20, 2010, is prior art under at least 35 U.S.C. §102(b).

109. Hussell discloses a “semiconductor light emitting apparatus” that leverages a “wavelength conversion tube” to obtain “high efficiency white light production.” (EX1121, Abstract, ¶[0038].) In one embodiment (depicted in Figure 17 below), the wavelength conversion tube is “analogized to the filament of a conventional incandescent lamp” wherein the “combination of the elongated

hollow wavelength conversion tube” and “packaged semiconductor devices” provide “a filament for a drop-in replacement for an incandescent bulb.” (EX1121, ¶[0052].)



Hussell, Annotated Figure 17

XII. GROUNDS OF OBVIOUSNESS

[GROUND 1] Claims 1-11, 18-20, 23-25 are rendered obvious by Krummacher, Stokes, and Shimizu

110. Krummacher discloses a white light LED light source with a blue light LED chip, a phosphor-containing wavelength conversion layer, and a TiO₂-particle-containing light diffusion layer, thus rendering obvious claims 1-11, 18-20, and 23-25 of the '539 patent.

FIG 1

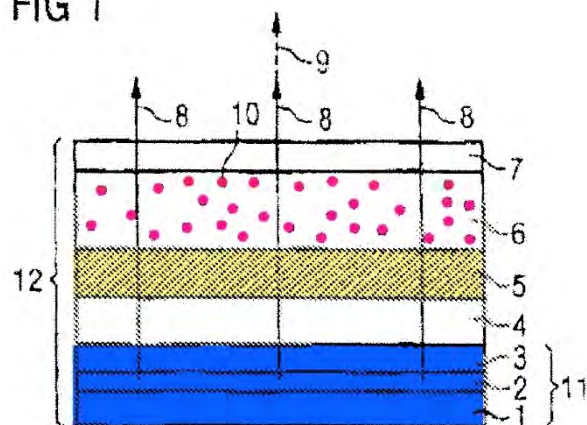
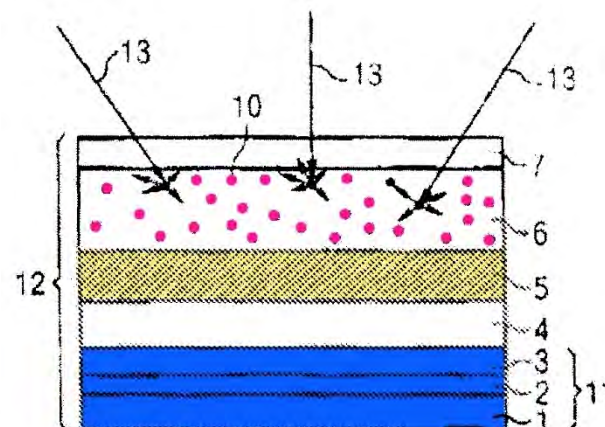


FIG 2



Independent Claim 1: Wavelength Conversion Component

111. Claim 1 of the '539 patent reads as follows:

[1pre] A wavelength conversion component for a light emitting device comprising:

[1a] at least one photoluminescence material; and

[1b] a light scattering material,

[1c] wherein 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,

[1d] wherein the wavelength conversion component is configured such that in operation a portion of the excitation light comprising blue light having a wavelength of greater than or equal to 440 nm is emitted through the wavelength conversion component to contribute to a final visible emission product;

[1e] wherein the light scattering material scatters the blue light at least twice as much as light generated by the at least one photoluminescence material.

112. Krummacher discloses each of these claim requirements as detailed below.

[1pre] A wavelength conversion component for a light emitting device

113. Krummacher discloses a wavelength conversion component.

Krummacher discloses:

An optoelectronic component having an active layer that emits electromagnetic radiation when the component is on and a luminescence conversion layer disposed after said active layer in a radiation direction of said electromagnetic radiation, the luminescence conversion layer is followed in the radiation direction by a light-scattering translucent layer. The luminescence conversion layer preferably appears white owing to the light-scattering translucent layer disposed after it.

(EX1107, [57].)

114. Accordingly, it is my opinion that Krummacher discloses a light emitting device with a wavelength conversion component.

[1a] at least one photoluminescence material

115. Krummacher discloses the inclusion of a wavelength conversion layer comprising particles of at least one photoluminescence material. It is shown, for example, as layer 5 in the annotated Figures 1 and 2 above.

116. Krummacher discloses that “[t]he luminescence conversion material of the luminescence conversion layer 5 is advantageously embedded in a transparent matrix, for example in polycarbonate, silicone, epoxy or PMMA.” (EX1107, [0037]; *see also id.*, [0023].) Krummacher describes the purpose of the layer as follows:

At least a portion of the radiation emitted by the active layer 2 is converted by the luminescence conversion layer 5 to a longer wavelength. In particular, ultraviolet or blue radiation emitted by active layer 2 can be converted to radiation having a longer wavelength, particularly of a complementary color, such as yellow, for example, to produce white light. Luminescence conversion materials suitable for this purpose are known, for example, from the document WO97/50132, whose disclosure content in this regard is hereby incorporated by reference. Particularly suitable are cerium-doped garnets, such as YAG:Ce, for example.

(EX1107, [0036].)

117. A POSA would understand YAG:Ce to be present as particles in the wavelength conversion layer for embedding in silicone or epoxy (EX1107, ¶[0037]), as taught by Stokes and Shimizu, and that such particles are “photoluminescence materials” because they absorb blue light (high energy) and radiate light at a lower energy state.

118. Accordingly, it is my opinion that Krummacher discloses a wavelength conversion layer comprising particles of at least one photoluminescence material.

[1b] a light scattering material

119. Krummacher discloses the inclusion of a light diffusing layer comprising particles of a light scattering material. It is shown, for example, as layer 6 in the annotated Figures 1 and 2 above.

120. In particular, Krummacher discloses that:

The luminescence conversion layer 5 is followed in the radiation direction 9 by a light-scattering translucent layer 6. Said light-scattering translucent layer 6 is advantageously at least partially transparent to the radiation 8 emitted by active layer 2 and at least partially converted by luminescence conversion layer 5.

(EX1107 at [0038].) Krummacher further discloses the light diffusing layer containing TiO₂ particles:

In this exemplary embodiment, the light-scattering translucent layer 6 contains light-scattering particles 10, which, as illustrated in FIG. 2, serve to scatter environmental light 13 striking the optoelectronic component from the outside. Such scattering particles are known, for example, in the production of frosted glass. Particularly suitable are particles of TiO₂ or Al₂O₃, preferably having a radius of between 50 nm inclusive and 1000 nm inclusive. Alternatively, spherical or hollow-sphere-shaped particles of glass or synthetic material are also suitable.

(EX1107 at [0039].)

121. Accordingly, it is my opinion that Krummacher discloses a light diffusing layer comprising particles of a light scattering material.

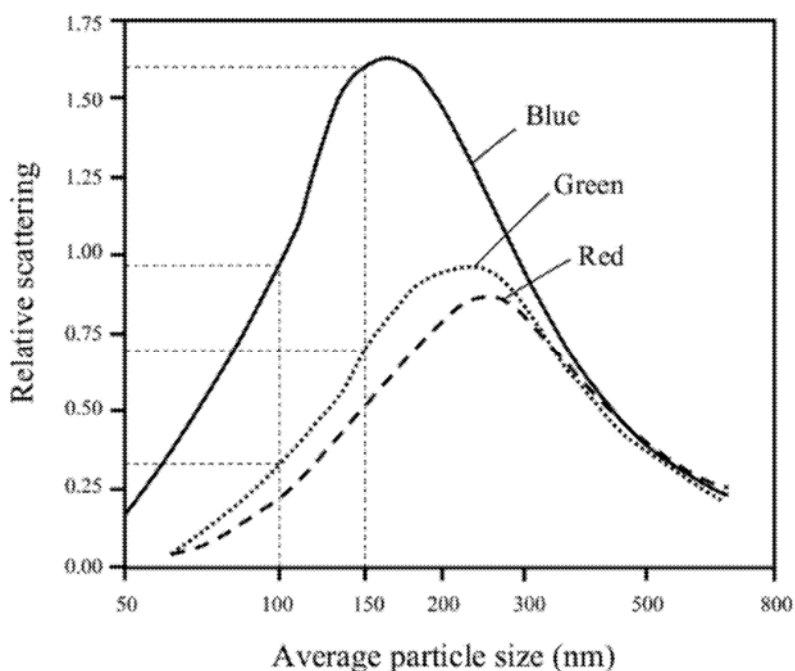
[1c] wherein the light scattering material has an average particle size that is selected such that the light scattering material will scatter excitation light from a radiation source relatively more than the light scattering material will scatter light generated by the at least one photoluminescence material

122. Stokes discloses:

In one preferred embodiment, 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.

(EX1108, 7:1-4.)

123. As discussed in detail above, Figure 10 of the '539 patent is essentially the same as graphs found in the prior art, including Figure 6 of Stokes, that were derived from the DuPont model described above. In particular, the graphs purport to show the relative scattering power of TiO₂ based on particle size for different colors of light.



'539 Patent, Figure 10

124. Krummacher discloses a light scattering material with TiO₂ particles “preferably having a radius of between 50 nm inclusive and 1000 nm inclusive.” (EX1107, ¶[0039].) According to the DuPont model, TiO₂ particles of such a size generally scatter more blue light (e.g., excitation light) than red or green light (e.g., light emitted by the phosphor). Accordingly, Krummacher renders obvious claim

[1c] by literally disclosing the selection of average particle sizes that preferentially scatter blue light.

125. To the extent that the claim language “an average particle size that is selected such that [it preferentially scatters blue light]” requires an average particle size selected for that reason (rather than an average particle size that leads to that outcome), this claim element is rendered obvious by Stokes. As discussed above, Stokes explicitly discloses the selection of an average particle size “such that the particles preferentially scatter blue ... LED light as compared to yellow ... light from the luminescent material.” (EX1108, 7:1-4.)

126. As discussed above, Krummacher in view of Shimizu and Stokes discloses white-light LED light sources with TiO₂-containing light diffusing layers, meeting every requirement of this claim, including the claimed average particle size. To the extent this claim requirement is understood to also claim the basis for selecting a particular average particle size, a POSA would have had reason to use such a basis for selecting average particle size as taught by Stokes.

127. For example, Stokes discloses:

[The relevant] particle size range is advantageous because it enhances the scattering of the radiation source radiation while it decreases the amount of scattering of the luminescent material radiation. Therefore, the lamp radiation output is rendered more uniform because a

greater amount of radiation source radiation is scattered toward the luminescent material, while a lesser amount of the luminescent material radiation that is emitted downward toward the radiation source is scattered back toward the luminescent material.

(EX1108, 7:17-26.)

128. Thus, a POSA would have been motivated to apply this principle to Krummacher, because it would increase the conversion of blue light to yellow light and improve the uniformity of the light source. Conversion of blue light to yellow light is improved by maximizing the scattering of blue light. Uniformity is improved by preferentially scattering the concentrated light from the blue-light LED chip instead of the disperse light emitted by the phosphor.

129. A POSA would have had a reasonable expectation of success applying this principle to Krummacher, because the relevant particle size range includes the range disclosed by Krummacher. A POSA would have recognized selecting an average particle size as a design decision to be made based on a number of factors, including the light scattering properties of the particles, and well within the skill of the art.

130. Thus, it is my opinion that Krummacher in view of Shimizu and Stokes teaches this claim element.

[1d] 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

131. Krummacher discloses that 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 the final visible emission product.

132. That is, for example, Krummacher discloses that:

Known from the document WO 97/50132 is a radiation-emitting optoelectronic component in which at least a portion of the radiation emitted by an active layer of said optoelectronic component is converted to larger wavelengths by means of a luminescence conversion layer. In this way, for example a radiation-emitting active region that emits blue or ultraviolet light can be used to generate mixed-color or white light. As a rule, blue or ultraviolet light is converted by such a luminescence conversion layer to light of a longer wavelength, particularly to light of a complementary color, such as yellow, for example, such that the blue or ultraviolet radiation emitted by the active region is superimposed on the fraction converted to the complementary color to yield white light.

(EX1107 at [0003].)

133. Although Krummacher does not specify the wavelength of blue light emitted by its LED chip, a POSA would have understood it to include blue light with a wavelength greater than 440 nm. In addition to being a white light emitting LED device, Krummacher discloses that “the optoelectronic component is for example an LED or an LED light source comprising one or more radiation-emitting semiconductor chips, in which case said semiconductor chip or chips emit blue or ultraviolet light that is converted to white light by the luminescence conversion layer. (EX1107 at [0022].) Krummacher discloses that “active layer 2 is preferably an organic light-emitting layer, particularly emitting blue light” or “an inorganic semiconductor material, preferably emitting in the blue and/or ultraviolet region of the spectrum.” (EX1107 at [0031]-[0032].) “The active layer 2 can in particular comprise a nitride compound semiconductor material, for example $\text{In}_x\text{Al}_y\text{Ga}_{1-x-y}$ where $0 \leq x \leq 1$ and $x+y \leq 1$.” (EX1107 at [0032].)

134. Moreover, a white light LED light source containing a blue light LED chip generating “blue light having a wavelength of greater than or equal to 440 nm” would have been obvious in view of Stokes, which incorporates Shimizu. Stokes and Shimizu both disclose white light LED light sources consistent with claims 1 and 19 of the '539 patent. As discussed above with respect to the state of the art, Shimizu provides wavelength charts for multiple blue light LED chips, all of which show emission light including wavelengths above 440 nm. (EX1110,

Figs.) Shimizu further discloses a dozen examples with blue light LED chips having emission peaks at 450 nm (23:43, 27:4-5, 28:55), 460 nm (25:24-25), or 470 nm (29:45), but none at shorter wavelengths. And Stokes discloses an LED chip that “emits blue light 48 having a wavelength between about 420 and 480 nm” (EX1108 at 4:37-40) along with “blue emitting LEDs having a peak emission wavelength of $\lambda=450$ nm” or “peak emission wavelength of $\lambda=480$ nm” (EX1108 at 6:62-67).

135. A POSA would have been motivated to use a white light LED light source disclosed by Stokes and Shimizu as the conventional white light LED called for by Krummacher. Shimizu, in particular, is cited by both the '539 patent and the prior art. Thus, it would have been obvious to look to Shimizu and Stokes for details of the conventional white light LED light source used in Krummacher. And a POSA would have had a reasonable expectation of success in doing so, because they would simply be using the conventional white light LED disclosed in the prior art as directed by Krummacher. In other words, not only does Krummacher suggest the use of an LED like that disclosed in Stokes and Shimizu, to do so would have been the simple substitution of one known element for another to obtain predictable results.

136. Accordingly, it is my opinion that Krummacher discloses or suggests the wavelength conversion component is configured such that in operation a

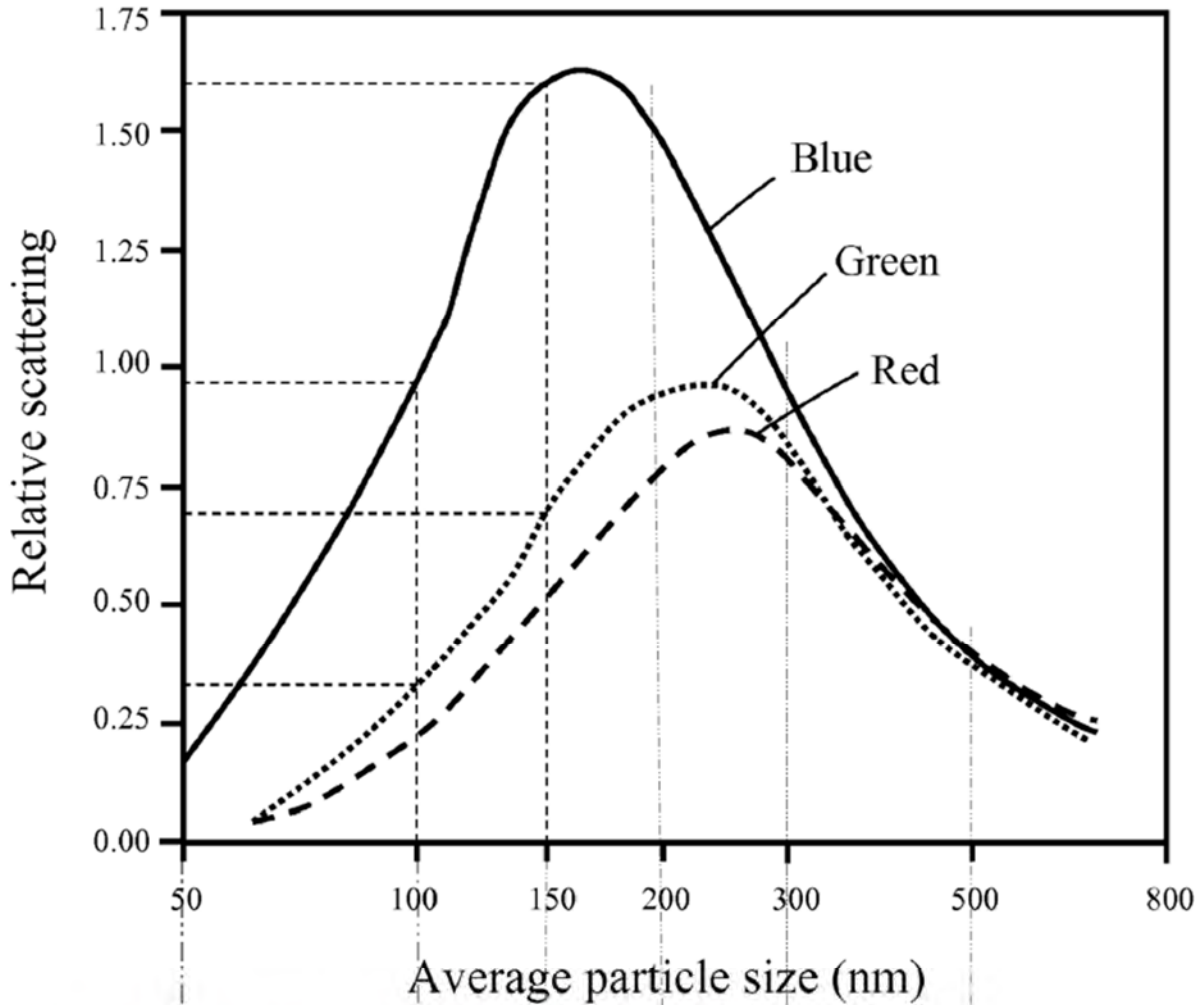
portion of excitation light comprising blue light having a wavelength of greater than or equal to 440 nm generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product.

[1e] wherein the light scattering material scatters the blue light at least twice as much as light generated by the at least one photoluminescence material

137. As discussed above, Krummacher in view of Shimizu and Stokes renders obvious claim element [1c]. Claim element [1e] only further requires that the “relatively more” of [1c] be “at least twice as much.” The ’539 patent discloses no particular significance to “at least twice as much” which represents a straightforward narrowing of the claimed average particle size range from claim element [1c] so that it extends only up to around 175 nm, with the ’539 patent disclosing a preferred range of 0.10 to 0.15 microns (100 nm to 150 nm). (EX1101, 11:65-12:2.)

138. I have been advised by counsel that a *prima facie* case of obviousness typically exists when the ranges of a claimed composition overlap the ranges disclosed in the prior art, and that, in the absence of evidence indicating that there is something special or critical about the claimed range, an overlap shows that the claimed range was disclosed in, and therefore obvious in light of, the prior art.

139. The annotated Figure 10 on the following page compares the ranges claimed in the ’539 patent to the ranges disclosed by Stokes.



Stokes, 7:4-17 – “preferentially scatter” blue light

Stokes, *id.* – “scatter at least 50% more” (up to ≈ 225 nm)

Stokes, *id.* – “100 to 200 nm” (exemplary range)

'539 patent, claim 1c – scatter “relatively more” blue light than red/green

'539 patent, claim 1e – “scatter at least twice as much” (up to ≈ 175 nm, *see* 12:5-8)

'539 patent, claim 2 – “less than 150 nm”

'539 patent, 8:50-54 – “100 to 150 nm” (exemplary range)

Annotated Figure 10

140. Consistent with claim element [1e], Stokes discloses the routine optimization of average particle size⁶ to preferentially scatter blue light. In particular, as reflected in the annotated Figure 10 of the '539 patent above, Stokes explicitly discloses selecting an average particle size that scatters excitation light at least 1.5 times as much as light emitted by the phosphor and gives an exemplary range of 0.10 to 0.20 microns (100 to 200nm).

141. In particular, Stokes discloses:

Preferably, the particle size is selected such that the particles scatter *at least 50% more* radiation source radiation than luminescent material radiation. FIG. 6 illustrates the relationship between the particle diameter and the wavelength of the scattered light for Ti-Pure® rutile TiO₂ particles made by DuPont. As illustrated in FIG. 6, the relative scattering power of 100 to 200 nm TiO₂

⁶ Consistent with the DuPont model being theoretical, the DuPont graphs and related prior art such as Stokes are based on exact particle size, not the more practical average particle size. A broad distribution of particle sizes may have the same average particle size as a narrower distribution while having very different scattering properties. Given that the average particle size of a set of exact theoretical particles is the same as the exact particle size, the distinction does not matter for obviousness.

particles is above 1 for blue incident radiation, while it is below 1 for green and red incident radiation. Therefore, as illustrated in FIG. 6, ***100 to 200 nm particles have at least a 50% greater scattering power*** for blue radiation (i.e., such as that emitted by a blue emitting LED) than green or red (or for that matter yellow) radiation (i.e., such as that emitted by the phosphor or dye).

(EX1108, 7:4-17; *see also* EX1124 (Toquin) at ¶¶[0080]-[0081] (disclosing preferentially scattering blue light using particles of approximately 150 nm).)

142. In other words, Krummacher discloses the use of particles with “at least a 50% greater scattering power for blue radiation,” which includes the particles that that “scatter[] the blue light at least twice as much.” Thus, as illustrated in the annotated Figure 10 above, the range of average particle size disclosed by Stokes based on preferentially scattering blue light overlaps and entirely encompasses the similar range required by this claim element.

143. Neither Stokes nor the '539 patent assign any particular significance to the disclosed ranges, other than that they are based on preferentially scattering blue light. The values recited for the endpoints of both ranges appear to be based on rough estimations in reading DuPont's chart. And the difference between the disclosed ranges is one of degree rather than kind.

144. As discussed above, a POSA would have recognized selecting an average particle size as a design decision to be made based on a number of factors,

including the light scattering properties of the particles, and well within the skill of the art. For example, a POSA would weigh the benefits of maximizing the ratio of blue light scattered compared to yellow light with the potential downsides, including not maximizing blue light scattered, decreasing light output due to increased internal reflection, and limiting the commercially-practical options for rutile TiO₂ by requiring a narrower range of average particle size.

145. Thus, it is my opinion that Krummacher in view of Shimizu and Stokes teach this claim element.

146. It is my opinion that Krummacher thus teaches all of the elements of claim 1 and renders claim 1 obvious as a whole.

Claim 2: Average Particle Size Less Than 150nm

147. Claim 2 requires “[t]he component of claim 1, wherein the light scattering material has an average particle size that is less than about 150 nm.”

148. As discussed above, Krummacher in view of Stokes and Shimizu renders obvious claim 1. Claim 2 claims a range of average particle sizes with the lower bound of claim element 1c (“relatively more”) and the upper bound of the exemplary range disclosed by the ’539 patent (150 nm). The ’539 patent discloses no particular significance to any of these ranges. With respect to the 150 nm bound, the ’539 patent simply states:

Light diffractive particles within the light diffusing layer are selected to have a size such that the particles will scatter blue light generated by the LED relatively more than they will scatter light generated by a wavelength conversion layer, e.g., where the particles have an average particle size that is less than about 150 nm.

(EX1101, 25:57-62.)

149. As discussed in detail above, consistent with claim 2, Stokes discloses the routine optimization of average particle size to preferentially scatter blue light and discloses a preferred range of about 100 to 200 nm. (*See, e.g.*, EX1108, 7:4-17.) Thus, as shown in the annotated Figure 10 above, Stokes discloses ranges of average particle size that encompass and overlap the claimed range of average particle sizes—including the 100 to 150 nm range that is described as advantageous (EX1101, 8:53-54) and essentially the same as the range required by claim element 1e—rendering claim 2 obvious. As discussed above, these ranges have no particular significance, other than that they are based on preferentially scattering blue light. As also discussed above, a POSA would have recognized selecting an average particle size as a design decision to be made based on a number of factors, including the light scattering properties of the particles, and well within the skill of the art. (*Id.*)

150. It is my opinion that Krummacher in view of Stokes and Shimizu thus teaches all of the elements of claim 2 and renders claim 2 obvious as a whole.

Claim 3: Light Scattering Material is TiO₂

151. Claim 3 requires “[t]he component of claim 1, wherein the light scattering material is selected from the group consisting of: titanium dioxide, barium sulfate, magnesium oxide, silicon dioxide and aluminum oxide.”

152. As discussed above, Krummacher discloses or renders obvious claim 1. As also discussed above with respect to the light diffusing layer requirement of claim 1, Krummacher discloses TiO₂ as a light scattering material. (EX1107 at [0039] (“Particularly suitable are particles of TiO₂ or Al₂O₃, preferably having a radius of between 50 nm inclusive and 1000 nm inclusive.”).)

153. It is my opinion that Krummacher thus teaches all of the elements of claim 10 and renders claim 3 obvious as a whole.

Claim 4: Wavelength Conversion and Diffusing Layers

154. Claim 4 requires “[t]he component of claim 1 wherein the at least one photoluminescence material is located in a wavelength conversion layer and the light scattering material is located in a diffusing layer.”

155. As discussed above, Krummacher in view of Stokes and Shimizu renders obvious claim 1. As also discussed above with respect to [1a] the photoluminescence material requirement and [1b] the light scattering material requirement of claim 1 above, Krummacher discloses a wavelength conversion

layer containing a photoluminescent material and a separate diffusing layer containing a light scattering material.

156. It is my opinion that Krummacher in view of Stokes and Shimizu thus teaches all of the elements of claim 4 and renders claim 4 obvious as a whole.

Claim 5: Layers in Direct Contact

157. Claim 5 requires “[t]he component of claim 4, wherein the wavelength conversion layer and the light diffusing layer are in direct contact with each other.”

158. As discussed above, Krummacher discloses or renders obvious claim 4.

159. Krummacher further discloses that the wavelength conversion layer and the light diffusing layer are in direct contact with each other. As shown in Figures 1 and 2 (annotated here), “[t]he luminescence conversion layer 5 is followed in the radiation direction 9 by a light-scattering translucent layer 6” and the layers are in direct contact. (EX1107 at [0038].) Indeed, “[i]n a particularly preferred embodiment, the light scattering translucent layer is applied directly to the luminescence conversion layer.” (EX1107 at [0018].)

FIG 1

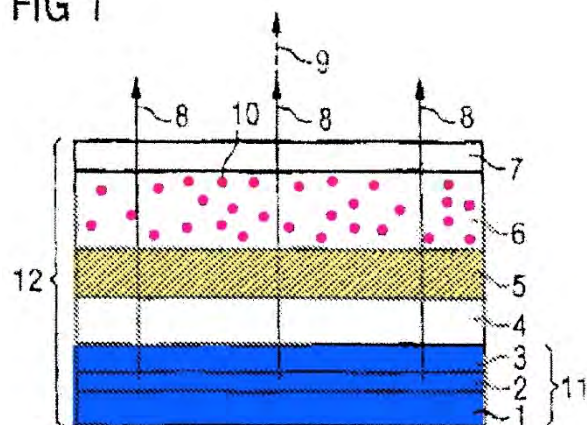
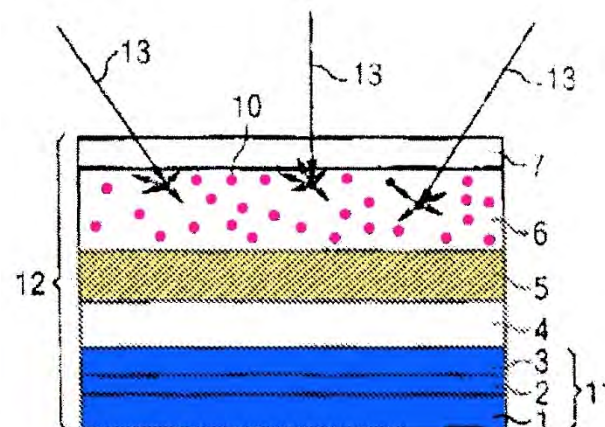


FIG 2



160. It is my opinion that Krummacher thus teaches all of the elements of claim 5 and renders claim 5 obvious as a whole.

Claim 6: Layers in Light Transmissive Binder

161. Claim 6 requires “[t]he component of claim 4, wherein the wavelength conversion layer comprises a mixture of the at least one phosphor material and a light transmissive binder and the light diffusing layer comprises a mixture of the light scattering material and the light transmissive binder.”

162. As discussed above, Krummacher discloses or renders obvious claim 4. Krummacher further discloses the wavelength conversion layer and the light diffusing layer both being mixtures including a light transmissive binder, such as silicone.

163. As discussed above, Krummacher discloses that “[t]he luminescence conversion material of the luminescence conversion layer 5 is advantageously

embedded in a transparent matrix, for example in polycarbonate, silicone, epoxy or PMMA.” (EX1107 at [0037].) Krummacher further discloses:

In a further preferred embodiment, the light-scattering translucent layer is a layer of synthetic material. The layer of synthetic material can in particular be applied by laminating or gluing. Alternatively, the layer of synthetic material can also be produced by spin coating, for example. In this fashion, even relatively large radiation-emitting areas, particularly large-area lighting units, can be provided with the light-scattering translucent layer with relatively little production expenditure.

(EX1107 at [0014].)

164. Silicone is an example of an appropriate synthetic material and is disclosed by Krummacher. Accordingly, Krummacher discloses that both the light diffusing layer and the wavelength converting layer may be made of a mixture with a light transmissive binder such as silicone.

165. Although Krummacher does not expressly specify that both layers use the same light transmissive binder, a POSA would have understood Krummacher to disclose both layers being a silicone binder. A POSA would understand that using a single transmissive binder would result in the layers having similar refractive indexes and thus minimize reflection loss. (*See* EX1107 at [0002] (“Further, it is advantageous if the refractive index of the adhesive is matched to

the refractive index of the light-scattering translucent layer and/or of the luminescence conversion layer to minimize reflection losses at the interface.”). (See EX1107 at [0012])). While it is possible to find binder materials with the same refractive indexes, the most obvious way to do so is to use the same materials. Using a silicone binder is also consistent with avoiding absorption losses. (See EX1107 at [0016] (“The thickness of the light-scattering translucent layer is advantageously selected so that it has a sufficient light-scattering effect but absorption losses in the layer are quite low. The layer thickness of the translucent layer is preferably 500 μm or less.”).)

166. Moreover, Shimizu discloses that the light diffusing layer is made of silicone: “the molding material 104, transparent materials having high weatherability such as epoxy resin, urea resin, silicon[e] resin or glass is preferably employed.” (EX1110 at 17:6-9). Shimizu further discloses that the wavelength conversion layer is made of silicone: “The coating material [101] may be a transparent material having good weatherability such as epoxy resin, urea resin and silicon[e] or glass.” (EX1110 at 16:47-49.)

167. Stokes also discloses that the light diffusing layer is made of silicone: “the radiation scattering particles comprise ceramic or other insulating particles dispersed in the carrier medium selected from glass, such as SiO₂, or a plastic material or a polymer, such as epoxy, silicone or urea resin.” (EX1108 at 6:36-40.)

Stokes further discloses that the wavelength conversion layer is made of silicone: “the luminescent material 45 comprises a packed phosphor particle layer or a dispersion of phosphor particles in a polymer encapsulating material[, which] may comprise epoxy or silicone.” (EX1108 at 6:6-9.)

168. A POSA would have been motivated to use the binder disclosed by Stokes and Shimizu with the conventional white light LED called for by Krummacher. Shimizu, in particular, is cited by both the '539 patent and the prior art. Thus, it would have been obvious to look to Shimizu and Stokes for details of the conventional white light LED light source used in Krummacher. And a POSA would have had a reasonable expectation of success in doing so, because they would simply be using the conventional white light LED disclosed in the prior art as directed by Krummacher. In other words, not only does Krummacher suggest the use of an LED with a binder like that disclosed in Stokes and Shimizu, to do so would have been the simple substitution of one known element for another to obtain predictable results.

169. It is my opinion that Krummacher thus discloses or suggests all of the elements of claim 6 and renders claim 6 obvious as a whole.

Claim 7: Light Transmissive Binder is Silicone

170. Claim 7 requires “[t]he component of claim 6, wherein the light transmissive binder comprises a curable liquid polymer selected from the group

consisting of: a polymer resin, a monomer resin, an acrylic, an epoxy, a silicone and a fluorinated polymer.”

171. As discussed above, Krummacher discloses or renders obvious claim 6. As also discussed above with respect to claim 6, Krummacher particularly discloses silicone as a light-transmissive binder. That is, Krummacher discloses that “[t]he luminescence conversion material of the luminescence conversion layer 5 is advantageously embedded in a transparent matrix, for example in polycarbonate, silicone, epoxy or PMMA.” (EX1107 at [0037].)

172. Moreover, Shimizu discloses that the light diffusing layer is made of silicone: “the molding material 104, transparent materials having high weatherability such as epoxy resin, urea resin, silicon[e] resin or glass is preferably employed.” (EX1110 at 17:6-9). Shimizu further discloses that the wavelength conversion layer is made of silicone: “The coating material [101] may be a transparent material having good weatherability such as epoxy resin, urea resin and silicon[e] or glass.” (EX1110 at 16:47-49.)

173. Stokes also discloses that the light diffusing layer is made of silicone: “the radiation scattering particles comprise ceramic or other insulating particles dispersed in the carrier medium selected from glass, such as SiO₂, or a plastic material or a polymer, such as epoxy, silicone or urea resin.” (EX1108 at 6:36-40.) Stokes further discloses that the wavelength conversion layer is made of silicone:

“the luminescent material 45 comprises a packed phosphor particle layer or a dispersion of phosphor particles in a polymer encapsulating material[, which] may comprise epoxy or silicone.” (EX1108 at 6:6-9.)

174. A POSA would have been motivated to use the binder disclosed by Stokes and Shimizu with the conventional white light LED called for by Krummacher. Shimizu, in particular, is cited by both the '539 patent and the prior art. Thus, it would have been obvious to look to Shimizu and Stokes for details of the conventional white light LED light source used in Krummacher. And a POSA would have had a reasonable expectation of success in doing so, because they would simply be using the conventional white light LED disclosed in the prior art as directed by Krummacher. In other words, not only does Krummacher suggest the use of an LED with a binder like that disclosed in Stokes and Shimizu, to do so would have been the simple substitution of one known element for another to obtain predictable results.

175. It is my opinion that Krummacher thus teaches all of the elements of claim 7 and renders claim 7 obvious as a whole.

Claim 8: Weight Loading of Light Scattering Material

176. Claim 8 depends from claim 6 and includes the limitation “wherein the weight loading of light scattering material to binder selected from the group consisting of: 7% to 35% and 10% to 20%.”

177. Krummacher in view of Stokes and Shimizu discloses or renders obvious this limitation. For example, Stokes discloses that “[p]referably, layer 156 comprises a silicone layer containing a dispersion of 5-10% amorphous silica particles having a mean diameter of 120 to 200 nm...” (EX1108, 8:21-24.)

178. It is my opinion that Krummacher in view of Stokes and Shimizu thus teaches all of the elements of claim 8 and renders claim 8 obvious as a whole.

Claim 9: Deposition Methods

179. Claim 9 depends from claim 4 and includes the limitation “wherein the wavelength conversion and light diffusing layers are deposited using a method selected from the group consisting of: screen printing, slot die coating, spin coating, roller coating, drawdown coating and doctor blading.”

180. Krummacher in view of Stokes and Shimizu discloses or renders obvious this limitation. For example, Krummacher teaches that

The layer of synthetic material can in particular be applied by laminating or gluing. Alternatively, the layer of synthetic material can also be produced by spin coating, for example.

(EX1107, ¶[0014].) Stokes similarly discloses a layer of “preferably about 0.5 micron thick [is] vacuum deposited or spin-on SiO₂ layer over the top of the LED chip 53.” (EX1108, 7:57-59.)

181. It is my opinion that Krummacher in view of Stokes and Shimizu thus teaches all of the elements of claim 9 and renders claim 9 obvious as a whole.

Claim 10: Planar Shapes

182. Claim 10 requires “[t]he component of claim 4 in which the wavelength conversion layer and the light diffusing layer comprises planar shapes.”

183. As discussed above, Krummacher discloses or renders obvious claim 4. As in Figures 1 and 2 above, Krummacher discloses a wavelength conversion layer and light diffusing layers that comprise planar (i.e., flat) shapes, because they are flat layers. Indeed, Krummacher teaches:

The thickness of the light-scattering translucent layer is advantageously selected so that it has a sufficient light-scattering effect but absorption losses in the layer are quite low. The layer thickness of the translucent layer is preferably 500 μm or less.

(EX1107 at [0016].)

184. It is my opinion that Krummacher thus teaches all of the elements of claim 10 and renders claim 10 obvious as a whole.

Claim 11: Dome or Elongated Dome Shaped Light Diffusing Layer

185. Claim 11 depends from claim 4 and requires that “the light diffusing layer comprises a dome or elongated dome shape.”

186. As discussed above, Krummacher in view of Stokes and Shimizu renders obvious claim 4. Krummacher in view of Stokes and Shimizu also discloses or renders obvious this limitation. In particular, Stokes and Shimizu disclose LED light sources with light diffusing layers and that such devices may have a dome shape. (*See, e.g.*, EX1108, fig. 4 (Stokes duplicating Shimizu).)

187. Thus it is my opinion that Krummacher in view of Stokes and Shimizu thus teaches all of the elements of claim 11 and renders claim 11 obvious as a whole.

Independent Claim 18: Light Emitting Device

188. Claim 18 of the '539 patent reads as follows:

18. A light emitting device, comprising:
at least one solid-state light emitter operable to generate
excitation light; and
a wavelength conversion component comprising:
at least one photoluminescence material; and
a light scattering material, wherein the light scattering material
has an average particle size that is selected such that the
light scattering material will scatter excitation light from the
at least one solid-state light emitter relatively more than the
light scattering material will scatter light generated by the at
least one photoluminescence material,

wherein the wavelength conversion component is configured such that in operation a portion of the excitation light comprising blue light having a wavelength of greater than or equal to 440 nm 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 photoluminescence material.

189. In other words, claim 18 requires a “light emitting device comprising” the wavelength conversion component of claim 1 and “at least one solid-state light emitter operable to generate excitation light.”

190. Krummacher discloses a “light emitting device” in the form of an LED or LED light source comprising a blue-light-emitting semiconductor chip coupled with a luminescent conversion layer to produce white light. (EX1107 at [0022].) Claim 18 is essentially identical to claim 1 except that claim 18 also encompasses the “solid-state light emitter operable to generate excitation light,” or LED chip. As discussed in detail above with respect to claim 1, Krummacher discloses each of these claim requirements as arranged in the claim, including the LED chip. (*See also* EX1107 at [0004] (explaining relevance to lighting based on “organic light-emitting diodes (OLEDs)” and “LEDs or LED light sources having

one or more radiation-emitting semiconductor chips”). Stokes and Shimizu each disclose blue LEDs emit at wavelengths of 440nm or greater.

191. It is my opinion that the combination of Krummacher, Stokes, and Shimizu thus discloses or suggests all of the elements of claim 18 and renders claim 18 obvious as a whole.

Claim 19: Applications for the Light Emitting Device

192. Claim 19 requires “The device of claim 18, wherein the light emitting device is selected from the group consisting of: ... traffic lights ... and signs.” Shimizu discloses a “light emitting diode used in LED display, back light source, traffic signal, railway signal, illuminating switch, indicator, etc.” (EX1110, 1:12-14.)

193. It is my opinion that the combination of Krummacher, Stokes, and Shimizu thus discloses or suggests all of the elements of claim 19 and renders claim 19 obvious as a whole.

Claim 20: Improved Off-State White Appearance

194. Claim 20 requires “[t]he device of claim 18 in which the light scattering material within the light diffusing layer corresponds to an average particle size that improves the OFF state white appearance of the wavelength conversion component.”

195. Krummacher discloses that in conventional optoelectronic components:

“[T]he optical impression produced by the optoelectronic component when it is in the off state frequently is not satisfactory. The reason for this is that in a bright environment, the luminescence conversion layer is stimulated to emit yellow light even when the optoelectronic component is off, but without the superimposition of blue light to yield white light, as when it is on. As a result, in the off state, the surface of the optoelectronic component in the areas provided with the luminescence conversion layer exhibit the color of the longer wavelength produced by luminescence conversion—yellow, for example—which is often found unattractive by observers.” (EX1107, ¶[0004].)

196. Krummacher solves this problem, explaining that:

“Advantageously, the distribution, size and material of the light-scattering particles 10 in light-scattering translucent layer 6 are selected such that the surface of light scattering translucent layer 6 appears white. In this way, the luminescence conversion layer 5 is advantageously prevented from exhibiting a yellowish hue, in the off state of the optoelectronic component depicted in FIG. 2, due to stimulation of the luminescence conversion materials by environmental light 13 incident from the outside.” (EX1107, ¶[0041].)

197. Accordingly, Krummacher discloses the light diffusing layer improves an off-state white appearance of the light emitting device. The combination of Krummacher, Stokes, and Shimizu thus discloses or suggests all of the elements of claim 20 and renders claim 20 obvious as a whole. Given that Krummacher discloses the light diffusing layer improves an off-state white appearance, the light diffusing layer has “an average particle size that improves the OFF state white appearance” as required by claim 20. In any case, Krummacher also discloses that the light-scattering particles “[p]articularly suitable are particles of TiO_2 or Al_2O_3 , preferably having a radius of between 50 nm inclusive and 1000 nm inclusive. (EX1107 at [0010].)

198. Moreover, an “average particle size that improves OFF state white appearance” would have been obvious in view of Stokes and Shimizu. Shimizu teaches this requirement. It discloses “[a]s a dispersant, barium titanate, titanium oxide [i.e., titanium(IV) oxide, or TiO_2], aluminum oxide, silicon dioxide and the like can be used.” (EX1110 at 17:9-11.) It further discloses:

According to the present invention, adding the dispersant and/or a coloration agent in the molding material has the effects of masking the color of the fluorescent material obscured and improving the color mixing performance. That is, the fluorescent material absorbs blue component of extraneous light and emits light thereby to give such an appearance as though colored in yellow. However, the

dispersant contained in the molding material gives milky white color to the molding material and the coloration agent renders a desired color. Thus the color of the fluorescent material will not be recognized by the observer.

(EX1110 at 17:25-35.) Given that, as discussed in detail above, Shimizu discloses a white light LED light source consistent with the claims and covered by a light diffusing layer of silicone containing TiO₂ particles, Shimizu alone anticipates every requirement of claim 1.

199. Stokes also discloses a light diffusing layer that contains TiO₂ particles. Stokes discloses considerations for choosing an average particle size in the context of a light diffusing layer. (*E.g.*, EX1108 at 7:1:26.) Of particular note, Stokes discloses that:

In one preferred embodiment, 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. Preferably, the particle size is selected such that the particles scatter at least 50% more radiation source radiation than luminescent material radiation. FIG. 6 illustrates the relationship between the particle diameter and the wavelength of the scattered light for Ti-Pure® rutile TiO₂ particles made by DuPont. As illustrated in FIG. 6, the relative scattering power of 100 to 200 nm TiO

particles is above 1 for blue incident radiation, while it is below 1 for green and red incident radiation. Therefore, as illustrated in FIG. 6, 100 to 200 nm particles have at least a 50% greater scattering power for blue radiation (i.e., such as that emitted by a blue emitting LED) than green or red (or for that matter yellow) radiation (i.e., such as that emitted by the phosphor or dye). This particle size range is advantageous because it enhances the scattering of the radiation source radiation while it decreases the amount of scattering of the luminescent material radiation. Therefore, the lamp radiation output is rendered more uniform because a greater amount of radiation source radiation is scattered toward the luminescent material, while a lesser amount of the luminescent material radiation that is emitted downward toward the radiation source is scattered back toward the luminescent material.

(EX1108 at 7:1-26.) As shown below, Figure 6 of Stokes is essentially identical to Figure 10 of the '539 patent. It appears that the applicants copied Figure 10 from a 2007 DuPont brochure (EX1112, fig.4; EX1113, fig.7) without attribution.

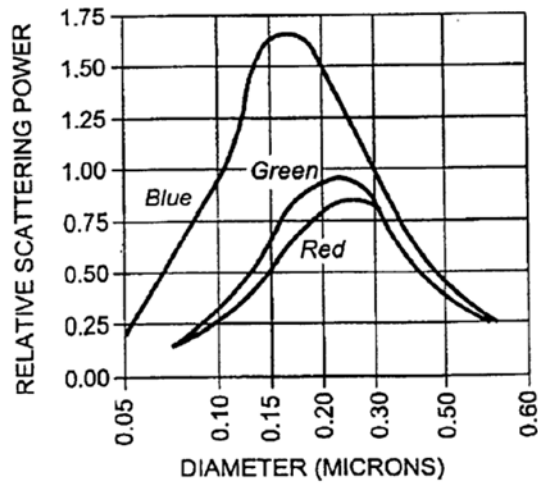


fig. 6
(PRIOR ART)

2:

:

(EX1108).

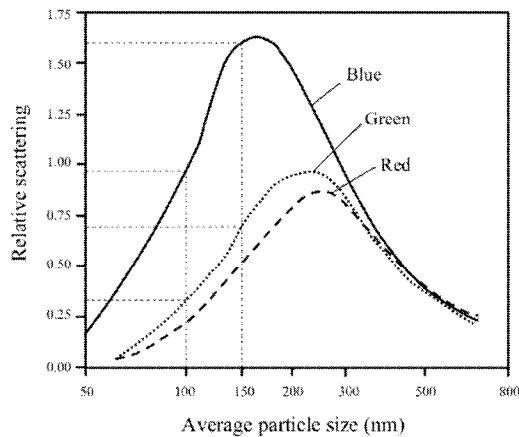


FIG. 10

(EX1101).

200. As discussed above, a POSA would have looked to the state of the art such as Stokes for the details of a conventional white light LED, particularly because it is directed to a light diffusing layer. Thus, it would have been obvious to look to Stokes, which incorporates Shimizu, for details of the conventional white

light LED light source used in Krummacher. A POSA would have had a reasonable expectation of success given that the disclosures would be used for their expected functions.

201. It is my opinion that Krummacher thus discloses or suggests all of the elements of claim 20 and renders claim 20 obvious as a whole.

Claim 23: Average Particle Size Less Than 150nm

202. Claim 23 claims a range of average particle sizes with the lower bound of claim element 1c (“relatively more”) and the upper bound of the exemplary range disclosed by the ’539 patent (150 nm). The ’539 patent discloses no particular significance to any of these ranges. With respect to the 150 nm bound, the ’539 patent simply states:

Light diffractive particles within the light diffusing layer are selected to have a size such that the particles will scatter blue light generated by the LED relatively more than they will scatter light generated by a wavelength conversion layer, e.g., where the particles have an average particle size that is less than about 150 nm.

(EX1101, 25:57-62.)

203. As discussed in detail above, consistent with claim 2, Stokes discloses the routine optimization of average particle size to preferentially scatter blue light and discloses a preferred range of about 100 to 200 nm. (*See, e.g.*, EX1108, 7:4-17.) Thus, as shown in the annotated Figure 10 above, Stokes discloses ranges of

average particle size that encompass and overlap the claimed range of average particle sizes—including the 100 to 150 nm range that is described as advantageous (EX1101, 8:53-54) and essentially the same as the range required by claim element 1e and claim 18—rendering claim 23 obvious. As discussed above, these ranges have no particular significance, other than that they are based on preferentially scattering blue light. As also discussed above, a POSA would have recognized selecting an average particle size as a design decision to be made based on a number of factors, including the light scattering properties of the particles, and well within the skill of the art.

204. It is my opinion that Krummacher in view of Stokes and Shimizu thus teaches all of the elements of claim 23 and renders claim 23 obvious as a whole.

Claim 24: Planar Shapes

205. Claim 24 requires “[t]he device of claim 18 in which the wavelength conversion layer and the light diffusing layer comprises planar shapes.”

206. As discussed above, Krummacher discloses or renders obvious claim 18. And as discussed in detail with respect to claim 10, Krummacher further discloses that the wavelength conversion layer and the light diffusing layer comprises planar shapes.

207. It is my opinion that Krummacher thus teaches all of the elements of claim 24 and renders claim 24 obvious as a whole.

Claim 25: Dome or Elongated Dome Shaped Light Diffusing Layer

208. Claim 25 requires “the device of claim 18 in which the light diffusing layer comprises a dome or elongated dome shape.”

209. Krummacher in view of Stokes renders obvious this limitation. In particular, Stokes disclose LED light sources with light diffusing layers and that such devices may have a dome shape. (*See, e.g.*, EX1108, fig. 4 (Stokes duplicating Shimizu).)

210. It is my opinion that Krummacher in view of Stokes thus teaches all of the elements of claim 25 and renders claim 25 obvious as a whole.

[GROUND 2] Claims 18 and 28 are rendered obvious by Hussell, Krummacher, and Van Woudenberg

211. As discussed above, Ground 1 renders obvious independent claims 1 and 18 of the '539 patent. Ground 2 further includes the teaching of “light bulb” type LED emitters by Hussell. As discussed above, the prior art discloses conventional white-light LED light sources with light diffusing layers as required by the claims. Claim 28 further require that the white light LED light source be incorporated into a device such as a light bulb, specifically:

- 28. A light bulb comprising:
 - a connector base configured to be inserted in a socket to form an electrical connection for the light bulb;
 - a body comprising one or more solid-state light emitters;

a wavelength conversion component having a three dimensional shape that is configured to enclose the one or more solid-state light emitters and to in part at least define a light mixing chamber,
wherein the wavelength conversion component comprises at least one photoluminescence material; and
a light scattering material, wherein the light scattering material has an average particle size that is selected such that the light scattering material will scatter excitation light from the one or more solid-state light emitters relatively more than the light scattering material will scatter light generated by the at least one photoluminescence material,
wherein the wavelength conversion component is configured such that in operation a portion of the excitation light comprising blue light having a wavelength of greater than or equal to 440 nm 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 photoluminescence material.

Independent Claims 18 and 28: Light Emitting Devices

212. Hussell discloses every feature required by independent claims 18 and 28 except Hussell does not explicitly disclose (i) light scattering material that has an average particle size that is selected such that the light scattering material will

scatter excitation light from the at least one solid-state light emitter relatively more than the light scattering material will scatter light generated by the at least one photoluminescence material, and (ii) that the wavelength of blue light emitted by the semiconductor light emitting device is greater than or equal to 440 nm.

213. Hussell discloses a light bulb containing LED “filaments” which it also refers to as “wavelength conversion tubes.” (EX1111, ¶[0052].) These filaments have YAG phosphor located on or near the outer surface of the tube to convert blue light. But such YAG phosphors – the same phosphors disclosed in Krummacher, Stokes, and Shimizu – appear yellow in the off-state. As disclosed in Krummacher (and other references discussed herein), such yellow appearance is undesirable. POSA would have thus been motivated to avoid such an appearance and would find success doing so by coating the filaments in Hussell with a light diffusing layer as taught by Krummacher. Stokes further discloses that a light diffusing layer, such as in Krummacher, may preferentially scatter blue light. (EX1108, fig.6.) And Van Woudenberg discloses the wavelength range of blue LEDs like those in Hussell. (EX1120, 5:14-24; Fig. 2.)

214. Both claims recite substantially overlapping subject matter. In particular, the wavelength conversion component recited in both claims has identical requirements to the requirements of the wavelength conversion

component of claim 1. For ease of discussion, I address these requirements together.

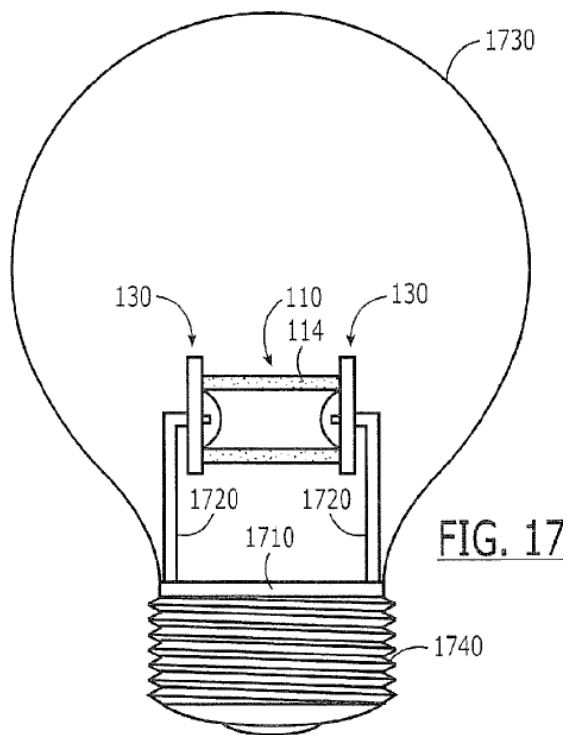
[pre/a] A light emitting device or light bulb comprising at least one solid-state emitter

215. Claim 18 covers any light-emitting device, while claim 28 covers a light bulb with a connector base configured to be inserted in a socket. Both require at least one “solid-state light emitter.”

216. Hussell discloses a “semiconductor light emitting apparatus” (EX1111, Abstract) that can be implemented in various configurations such as a light bulb. (*See id.* Fig. 17, ¶[0014], ¶[0052] (Figure 17 includes “bulb 1730”).) In the Figure 17 embodiment, Hussell teaches that the bulb “is connected to the screw-type base and surrounds the hollow wavelength conversion tube and the first and second semiconductor light emitting devices.” (EX1111, ¶[0014].) Hussell thus discloses a body (the bulb and the base) that is comprised of two solid-state light emitters (e.g., first and second semiconductor light emitting devices) which generate excitation light.

217. With respect to claim 28, Hussell discloses a light bulb with “a connector base configured to be inserted in a socket to form an electrical connection for the light bulb.” Figure 17 depicts an embodiment of the Hussell “semiconductor light emitting apparatus” in a light bulb having an Edison screw base which is a connector base configured to be inserted in a socket to form an

electrical connection for the light bulb. Moreover, as shown below, Figure 17 includes “bulb 1730” and “screw-type base 1740” and Hussell notes that the wavelength conversion tube 110 and packaged light emitting devices 130 “provides a **filament** for drop-in replacement for an incandescent bulb.” (EX1111, ¶[0052] (emphasis added).) Such a bulb “may also employ voltage conversion circuits, thermal management systems, etc.” to facilitate electrical operation of the light bulb. *Id.*



Hussell, Figure 17

[b]: ...wavelength conversion component ... defining a light mixing chamber

218. Claim 18 requires a wavelength conversion component, and claim 28 further requires the wavelength conversion component to define a light mixing

chamber. Hussell discloses the LED devices configured so that claimed wavelength conversion component defines a light mixing chamber.

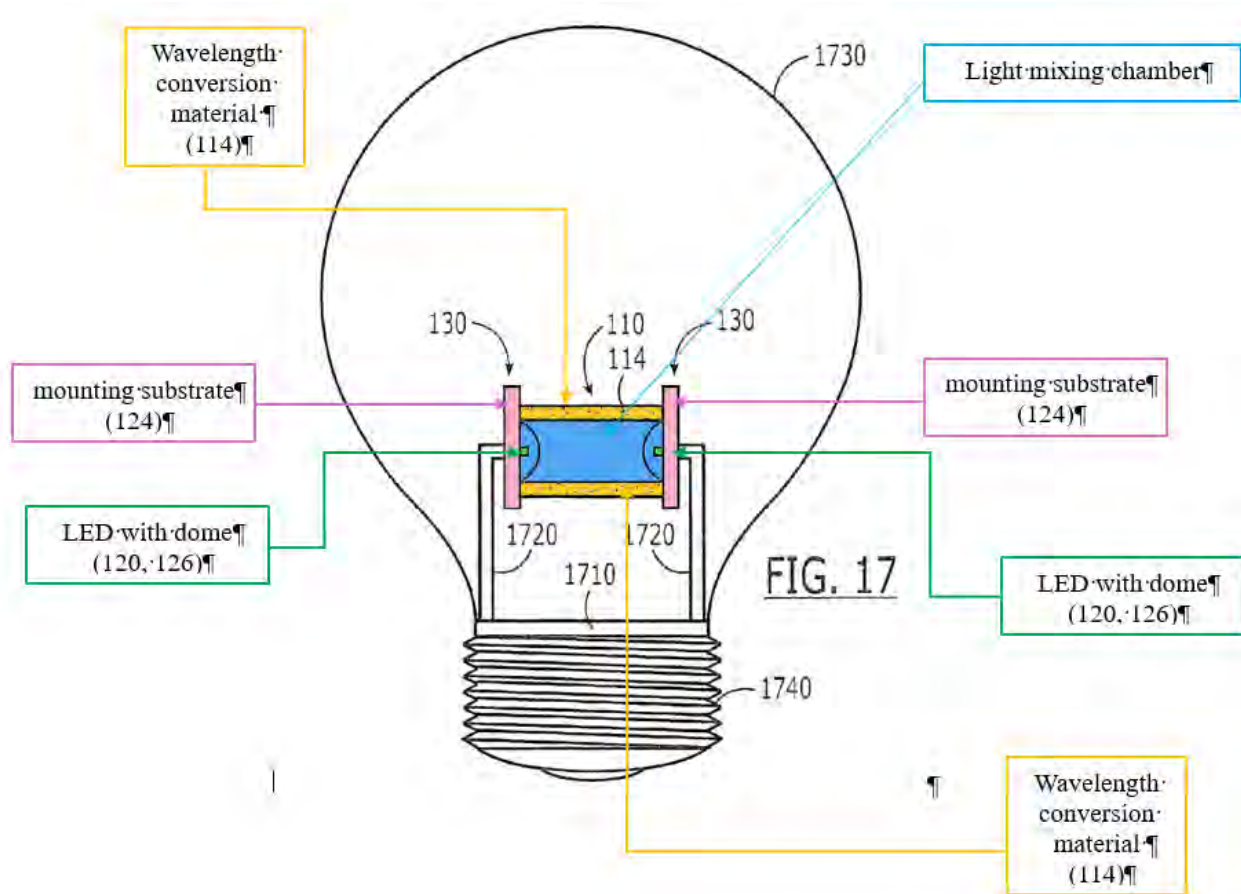
219. In the Figure 17 embodiment, Hussell teaches that the bulb “is connected to the screw-type base and surrounds the hollow wavelength conversion tube and the first and second semiconductor light emitting devices.” (EX1111, ¶[0014].) Hussell thus discloses a body (the bulb and the base) that is comprised of two solid-state light emitters (e.g., first and second semiconductor light emitting devices) which generate excitation light.

220. Moreover, as shown in the annotated Figure 17 below, the two LEDs in Hussell are contained within the ends of a three-dimensional wavelength conversion tube 110. (*See also* EX1111, ¶[0052] (“as shown in Fig. 17, an elongated hollow wavelength conversion tube 110 includes a packaged semiconductor device 130 at either end”).) (*See also* EX1111, ¶[0032], Fig. 1.)

221. The interior volume of hollow wavelength conversion tube 110 in the Figure 17 embodiment defines a light mixing chamber as shown in the image below.⁷ (*See also* EX1111, ¶[0017] (“A respective light emitting filament

⁷ The '539 patent equates the light mixing chamber of the wavelength conversion component with its interior volume. (EX1101, 24:54-55 (“The interior volume may also be referred to as a light mixing chamber.”).)

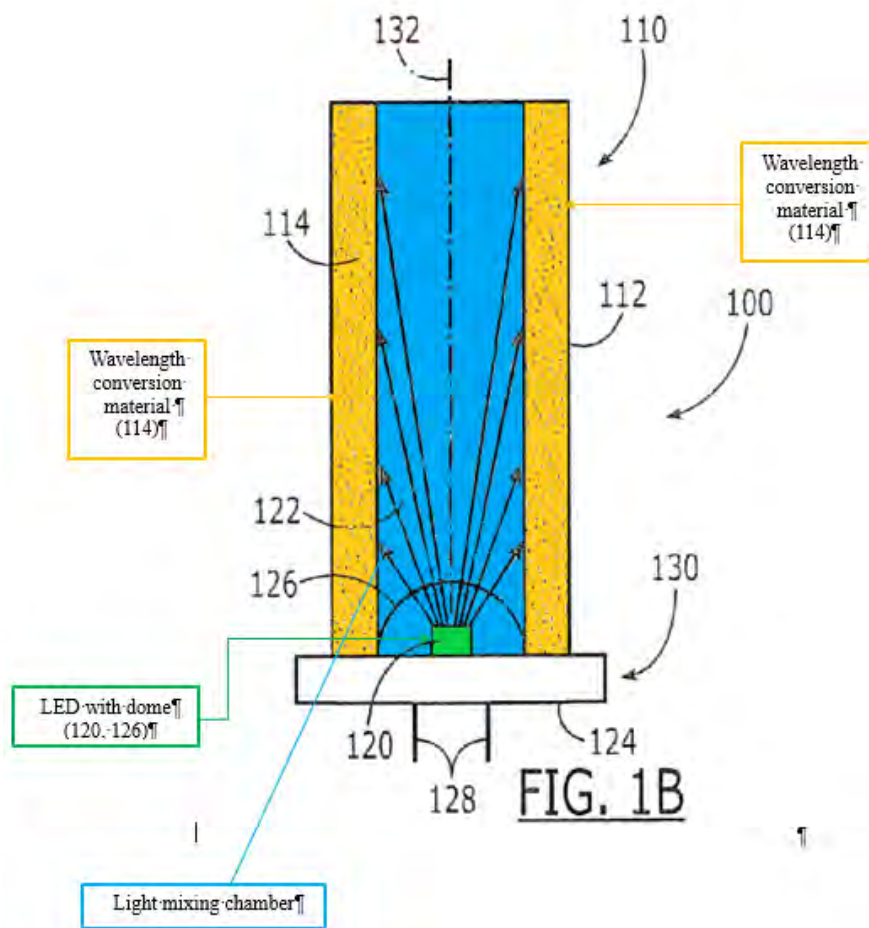
comprises an elongated hollow wavelength conversion tube that includes an elongated wavelength conversion tube wall having wavelength conversion material dispersed therein, and a semiconductor light emitting device that is oriented to emit light inside the elongated hollow wavelength conversion tube.”); ¶[0041] (“the emitted light 122 from the semiconductor light emitting device 120 reflects off the inner surface of the tube wall 110, as shown by ray 310, and also refracts within the tube wall”).)



Hussell, Annotated Figure 17

[c] at least one photoluminescence material; and

222. The combination of Hussell and Krummacher discloses these limitations. As noted above, Hussell discloses a wavelength conversion tube. The wavelength conversion tube includes a “tube wall having wavelength conversion material, such as phosphor, disposed therein.” (EX1111, Abstract.) Phosphor is a photoluminescence material because it converts light from one wavelength to another and is excitable by the blue, excitation light. “The tube wall may have a thickness of between about 0.05 mm and about 2 mm. Wavelength conversion particles 114 may be dispersed therein at concentrations between about 1% and about 70% by weight.” (*Id.*, ¶[0037].) “In order for the light 122, such as blue light, that emerges from the semiconductor light emitting device 120 to convert, for example to yellow light, it must impinge on a wavelength conversion material (e.g., phosphor) particle 114.” (*Id.*, ¶[0042].) The contents of the interior of the tube wall constitute the claimed wavelength conversion layer as shown in annotated Figure 1B below.



223. Hussell thus discloses a wavelength conversion component that includes a wavelength conversion layer comprising particles of at least one photoluminescence material.

[d] a light scattering material

224. It would have been obvious to a POSA to add a light diffusing layer on the outer surface of the tube wall in the wavelength conversion tube in Hussell in order to create an off-state white appearance in the “filament” disclosed in Hussell’s Figure 17 embodiment. Hussell discloses cerium-doped yttrium

aluminum garnet (YAG)⁸ as an exemplary “yellow phosphor” that can be used in the wavelength conversion tube. (EX1111, ¶[0006].) A POSA would understand that the YAG phosphor disclosed in Hussell (*see* EX1111, ¶[0036]) has the same unseemly yellow-ish appearance in the off state as the YAG phosphors in Krummacher. As discussed in detail above, Krummacher discloses a light-scattering layer:

Advantageously, the distribution, size and material of the light-scattering particles 10 in light-scattering translucent layer 6 are selected such that the surface of light scattering translucent layer 6 appears white. In this way, the luminescence conversion layer 5 is advantageously prevented from exhibiting a yellowish hue, in the off state of the optoelectronic component depicted in FIG. 2, due to stimulation of the luminescence conversion materials by environmental light 13 incident from the outside.

(EX1107, ¶41.)

225. A POSA’s motivation to modify the off-state appearance of the LED filament in Hussell is also evidenced by the teachings in Van Woudenberg (EX1120). Specifically, Van Woudenberg discloses the need to create an off-state

⁸ This is the same YAG phosphor used in Van Woudenberg, Krummacher, and Stokes for the same purpose – creating white light through phosphor conversion with a blue light LED. (*See, e.g.*, EX1120, 5:19-20.)

white appearance in YAG phosphor-coated LEDs (pc-LEDs) used in general lighting devices such as luminaires and downlights. (See EX1120, Abstract.) As explained by Van Woudenberg:

pc-LEDs are applied in automotive headlights and in torches (for either terrestrial handheld, mountaineering headsets or diving purposes). Furthermore, as the efficacy and output power of pc-LEDs increases their penetration in general purpose illumination devices is expected to grow considerably.

In a large number of the above-mentioned applications of pc-LEDs the user can look directly into the LED package(s) assembled in the lighting device. . . .

Whenever the pc-LED package is visible to the user in the functional off state of the lighting device it can be clearly recognized by its distinguished yellowish color.

....

The distinguished yellowish appearance of pc-LEDs and the luminaires in their functional off state is in a large number of applications a disturbing feature.

(See EX1120, 1:14-28.)

226. Hussell, like Van Woudenberg, teaches a general illumination device, an LED light bulb. Accordingly, Van Woudenberg evidences why a POSA would be motivated to change the unattractive off-state yellow-ish appearance of

Hussell's YAG phosphor wavelength conversion tube to a more neutral off-state white appearance.

227. Like Van Woudenberg, Krummacher discloses using a light scattering layer to improve an off state white appearance. (EX1107, ¶41.) Thus, in view of Van Woudenberg, a POSA would be motivated to use the solution provided by Krummacher in general lighting applications like light bulbs.

228. Moreover, a POSA would have had a reasonable expectation of success in adding a light diffusing layer comprising particles of a light scattering material to the outer surface of the wavelength conversion tube in Hussell in order to create a white appearance in the off-state. As discussed above, the light diffusing layer in Krummacher is comprised of light scattering particles (e.g., TiO₂) dispersed in silicone. (*See supra* claims 6, 7.) Krummacher discloses that the light diffusing layer can be “produced by spin coating” or “applied by laminating or gluing.” (EX1107, ¶[0031].) A POSA would understand that a layer that is “produced by spin coating” is simply a coating applied to another material. Moreover, because Hussell discloses that the wavelength conversion tube can be constructed from a wide variety of materials including plastic, epoxy or silicone, (EX1111, ¶[0034]) a POSA would have a reasonable expectation of success in applying light scattering particles (e.g., TiO₂) dispersed in silicone as taught in

Basin-2007 to the outer surface of the wavelength conversion tube in a coating or other method taught by Hussell such as molding or extrusion. (EX1111, ¶[0036]).

229. Hussell also teaches that it is desirable to increase the light scattering properties of the wavelength conversion tube by texturing the exterior surface. (“[T]he elongated tube wall 112 includes inner and outer surfaces wherein the inner and/or outer surfaces are textured as shown. The texturing may be uniform and/or non-uniform. Texturing may enhance scattering of light.” (EX1111, ¶[0048].) Adding a light scattering structure to the exterior surface of the tube as taught by Krummacher would also enhance light scattering. (*See, e.g.*, EX1107, ¶[0011].) This provides a separate motivation for a POSA to combine the TiO₂-containing layer of Krummacher with Hussell.

230. Thus, the wavelength conversion tube in Hussell as modified to include a light diffusing layer on the outer surface, constitutes the “wavelength conversion component” as claimed in this limitation.

[e] wherein 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

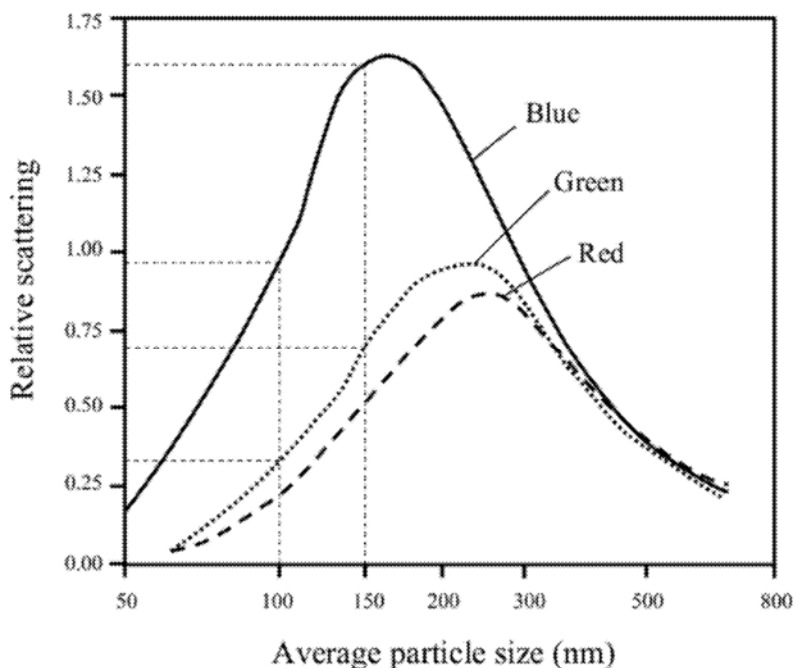
231. Stokes discloses:

In one preferred embodiment, 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.

(EX1108, 7:1-4.)

232. As discussed in detail above, Figure 10 of the '539 patent is essentially the same as graphs found in the prior art, including Figure 6 of Stokes, that were derived from the DuPont model described above. In particular, the graphs purport to show the relative scattering power of TiO₂ based on particle size for different colors of light.



'539 Patent, Figure 10

233. Krummacher discloses a light scattering material with TiO₂ particles “preferably having a radius of between 50 nm inclusive and 1000 nm inclusive.” (EX1107, ¶[0039].) According to the DuPont model, TiO₂ particles of such a size generally scatter more blue light (e.g., excitation light) than red or green light (e.g.,

light emitted by the phosphor). Accordingly, Krummacher renders obvious claim [1e] by literally disclosing the selection of average particle sizes that preferentially scatter blue light.

234. To the extent that the claim language “an average particle size that is selected such that [it preferentially scatters blue light]” requires an average particle size selected for that reason (rather than an average particle size that leads to that outcome), this claim element is rendered obvious by Stokes. As discussed above, Stokes explicitly discloses the selection of an average particle size “such that the particles preferentially scatter blue ... LED light as compared to yellow ... light from the luminescent material.” (EX1108, 7:1-4.)

235. As discussed above, Krummacher in view of Shimizu and Stokes discloses white-light LED light sources with TiO₂-containing light diffusing layers, meeting every requirement of this claim, including the claimed average particle size. To the extent this claim requirement is understood to also claim the basis for selecting a particular average particle size, a POSA would have had reason to use such a basis for selecting average particle size as taught by Stokes.

236. For example, Stokes discloses:

[The relevant] particle size range is advantageous because it enhances the scattering of the radiation source radiation while it decreases the amount of scattering of the luminescent material radiation. Therefore, the lamp

radiation output is rendered more uniform because a greater amount of radiation source radiation is scattered toward the luminescent material, while a lesser amount of the luminescent material radiation that is emitted downward toward the radiation source is scattered back toward the luminescent material.

(EX1108, 7:17-26.)

237. Thus, a POSA would have been motivated to apply this principle to Krummacher, because it would increase the conversion of blue light to yellow light and improve the uniformity of the light source. Conversion of blue light to yellow light is improved by maximizing the scattering of blue light. Uniformity is improved by preferentially scattering the concentrated light from the blue-light LED chip instead of the disperse light emitted by the phosphor.

238. A POSA would have had a reasonable expectation of success applying this principle to Krummacher, because the relevant particle size range includes the range disclosed by Krummacher. A POSA would have recognized selecting an average particle size as a design decision to be made based on a number of factors, including the light scattering properties of the particles, and well within the skill of the art.

239. Thus, it is my opinion that Krummacher in view of Shimizu and Stokes teaches this claim element.

[f] wherein the wavelength conversion component is configured such that in operation a portion of light comprising blue light having a wavelength of greater than or equal to 440 nm generated by the [at least one/ one or more] solid-state light emitter[s] is emitted through the wavelength conversion component to contribute to a final visible emission product.

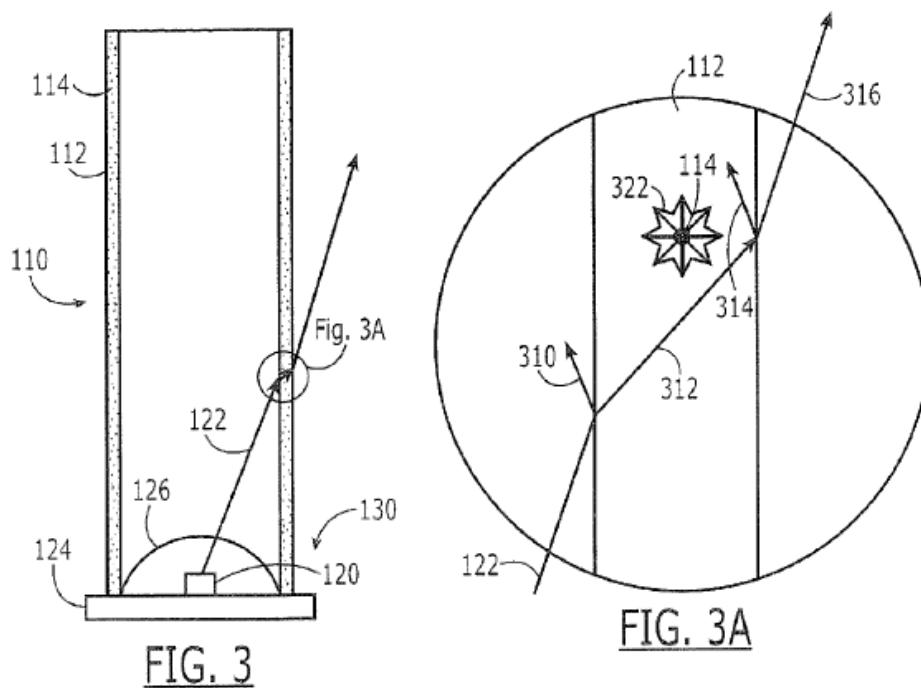
240. The combination of Hussell in view of Krummacher, Stokes, and Van Woudenberg discloses this limitation. Hussell discloses a tube wall having a thickness of between about 0.05 mm and about 2 mm with wavelength conversion particles dispersed therein at concentrations between about 1% and about 70% by weight. The use of an elongated hollow wavelength conversion tube according to various embodiments of the invention may provide efficient white light.”

(EX1111, ¶[0037].) At least some blue light emitted from the semiconductor device would thus be emitted through the wavelength conversion component at a wavelength greater than or equal to 440 nm. Indeed, Hussell itself explains, through reference to Figures 3 and 3A, why this is the case:

[R]eferring to FIGS. 3 and 3A, the emitted light 122 from the semiconductor light emitting device 120 reflects off the inner surface of the tube wall 110, as shown by ray 310, and also refracts within the tube wall, as shown by ray 312. Additional internal reflection takes place from the outer wall, as shown as by ray 314, and **some of the original light 316 emerges from the tube.** The path through the wall 112 is indicated by ray 312. In contrast, when light strikes a phosphor particle 114 that is

embedded within the tube wall 112, it is converted and scattered in all directions, as shown by the rays 322.

(EX1111, ¶[0041] (emphasis added).) (See also *id.*, ¶[0042] and ¶[0006] (“[A] blue emitting LED may be surrounded by a yellow phosphor... The resulting light, which is a combination of blue light and yellow light, may appear white to an observer.”).)



241. A POSA would likewise understand that the blue light emitted by the semiconductor light emitting device in Hussell in view of Van Woudenberg, further in view of Krummacher has a wavelength of greater than or equal to 440 nm. As explained in Van Woudenberg, the “primary light” emitted by an LED chip typically has a wavelength between 430 and 480 nm with the greatest distribution at around 440 nm. (EX1120, 5:14-24.) As shown in Figure 2 of Van Woudenberg

(reproduced below), light that hits the phosphor is converted to a much longer wavelength.

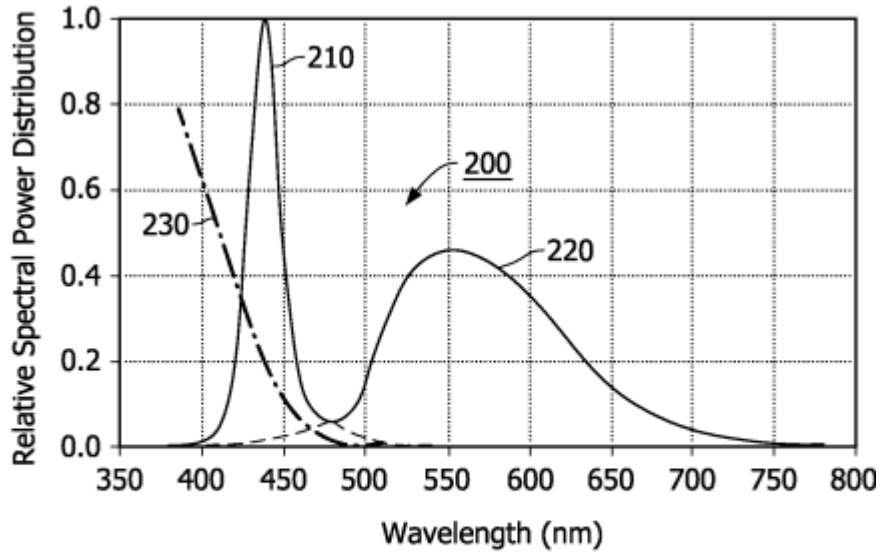


FIG. 2

242. Hussell has same purpose as Van Woudenberg – the creation of white light through YAG phosphor conversion using blue light LEDs – thus a POSA would have been motivated to use LEDs emitting blue light having wavelengths between 430-480nm according to Van Woudenberg in Hussell. Modifying Hussell to add a light diffusing layer would not have any effect on the wavelength of the blue light emitted through wavelength conversion component.

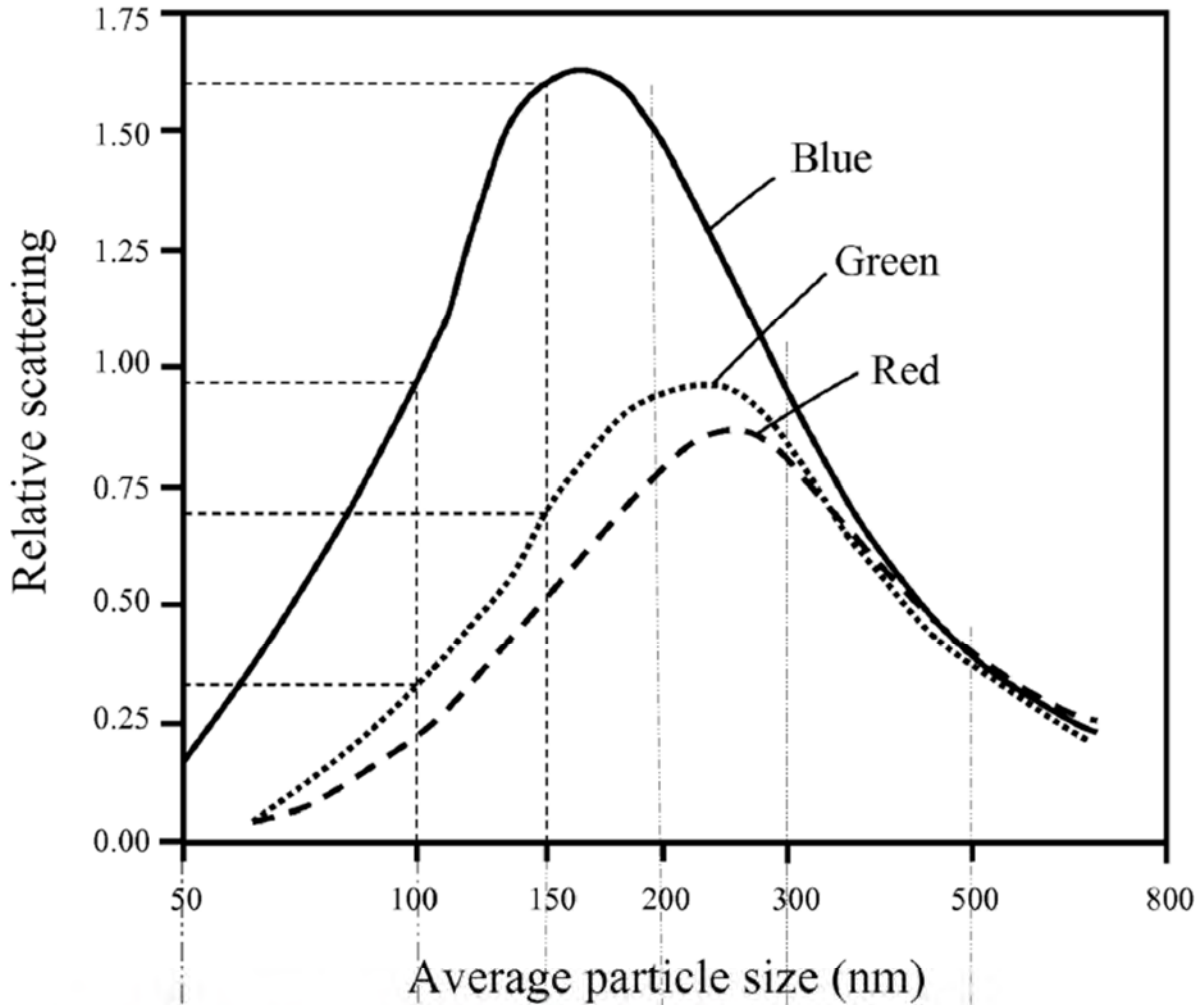
243. Hussell in view of Krummacher, Stokes, and Van Woudenberg thus discloses this limitation.

[g] wherein the light scattering material scatters the blue light at least twice as much as light generated by the at least one photoluminescence material

244. As discussed above, Krummacher in view of Shimizu and Stokes renders obvious claim element [e]. Claim element [g] only further requires that the “relatively more” of element [e] be “at least twice as much.” The ’539 patent discloses no particular significance to “at least twice as much” which represents a straightforward narrowing of the claimed average particle size range from claim element [e] so that it extends only up to around 175 nm, with the ’539 patent disclosing a preferred range of 0.10 to 0.15 microns (100 nm to 150 nm). (EX1101, 11:65-12:2.)

245. I have been advised by counsel that a *prima facie* case of obviousness typically exists when the ranges of a claimed composition overlap the ranges disclosed in the prior art, and that, in the absence of evidence indicating that there is something special or critical about the claimed range, an overlap shows that the claimed range was disclosed in, and therefore obvious in light of, the prior art.

246. The annotated Figure 10 on the following page compares the ranges claimed in the ’539 patent to the ranges disclosed by Stokes.



Stokes, 7:4-17 – “preferentially scatter” blue light

Stokes, *id.* – “scatter at least 50% more” (up to ≈ 225 nm)

Stokes, *id.* – “100 to 200 nm” (exemplary range)

'539 patent, claim 1c – scatter “relatively more” blue light than red/green

'539 patent, claim 1e – “scatter at least twice as much” (up to ≈ 175 nm, *see* 12:5-8)

'539 patent, claim 2 – “less than 150 nm”

'539 patent, 8:50-54 – “100 to 150 nm” (exemplary range)

Annotated Figure 10

247. Consistent with claim element [e], Stokes discloses the routine optimization of average particle size⁹ to preferentially scatter blue light. In particular, as reflected in the annotated Figure 10 of the '539 patent above, Stokes explicitly discloses selecting an average particle size that scatters excitation light at least 1.5 times as much as light emitted by the phosphor and gives an exemplary range of 0.10 to 0.20 microns (100 to 200nm).

248. In particular, Stokes discloses:

Preferably, the particle size is selected such that the particles scatter *at least 50% more* radiation source radiation than luminescent material radiation. FIG. 6 illustrates the relationship between the particle diameter and the wavelength of the scattered light for Ti-Pure® rutile TiO₂ particles made by DuPont. As illustrated in FIG. 6, the relative scattering power of 100 to 200 nm TiO₂

⁹ Consistent with the DuPont model being theoretical, the DuPont graphs and related prior art such as Stokes are based on exact particle size, not the more practical average particle size. A broad distribution of particle sizes may have the same average particle size as a narrower distribution while having very different scattering properties. Given that the average particle size of a set of exact theoretical particles is the same as the exact particle size, the distinction does not matter for obviousness.

particles is above 1 for blue incident radiation, while it is below 1 for green and red incident radiation. Therefore, as illustrated in FIG. 6, ***100 to 200 nm particles have at least a 50% greater scattering power*** for blue radiation (i.e., such as that emitted by a blue emitting LED) than green or red (or for that matter yellow) radiation (i.e., such as that emitted by the phosphor or dye).

(EX1108, 7:4-17; *see also* EX1124 (Toquin) at ¶¶[0080]-[0081] (disclosing preferentially scattering blue light using particles of approximately 150 nm).)

249. In other words, Krummacher discloses the use of particles with “at least a 50% greater scattering power for blue radiation,” which includes the particles that that “scatter[] the blue light at least twice as much.” Thus, as illustrated in the annotated Figure 10 above, the range of average particle size disclosed by Stokes based on preferentially scattering blue light overlaps and entirely encompasses the similar range required by claim element [g], rendering element [g] obvious.

250. Neither Stokes nor the '539 patent assign any particular significance to the disclosed ranges, other than that they are based on preferentially scattering blue light. The values recited for the endpoints of both ranges appear to be based on rough estimations in reading DuPont's chart. And the difference between the disclosed ranges is one of degree rather than kind.

251. As discussed above, a POSA would have recognized selecting an average particle size as a design decision to be made based on a number of factors, including the light scattering properties of the particles, and well within the skill of the art. For example, a POSA would weigh the benefits of maximizing the ratio of blue light scattered compared to yellow light with the potential downsides, including not maximizing blue light scattered, decreasing light output due to increased internal reflection, and limiting the commercially-practical options for rutile TiO₂ by requiring a narrower range of average particle size.

Thus, it is my opinion that Krummacher in view of Shimizu and Stokes teaches all of the elements this claim element.

252. Accordingly, Hussell in view of Krummacher, Stokes, and Van Woudenberg renders obvious independent claims 18 and 28.

XIII. SECONDARY CONSIDERATIONS

253. There is no evidence of nonobviousness which I am aware that affects—let alone overcomes—the strong cases of obviousness set out above.

XIV. CONCLUSION

254. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be

subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

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

Date: March 6, 2025

A handwritten signature in black ink, appearing to read "W. A. Doolittle", written over a horizontal line.

William A. Doolittle, Ph.D.