

LEARNING ABOUT LED LIGHTING TECHNOLOGY THROUGH PATENTS

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By

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ABSTRACT

Learning About LED Lighting Technology Through Patents

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Patents and published patent applications are valuable resources to students, engineers, and researchers for learning about technology. This thesis investigated the ability to learn about a technology through the disclosures that are made in published patent applications and issued patents.

This thesis first provides an overview of U.S. patent law, system, and resources that are available to the public. It is through an understanding of U.S. patent law and system that one can appreciate that patents and patent applications are a resource for learning about technology.

By providing the basic building blocks of LED lighting technology as learned through the teachings of patents and patent applications, this thesis proves that patents and patent applications are valuable resources for learning about technology. The patents and patent applications relied upon for this thesis teach that the basic building blocks of LED lighting technology include:

- LED device;
- Color management; and
- Heat management.

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1.0 Introduction

While many engineering students, educators, and researchers are generally aware of the protection aspects of the United States patent laws, much fewer rely on the detailed disclosures in patents to learn about technology. Given that inventors are required to disclose both the specifics of their invention and the best mode to practice their invention, patent disclosures can serve as valuable resources for students, educators, and researchers to learn about technology.

This thesis sets out to show that patent disclosures can be used to learn about a specific area of technology. This thesis project focused on learning about LED lighting technology because an understanding of such technology has become increasingly important. This importance is due to the proliferation of LED lighting systems in our everyday lives. This proliferation is largely driven by recent advancements in LED lighting technology and a global desire to become more energy efficient.

The patents that involve LED lighting technology describe three key components to an LED lighting system. The three key components are the LED device or package, the structures for producing the desired lighting color, and the heat dissipation mechanisms. At the end, this thesis will not only describe in detail the three key components of LED lighting technology, it will show that patents can be used to learn about a technology that one is interested in.

2.0 Overview of U.S. Patent Law

2.1 United States Constitution

The source of United States patent law protection is the Constitution of the United States of America that was adopted in 1787. Section eight of the United States Constitution provides that Congress shall have the “Power to promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries.” It is this language in the Constitution that provides Congress the authority to enact the patent laws that grant inventors the right to exclude others from practicing their invention for a limited time period.

2.2 Title 35 of the United States Code (35 U.S.C.)

Pursuant to the Constitution of the United States, Congress enacted Title 35 of the United States Code that sets forth U.S. patent law. Title 35 of United States Code not only sets for the rights and remedies that are available to an inventor, it sets forth the various requirements for patentability. The key patentability requirements are that the idea must be patentable subject matter, novel, and non-obvious. In addition, as a condition for granting patent protection, the law requires that the inventor discloses the invention in sufficient detail and describes the best mode of practicing the invention. While each of these requirements is important and described in greater detail below, it is the last two requirements that allows us to use patents as a resource for learning about a technology.

2.2.1 Patentable Subject Matter

35 U.S.C. Section 101 sets forth what subject matter is patentable. 35 U.S.C. Section 101 states that whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent. Generally, this language is interpreted to mean that anything man made can qualify as patentable subject matter. Conversely, ideas about things that occur in nature, are illegal, and mental processes cannot qualify as patentable subject matter.

2.2.2 Not Previously Disclosed

35 U.S.C. section 102 sets forth the conditions of patentability by setting forth situations when a patent should not be granted. These situations generally cover when an idea was previously disclosed to the public. Under 35 U.S.C. section 102 (a), a person shall be entitled to a patent unless (1) the claimed invention was patented, described in a printed publication, or in public use, on sale, or otherwise available to the public before the effective filing date of the claimed invention; or (2) the claimed invention was described in a patent issued under section 151, or in an application for patent published or deemed published under section 122 (b), in which the patent or application names another inventor and was effectively filed before the effective filing date of the claimed invention.

35 U.S.C. section 102 (b) also provides exceptions to 35 U.S.C. section 102(a). Disclosures made 1 year or less before the effective filing date of the claimed invention. Specifically, a disclosure made 1 year or less before the effective filing date of a claimed invention shall not be prior art to the claimed

invention if the disclosure was made by the inventor or joint inventor or by another who obtained the subject matter disclosed directly or indirectly from the inventor or a joint inventor; or the subject matter disclosed had, before such disclosure, been publicly disclosed by the inventor or a joint inventor or another who obtained the subject matter disclosed directly or indirectly from the inventor or a joint inventor. Additionally, a disclosure shall not be prior art to a claimed invention under subsection if the subject matter disclosed was obtained directly or indirectly from the inventor or a joint inventor; the subject matter disclosed had, before such subject matter was effectively filed, been publicly disclosed by the inventor or a joint inventor or another who obtained the subject matter disclosed directly or indirectly from the inventor or a joint inventor; or the subject matter disclosed and the claimed invention, not later than the effective filing date of the claimed invention, were owned by the same person or subject to an obligation of assignment to the same person.

2.2.3 Non-obvious

35 U.S.C. section 103 further provides that the invention must be non-obvious to be patentable. Under 35 U.S.C. section 103(a), a patent for a claimed invention may not be obtained, even if the claimed invention is not identically disclosed as set forth in section 102, if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains.

Notably, the law states that patentability shall not be negated by the manner in which the invention was made, but rather what the invention is claimed to be.

2.2.4 Written Description and Best Mode Requirements

In exchange for patent protection, the inventor is required disclose to the public the invention in sufficient detail and the best mode contemplated by the inventor of carrying out the invention. The disclosure is also referred to as the specification. 35 U.S.C. section 112, paragraph one, provides that the disclosure must have a specification containing a written description of the invention. The disclosure must describe the manner and process of making and using the invention, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor or joint inventor of carrying out the invention. Generally, the patent application is published and available to the public in eighteen months from the application filing date.

2.2.5 Patent Claims

The patent claim sets forth the metes and bounds of the invention. 35 U.S.C. section 112, paragraph two, provides that the specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter, which the inventor or a joint inventor regards as the invention. Patent claims are usually set forth at the end of the specification.

3.0 United State Patent & Trademark Office

3.1 United States Patent Office (“USPTO”)

The USPTO is the federal agency that examines patent applications and grants patents. The USPTO also advises the president of the United States, the secretary of Commerce, and various governmental agencies on intellectual property issues.

3.2 Manual of Patent Examination Procedure

A good source of understanding patent law is the Manual of Patent Examination Procedure (MPEP) that is published by the United States Patent & Trademark Office. The MPEP is primarily used by patent professionals and patent examiners as guidance on the patent application examination process. It is currently in its eighth edition (revision 9) released in August 2012. The MPEP is based on Chapter 37 of the Codes of Federal Regulations which derives its authority from Title 35 of United States Code. The MPEP also include interpretations of the patent laws by the United States Supreme Court and the United States Court of Appeals for the Federal Circuit.

3.3 Public Patent Access Information Retrieval (“Public PAIR”)

A patent application is kept secret until it is published. Prior to publication only the inventor and the USPTO registered attorney or agent that is representing the inventor can access information on the patent application. When the patent application is published, it is accessible on the U.S. Patent Office’s Public PAIR system. Public PAIR is the U.S. Patent & Trademark’s database that stores and provides the public with access to details of published

patent applications and issued patents. Public PAIR is available at www.USPTO.gov.

Public PAIR provides basic information about patent applications and patents such as filing date, publication date, issuance date, and the name of examiner. Public PAIR also provides transaction history, patent term adjustments, continuity data, status of patent maintenance fees, published documents associate with the patent application, correspondence address, and references cited in the patent application examination process. Most importantly, Public PAIR contains the file wrapper, which is the prosecution history of the patent application including a copy of the patent application documents, office actions, applicants' responses to the office actions, any amendments to the claims, notice of allowance, and information disclosure statements filed by the applicant.

4.0 Anatomy of a Patent

Title – Can be descriptive and has no legal effect.

(54) **LIGHTING DEVICE AND LIGHTING METHOD**

Figure 1: Exemplary Patent Title

(Source: U.S. Patent & Trademark Office)

Inventors – names and nationalities of the inventors that contributed to the claimed invention.

(75) Inventors: **Antony Paul Van De Ven**, Hong Hong (HK); **Gerald H. Negley**, Durham, NC (US)

Figure 2: Exemplary Patent Inventors

(Source: U.S. Patent & Trademark Office)

Assignee – name of the legal owner at time the patent application was filed.

(73) Assignee: **LED Lighting Fixtures, Inc.**, Morrisville, NC (US)

Figure 3: Exemplary Patent Assignees

(Source: U.S. Patent & Trademark Office)

Application Number – the number that the USPTO assigns to the patent application that is filed. The first two digits represent the year that the application was filed.

(21) Appl. No.: **11/566,440**

Figure 4: Exemplary Patent Application No.

(Source: U.S. Patent & Trademark Office)

Filing date – the date that the patent application was filed.

(22) Filed: **Dec. 4, 2006**

Figure 5: Exemplary Patent Filing Date

(Source: U.S. Patent & Trademark Office)

Related applications and priority dates – date that the patent application claims priority to. Typically a parent application or a foreign application that the patent application can claim priority to. This date sets forth whether certain references predate the patent application.

Related U.S. Application Data

- (60) Provisional application No. 60/752,555, filed on Dec. 21, 2005, provisional application No. 60/752,556, filed on Dec. 21, 2005, provisional application No. 60/792,859, filed on Apr. 18, 2006, provisional application No. 60/793,524, filed on Apr. 20, 2006, provisional application No. 60/793,530, filed on Apr. 20, 2006, provisional application No. 60/792,860, filed on Apr. 18, 2006, provisional application No. 60/793,518, filed on Apr. 20, 2006, provisional application No. 60/857,305, filed on Nov. 7, 2006, provisional application No. 60/839,453, filed on Aug. 23, 2006, provisional application No. 60/868,134, filed on Dec. 1, 2006.

Figure 6: Exemplary Patent Priority Dates

(Source: U.S. Patent & Trademark Office)

Abstract – a summary of what the claimed invention is. Typically the abstract is one paragraph in length.

(57)

ABSTRACT

A lighting device comprising first and second groups of solid state light emitters, which emit light having dominant wavelength in ranges of from 430 nm to 480 nm and from 600 nm to 630 nm, respectively, and a first group of lumiphors which emit light having dominant wavelength in the range of from 555 nm to 585 nm. If current is supplied to a power line, a combination of (1) light exiting the lighting device which was emitted by the first group of emitters, and (2) light exiting the lighting device which was emitted by the first group of lumiphors would, in an absence of any additional light, produce a sub-mixture of light having x, y color coordinates within an area on a 1931 CIE Chromaticity Diagram defined by points having coordinates (0.32, 0.40), (0.36, 0.48), (0.43, 0.45), (0.42, 0.42), (0.36, 0.38). Also provided is a method of lighting.

Figure 7: Exemplary Patent Abstract
(Source: U.S. Patent & Trademark Office)

Specification – detailed description of the figures that describe the invention including the preferred embodiment of the invention.

15 DETAILED DESCRIPTION OF THE
INVENTION

The expression “430 nm to 480 nm solid state light emitter” means any solid state light emitter which, if illuminated, would emit light having a dominant wavelength in the range of from about 430 nm to about 480 nm.

The expression “555 nm to 585 nm lumiphor” means any lumiphor which, if excited, would emit light having a dominant wavelength in the range of from about 555 nm to about 585 nm.

The expression “600 nm to 630 nm solid state light emitter” means any solid state light emitter which, if illuminated, would emit light having a dominant wavelength in the range of from about 600 nm to about 630 nm.

The term “current”, as used in the expression “if current is supplied to the first power line” means electrical current which is sufficient to cause the 430 nm to 480 nm solid state light emitter(s) to emit light having a dominant wavelength in the range of from about 430 nm to about 480 nm, to cause the 555 nm to 585 nm lumiphor(s) to emit light having a dominant wavelength in the range of from about 555 nm to about 585 nm, and/or to cause the 600 nm to 630 nm solid state light emitter(s) to emit light having a dominant wavelength in the range of from about 600 nm to about 630 nm.

Figure 8: Exemplary Patent Specification
(Source: U.S. Patent & Trademark Office)

Claims – the meets and bounds of the invention. Must be supported by the specification.

The invention claimed is:

1. A lighting device comprising:

- a first group of solid state light emitters, said first group of solid state light emitters including at least one solid state light emitter;
- a first group of lumiphors, said first group of lumiphors including at least one lumiphor;
- a second group of solid state light emitters, said second group of solid state light emitters including at least one solid state light emitter; and
- at least a first power line, each of said first group of solid state light emitters and each of said second group of solid state light emitters being electrically connected to said first power line,

Figure 9: Exemplary Patent Claim

(Source: U.S. Patent & Trademark Office)

5.0 Patent Teachings On LED Lighting Technology

5.1 LED Light Basics as Taught by U.S. Patent No. 7,213,940

U.S. Patent No. 7,213,940

Title: Lighting Device and Lighting Method

Issued Date: May 8, 2007

Filing Date: December 4, 2006

U.S. Patent No. 7,213,940 teaches the basics of LED lighting technology.

The basic components of a LED light system as shown in FIGURE 10 below (Fig. 4 of U.S. Patent No. 7,213,940) include solid-state light emitters, luminescent materials such as phosphors, power supplies such as AC/DC converters, heat dissipation mechanisms, and enclosures such as glass.

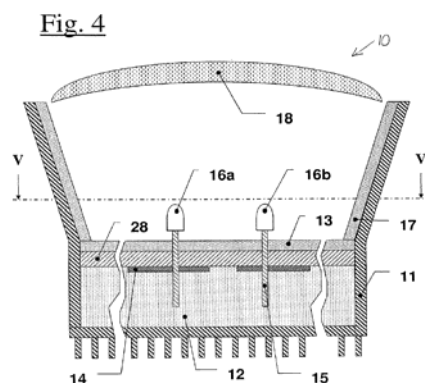


Figure 10: Figure 4 of U.S. Patent No. 7,213,940
(Source: U.S. Patent & Trademark Office)

A large proportion of the electricity consumption in the United States is attributed to lighting. Given increasing energy costs and a desire to reduce our carbon footprint, there is an ongoing need to develop more efficient lights. Unfortunately, the bulk of lighting systems are based on incandescent light bulbs,

which are generally very inefficient. The inefficiency is due to the fact that approximately ninety percent of the electricity consumed by incandescent light bulbs is released as heat instead of light. While florescent lights are more efficient than incandescent light bulbs, but not as efficient as LED lights and provide less favorable color reproduction.

The life span of incandescent light bulbs averages 750 to 1000 hours. The life span of florescent lights is longer averaging 10,000 to 20,000 hours. Notably, the lifespan of LED lights are much longer and usually measured in decades. The core component of all LED lights is the LED devices or packages consisting of light emitting diodes (LEDs). LEDs are semiconducting devices that emit light when a potential difference is applied across a p-n junction structure. The light produced can be ultraviolet, visible, or infrared light. A light emitting diode produces light by exciting electrons across the band gap that is between a conduction band and a valence band of a semiconductor active layer. The electron transition generates light at a wavelength that depends on the band gap. The color of the light emitted by a light emitting diode depends on the semiconductor materials of the active layers.

The characteristics of LEDs however pose certain challenges. These challenges include the emission spectrum of any particular light emitting diode is generally concentrated around a single wavelength. The single wavelength is dictated by the LED's composition and structure. Light that is perceived as white is necessarily a blend of the light of two or more colors or wavelengths because no single LED can produce white light. White LED lights are produced with a

light emitting diode package formed of a combination of red, green, and blue LEDs. White LED lights can also be produced with an LED package that generates blue light and then adding luminescent material such as phosphor. The luminescent material emits yellow light in response to excitation by the LED and the blue light mixed with the yellow light produce light that is perceived as white light.

A good resource for defining colors as weighted sums of colors is the 1931 and 1976 CIE Chromaticity Diagrams, as shown in FIGURES 11 and 12 respectively (Figs. 1 and 2 of U.S. Patent No. 7,213,940). The 1931 CIE Chromaticity Diagram is an international standard for primary colors and the 1976 CIE Chromaticity Diagram is similar to the 1931 version but modified such that similar distances on the Diagram represent similar perceived differences in color. A wide variety of luminescent materials as well as structures that contain luminescent materials (lumiphors or luminophoric media) exist.

Fig. 1

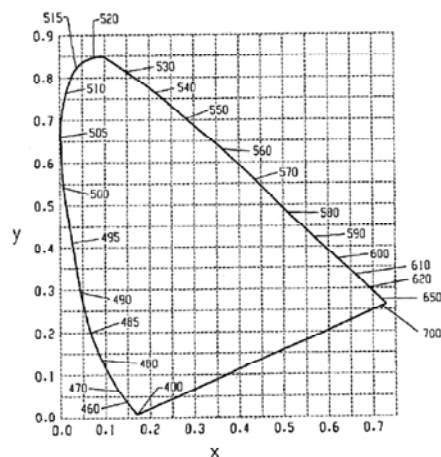


Figure 11: Figure 1 of U.S. Patent No. 7,213,940
(Source: U.S. Patent & Trademark Office)

Fig. 2

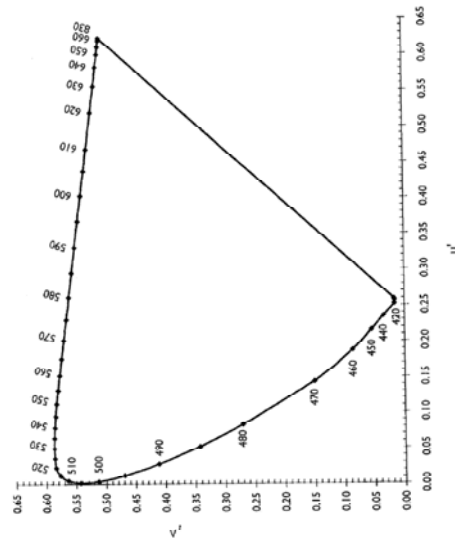


Figure 12: Figure 2 of U.S. Patent No. 7,213,940
(Source: U.S. Patent & Trademark Office)

Another basic component of a LED lighting system is a power supply or driver as shown in FIGURE 13 (Fig. 8 of U.S. Patent No. 7,213,940). The power supply or driver needs to have the maximum amount of capacity and smallest size possible. One method to achieve this is to configure a current source coupled in series with the LEDs, a current control circuit and a capacitor to provide energy storage. A voltage control circuit can be used together with a current limiter circuit configured to limit a current through LEDs to less than the current produced by the current source circuit. The power supply can also include a rectifier circuit having an input coupled to an input of the current source circuit.

Fig. 8

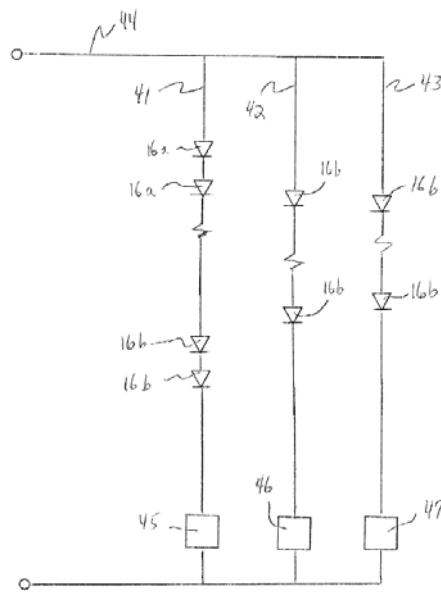


Figure 13: Figure 8 of U.S. Patent No. 7,213,940
(Source: U.S. Patent & Trademark Office)

5.2 LED Device Structure as Taught by EP 2413360 A2

EP 2413360 A2

Title: Multi-element LED lamp package

Filing Date: April 30, 2007

European patents and patent applications can also serve as a valuable resource to learn about a technology as the European patent system has similar disclosure requirements as the U.S. patent system. For example, EP 2413360 A2, a European Patent Application, teaches that an LED device structure includes a die, lead frame, and an encapsulation material such as an epoxy. FIGURE 14 below (Fig. 2 of EP 2413360 A2) depicts the LED device structure and FIGURE 15 below (Fig. 4 of EP 2413360 A2) depicts a LED light system with multiple LED device structures. LED dies are multi-layer optoelectronic devices

with one or more active light emitting layers deposited over a substrate. Active layers typically consist of III-V nitride materials such as GaN, AlN, InN, or alloys thereof. Alloys can be AlGaN or InGaN in pure form or as alloys such as Aluminum, Gallium, Indium, Arsenic, and/or Phosphorus such as GaAs, AlGaAs, GaPAs.

LED substrates are typically made with materials that include SiC and sapphire for III-V nitride materials and GaAs for alloy-containing materials. To optimize brightness of the LED output, the substrate is preferably selected to be transparent to the wavelength of light produced by the LED or minimal thickness as to reduce absorption. Conductive substrates such as SiC are employed to minimize the number of light absorbing wire bonds and contact pads on the front surface of the LED.

LED lead frames physically support the die and provides electrical and thermal conduction paths to and from the die. The encapsulation material surrounds and protects the die and disperses the light emitted from the die.

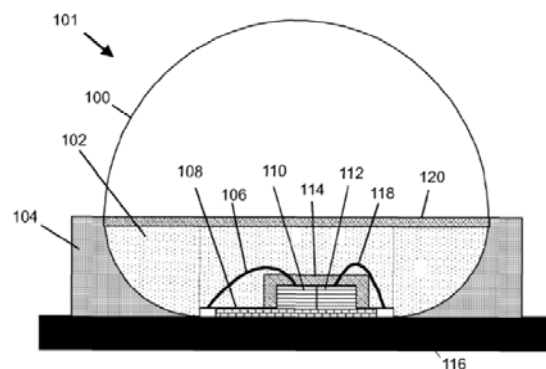


FIGURE 2

Figure 14: Figure 2 of EP 2413360 A2
(Source: European Patent Office)

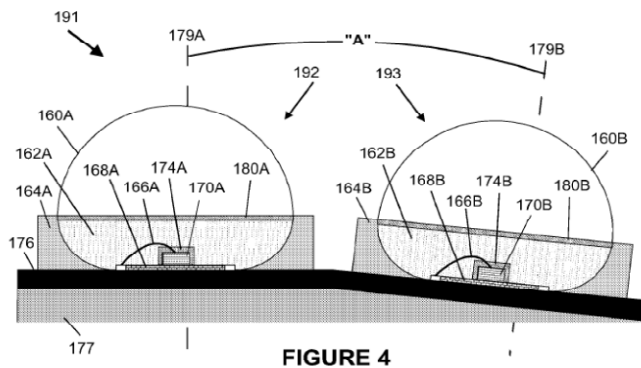


Figure 15: Figure 4 of EP 2413360 A2
(Source: European Patent Office)

5.3 LED Color Management as Taught by 2013/0170199

U.S. Patent Application Publication 2013/0170199

Title: LED Lighting Using Spectral Notching

Application Filing Date: December 30, 2011

U.S. Patent Application Publication 2013/0170199 teaches that LED based lighting systems are becoming more prevalent as replacements for traditional forms of lighting such as incandescent and fluorescent lights. Benefits of LED lights include consumption of less energy, durability, longer life, can be controlled to provide a multitude of colors, and generally contain no lead or mercury.

A typical LED lighting system includes a packaged light-emitting device that contains multiple LEDs. The LED may be semiconductors layers forming p-n junctions or organic light emission layers. A combination of red, green, and blue LEDs can be used to generate white light or near white light. A LED's light

output can be altered by separately adjusting the current supplied to the red, green and blue LEDs. Alternatively, white light may be generated using a lumiphor, such as phosphor, or stimulating phosphors or dyes of multiple colors with an LED source.

LED lighting systems typically includes some type of optical element to allow for localized mixing of color, collimate light, or provide a particular light pattern. The optical element may also serve as an enclosure for the LEDs. The optical elements can be either transmissive or reflective and can be reflectors, glass plates, or lenses.

Color reproduction is typically measured using the color rendering index (CRI). The CRI is a relative measurement of how the color rendition of an illumination system compares to that of a theoretical blackbody radiator. In other words, the CRI is a relative measure of the shift in surface color of an object when lit by a particular source. The CRI equals 100 if the color coordinates of a set of test surfaces being illuminated by the lamp are the same as the coordinates of the same test surface irradiated by the theoretical blackbody radiator. Daylight has the highest CRI of 100 and incandescent lights being relatively close to 100.

LED lighting systems, such as the one shown in FIGURE 16 (Fig. 2 of U.S. Published Patent Application 2013/0170199), are typically self-contained. LED lighting systems include a power supply, LEDs, and optical components. In order to maintain appropriate operating temperatures, a heatsink is usually included to cool both the LEDs and power supply. The challenge is that the

power supply and heatsink can block some of the light produced by the LEDs. As a result of the blockage, the light pattern produced by the LEDs will be substantially different from the intended light pattern.

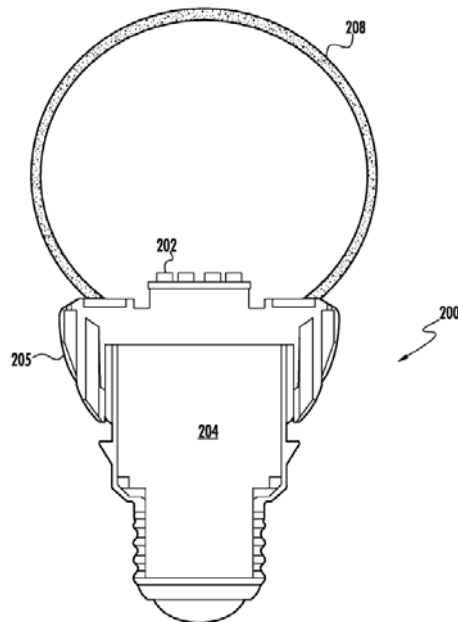


FIG. 2

Figure 16: Figure 2 of Patent Application 2013/0170199
(Source: U.S. Patent & Trademark Office)

U.S. Published Patent Application 2013/0170199 teaches spectral notch filtering optical elements to compensate for the light altering effects that power supplies and heatsinks have on the light produced by LEDs. Spectral notch is a portion of the color spectrum where the light is attenuated and forms a “notch” when the light intensity is plotted against wavelength. Depending on the type of optical elements, the spectral notch can occur between the wavelengths of 520 nm to 605 nm. FIGURE 17 (Fig. 9 of U.S. Published Patent Application 2013/0170199) illustrates the notch filtering properties of glass doped with a neodymium compound used with an LED device.

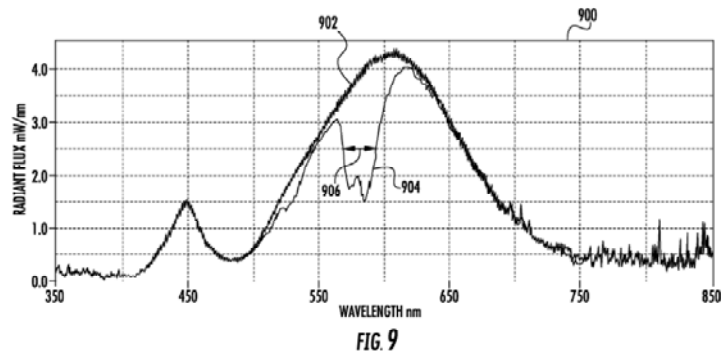


Figure 17: Figure 9 of Patent Application 2013/0170199
(Source: U.S. Patent & Trademark Office)

FIGURE 18 (Fig. 10 of U.S. Published Patent Application 2013/0170199) illustrates notch filtering at a different frequency than that shown in FIGURE 17 due to use of a different optical treatment. FIGURE 19 (Fig. 11 of U.S. Published Patent Application 2013/0170199) illustrates the notch filtering properties of an optical element with a color pigment. FIGURE 20 (Figs. 12A and 12B of U.S. Published Patent Application 2013/0170199) illustrates properties such as color rendering index and color rendering scale relative to notch depth that are possible with various optical elements.

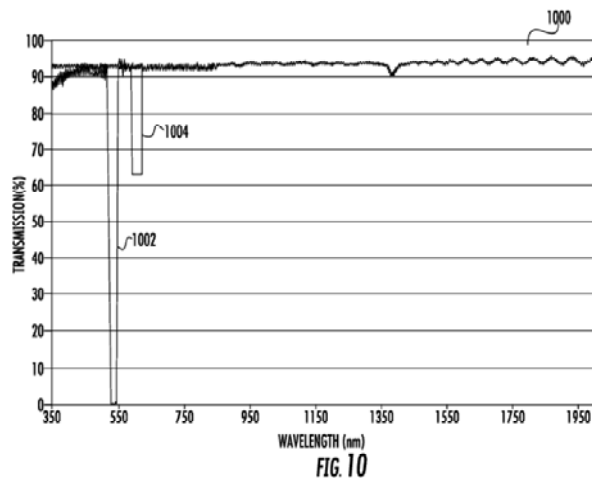


Figure 18: Figure 10 of Patent Application 2013/0170199
(Source: U.S. Patent & Trademark Office)

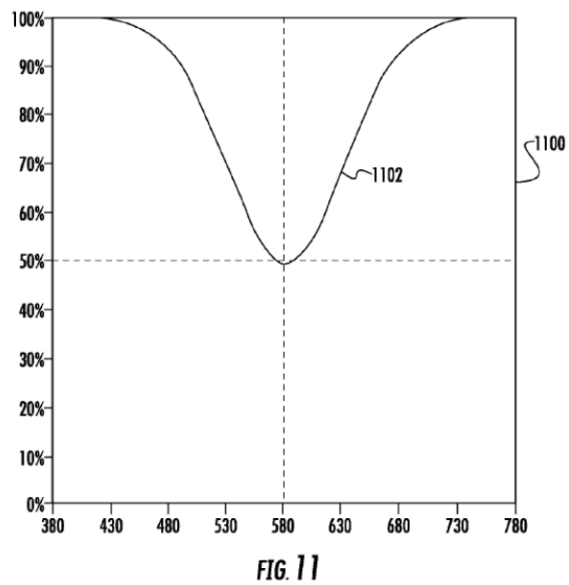


Figure 19: Figure 11 of Patent Application 2013/0170199
(Source: U.S. Patent & Trademark Office)

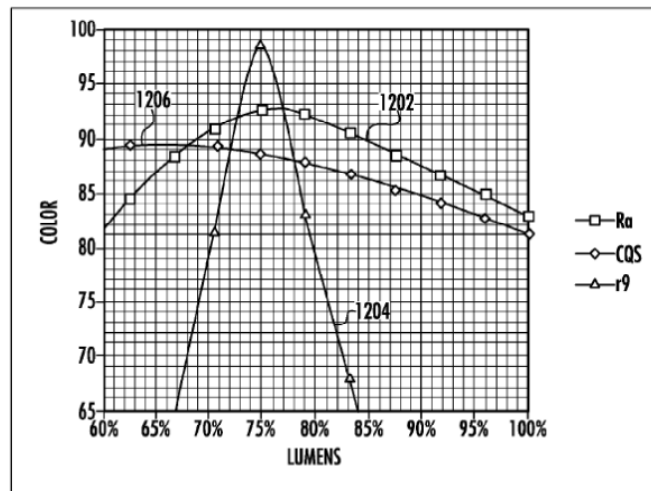


FIG. 12A

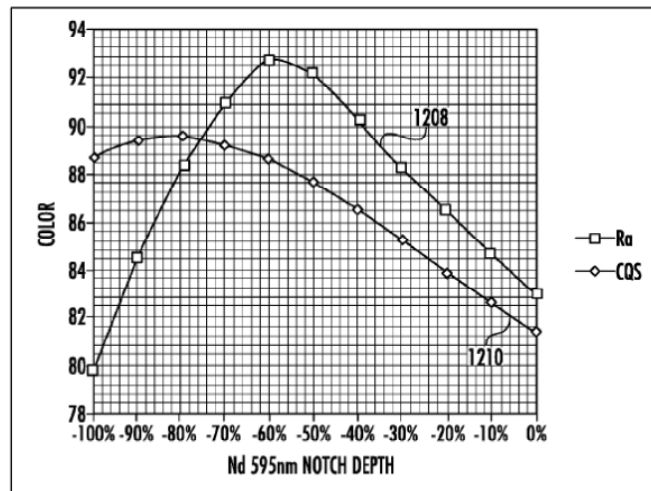


FIG. 12B

Figure 20: Figures 12A & B of Patent Application 2013/0170199
(Source: U.S. Patent & Trademark Office)

While the use of spectral notch filtering in traditional incandescent lights creates a more pleasing daylight like color the problem is that such filtering reduces the CRI of the light. For LED lights, the opposite occurs in that the CRI of the LED light is improved but the use of any type of filtering reduces the light output. The spectral notch filtering optical element can be that of a glass or polymer dome that is transmissive of light and coated with rare earth compounds

to effectuate a spectral notch such as the one shown in FIGURE 21 (Fig. 5 of U.S. Published Patent Application 2013/0170199). The rare earth compound can be neodymium oxide, didymium, dysprosium, erbium, holium, praseodymium and thulium. The optical element can alternatively be a reflective material. FIGURE 22 (Fig. 8 of U.S. Published Patent Application 2013/0170199) illustrates a cross sectional view in which the notch filtering is provided by a reflective optical element. In such applications, the reflector can be made to act like a notch filter by coating the reflecting optical element with an optical interference film. Another method to effectuate notch filtering involves encapsulating the LEDs with phosphor and allowing the light to pass through a small lens window. This method will create a light source of at least a CRI of 84.

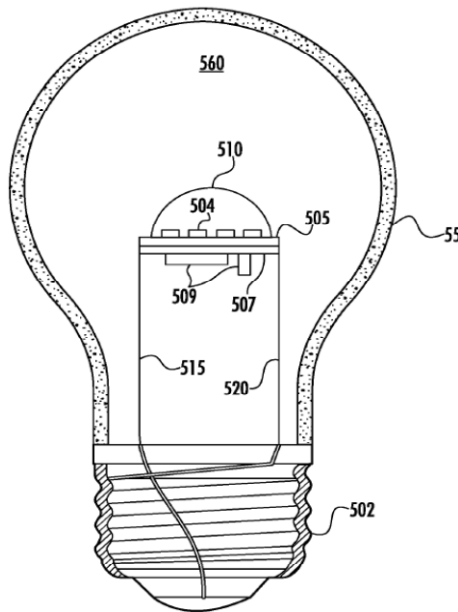


FIG. 5

Figure 21: Figure 5 of Patent Application 2013/0170199
(Source: U.S. Patent & Trademark Office)

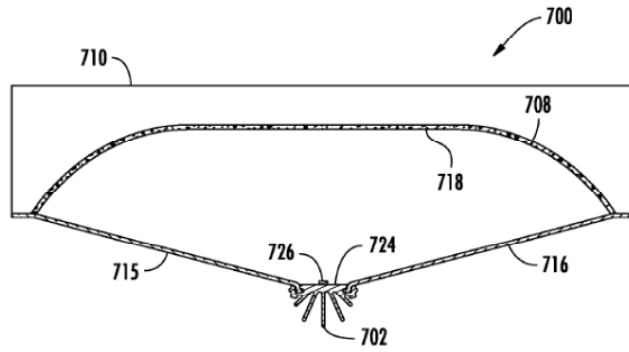


FIG. 8

Figure 22: Figure 8 of Patent Application 2013/0170199
(Source: U.S. Patent & Trademark Office)

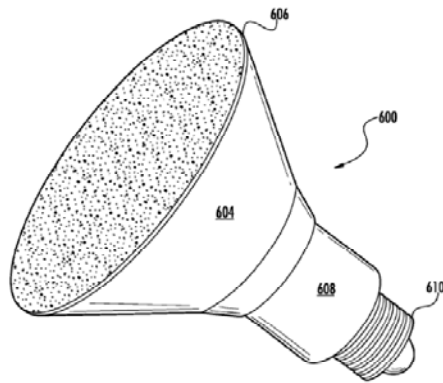


FIG. 6

Figure 23: Fig. 6 of Patent Application 2013/0170199
(Source: U.S. Patent & Trademark Office)

Alternatively, the encapsulated LED package such as the one shown in FIGURE 23 above (Fig. 6 of U.S. Patent Application 2013/0170199) illustrates can be filled with optically transmissive fluid that can effectuate spectral notch and thermal cooling. Fluids that can be used include perfluorinated polyether (PFPE) liquid, or other fluorinated or halogenated liquid or gel. The optically

transmissive fluid medium should be an index matching medium that is characterized by a refractive index that provides for the efficient light transfer with minimal reflection and refraction from the LEDs through the enclosures.

The index matching medium can have the same refractive as the material of the enclosure, the LED device package material, or the LED substrate material. Alternatively, the index matching medium can have a refractive index that is arithmetically in between the indices of two of those materials.

5.4 LED Lighting Enclosures as Taught by U.S. Patent No. 8,360,604

U.S. Patent No. 8,360,604

Title: Light Emitting Diode (LED) Lighting Systems Including Low Absorption, Controlled Reflectance Enclosures

Issue Date: January 29, 2013

Filing Date: September 30, 2009

U.S. Patent No. 8,360,604 further teaches that LED lighting devices can be gallium nitride (GaN)-based LEDs on silicon carbide (SiC)-based mounting substrates. LED lighting devices can also include ALGaInO LEDs on GaP mounting substrates; AlGaAs LEDs on GaAs mounting substrates; InGaAs LEDs on GaAs mounting substrates; AlGaAs LEDs on GaAs mounting substrates; SiC LEDs on SiC or sapphire mounting substrates; Group III-nitride-based LEDs on gallium nitride, silicon carbide, aluminum nitride, sapphire, zinc oxide and/or other mounting substrates. A power supply serves as a ballast for the LED lighting system by converting an input alternating current to a direct current. The power supply can also be a resistor that sets a bias current.

U.S. Patent No. 8,360,604 disclosure focuses on enclosures of LED lighting systems that address the fact that LEDs are relatively narrow spectrum light sources. In order to provide a broad spectrum light source, such as white or near white light, LED light needs to be shifted or spread in wavelength. LED lighting systems can use reflective and transmissive properties of a film or other surrounding material to provide mixed light output from the light sources contained within an enclosure defined by the material. When using film or surrounding material, there is a need to balance the reflectivity from the material that reflects light back into the enclosure with the transmission through the material (i.e., the transmittance to reflectance ratio) so that the light is transmitted substantially uniform color across the surface area of the material and absorption is reduced or minimized.

FIGURE 24 (Figs. 1 and 2 of U.S. Patent 8,360,604) show cross sectional views of an LED lighting system that includes the wavelength conversion material described above.

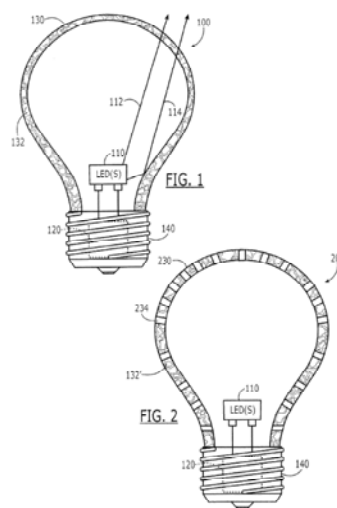


Figure 24: Figures 1 and 2 of U.S. Patent 8,360,604
(Source: U.S. Patent & Trademark Office)

Highly reflective and diffusive microcellular materials, such MCPET or DLR, have minimal loss in reflection of 2% or less, but also have microporous characteristics to allow the transmission of light. FIGURE 25 (Figs. 3 and 4 of U.S. Patent 8,360,604) shows the use of MCPET in various patterns. The level of transmission from an enclosure is controlled by varying the thickness of the transmissive/reflective layer on the MCPET or providing strips or dots of reflective material on the transmissive material. Adjusting the balance between the amount of light transmitted and the amount of light reflected controls the number of bounces of light within the enclosure before the light is transmitted through the enclosure material. The number of bounces of light should be sufficient to mix the light from different color sources of LED lights.

Low absorption diffusing materials such as MCPET/DLR is used in a manner that is different from their intended use (by making them thinner, non-uniform, with holes or micropores to increase their transmissivity. To produce white light or a white LED, one can coat a blue light emitting diode with an encapsulant material that includes a wavelength conversion material. The encapsulant material may be resin or silicon. The wavelength conversion material can be YAG:Ce phosphor that emits yellow light in response to blue light. The design must produce blue light that is not absorbed and combined with yellow light to ultimately produce perceived white light.

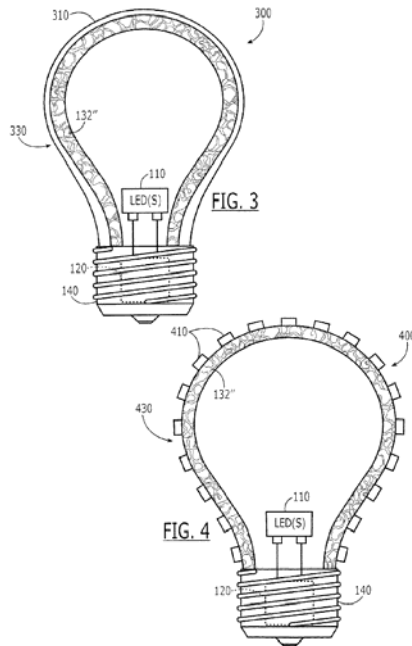


Figure 25: Figures 3 and 4 of U.S. Patent 8,360,604
(Source: U.S. Patent & Trademark Office)

Another method would be to mix red emitting phosphor with the yellow emitting phosphor to produce light with better color temperature and better color rendering properties. LEDs may be certified energy efficient by satisfying ENERGY STAR program requirements. These requirements are published in the “ENERGY STAR Program Requirements for Solid State Lighting Luminaires, Eligibility Criteria – Version 1.1”, Final: December 19, 2008.

Provide an enclosure that is adjacent to the LEDs and pass the light of the LEDs to the enclosure. The enclosure has a transmittance-to-reflectance ratio that is configured to homogenize light that emerges from the enclosure – both directly from the LED and after one or more reflections. The goal is to configure the enclosure to control the relative amount of light that is transmitted and

reflected so that light is evenly diffused and the colors are mixed to provide homogeneous light.

The enclosure is designed to be about 2% absorption to about 10% absorption. The enclosure is a microcellular layer having a mean cell diameter of less than 10 micrometer or a microporous layer. The enclosure includes a low absorption diffusion material such as a layer of microcellular polyethylene terephthalate (MCPET) or a layer of Diffuse Light Reflector (DLR) material. The transmittance-to-reflectance ratio can be varied at different areas in the enclosure. The MCPET and/or DLR material can be of different thickness to achieve this or can have an array of holes.

MCPET sheets reflect blue light with wavelengths of 400 nm and red light with 700 nm equally. A 1-millimeter thick MCPET sheet may achieve a total light reflectivity of 99% and a diffuse reflectivity of 96% compared to the conventional mirrored or metallic reflection panels that achieve only 10% diffuse reflectance ratio and restrict the total light to a single direction.

5.5 Heat Sinks with Fins as Taught by U.S. Patent App. 2013/0140974

U.S. Patent Application 2013/0140974

Title: LED-Light Heatsink and LED Lamp

Filing Date: December 20, 2012

Given the relatively large amount of heat generation by LED light source, heat dissipation mechanisms must be developed. U.S. Patent Application 2013/0140974 teaches the design of a LED light heatsink that includes a hollow circular heatsink body with fins on the exterior wall of the heatsink and a circular

base plate that encloses the bottom of the heatsink body as shown in FIGURE 26 (Fig. 1 of U.S. Patent Application 2013/0140974).

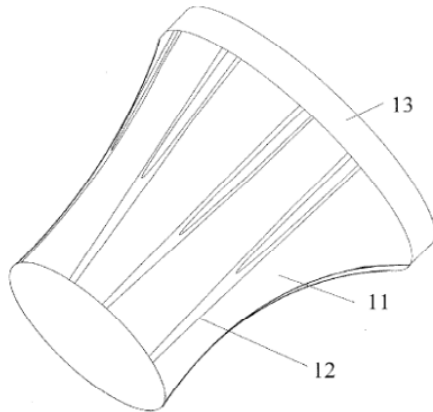


Figure 26: Figure 1 of Patent Application 2013/0140974
(Source: U.S. Patent & Trademark Office)

Parameters to adjust would be fin spacing, average thickness of the fins, average height of the fins, length of the fins, and thickness of the heatsink baseplate. The center of the circular baseplate should be thicker than the edges. The thickness should decrease gradually from the center to the edge. When the LED-light is located in the intermediate zone of the heatsink which will dissipate the heat to the surroundings. While the heatsink design can include straight fins, the flow-resistance coefficient is small but the heat storage may not be good and the heat transfer area is relatively small. The heatsink design can alternatively include oblique fins so that heat storage effect may be relatively good and the heat transfer area is relatively large, but the flow-resistance coefficient is increased. The present published patent application discloses an oblique fin that has low flow-resistance coefficient while maintaining good heat storage effect and a large heat transfer area.

The fins have a thickness that is greater at the body of the heatsink body than away from the heatsink body. The fins are also have a greater height at the heatsink baseplate than away from the baseplate. The fins also have a thickness that decreases gradually from a fin bottom (close to the heatsink body) to a fin top. Since heat is transferred from down to up, it is necessary to consider not only heat dissipation but also heat storage for the bottom of the fins to prevent impact of a thermal load. The heat is diminished when it is dissipated upward, and accordingly the thickness of the fins can be decreased at the top of the fins. Spacing of the fins should be set between 3.3 to 4.5mm. As the fin spacing decreases and the number of fins increases, the heat dissipation surface area is increased and the temperature of the LED heatsink is lowered. However, there is a point of diminishing returns. FIGURE 27 (Figs. 2 and 3 of U.S. Patent Application 2013/0140974) illustrate the heatsink described above.

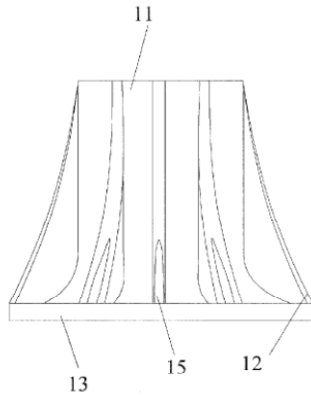


FIG.2

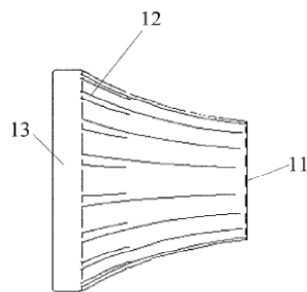


FIG.3

Figure 27: Figures 2 and 3 of Patent Application 2013/0140974
(Source: U.S. Patent & Trademark Office)

The thickness of the fins should be set between 2.0 to 2.7mm. When thickness is increased and reaches 2.56 mm, the maximum temperature of the LED-light heatsink is at its lowest value. The increase of the average height of the fins has great impact on heat loss. The height of the fins can be relatively large, but the height will be limited by the volume shape of the heatsink structure. The average height of the fins should not exceed three to four times of the fin spacing, otherwise it will result in a relatively large density of arrangement of the fins and ultimately thermal reflow. In order to achieve a good heat dissipation, the average height of the fins are 6.5 to 9.0 mm.

The length of the fins is also generally determined by the volume shape of the LED-light heatsink. The value of the length are 40 to 50 mm.

Bifurcating the bottom of the fins will increase heat dissipation area when the heat is conducted to an upper portion of the fins. The heatsink includes a baseplate with open holes for each LED-light that increase air convection and improve heat dissipation.

While it is necessary in the design of the heatsink to consider a steady state buffer effect to a heat flow (for resisting a transient heat load), the heatsink baseplate is too thin the thermal resistance is reduced but the heat storage effect is not good. However, if the heatsink baseplate is too thick, the thermal resistance is relatively large, and the weight and cost of the heatsink is increased. Thus, the thickness of the heatsink baseplate should be moderate. The thickness of the baseplate should be set 4.5 to 5.8 mm. When the fins are relatively long and high, the thickness of the baseplate needs to be relatively thick. Ideally, two to three times larger than the average thickness of the fins. FIGURE 28 (Fig. 5 of U.S. Patent Application 2013/0140974) illustrates the relationship between maximum temperature and a fin spacing of the LED-light heatsink. FIGURE 29 (Fig. 6 of U.S. Patent Application 2013/0140974) illustrates the relationship between maximum temperature and a fin thickness of the LED-light heatsink.

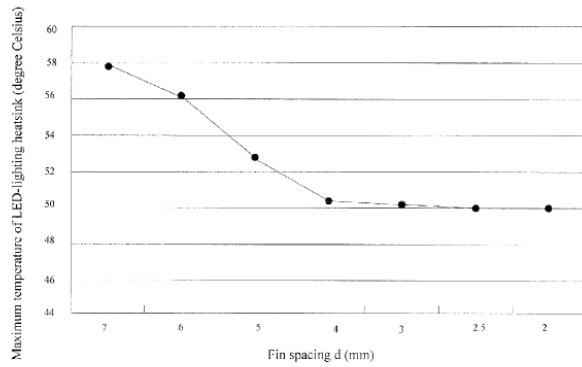


FIG.5

Figure 28: Figure 5 of Patent Application 2013/0140974
(Source: U.S. Patent & Trademark Office)

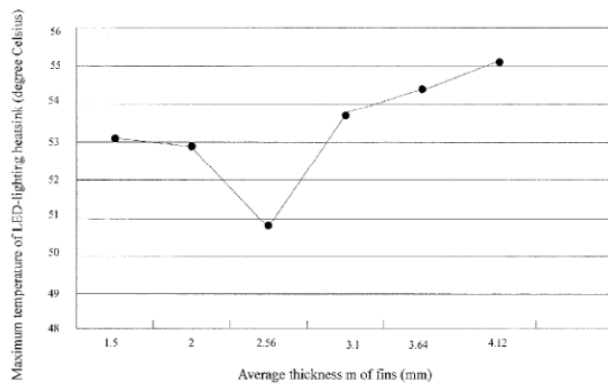


FIG.6

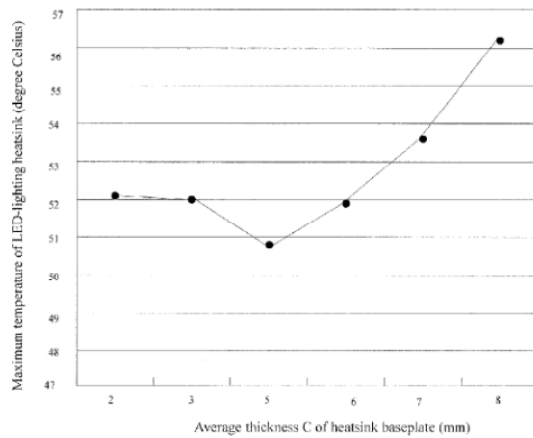


Figure 29: Figure 6 of Patent Application 2013/0140974
(Source: U.S. Patent & Trademark Office)

5.6 Forged Heatsink as Taught By U.S. Patent No. 8,476,812

U.S. Patent No. 8,476,812

Title: Solid State Lighting Device With Improved Heatsink

Issue Date: July 2, 2013

High power solid state emitters can draw large currents, thereby generating significant amounts of heat that must be dissipated. Solid state lighting systems utilize heatsinks in thermal communication with the heat-generating solid state light sources. Heatsinks must provide enhanced thermal performance, reduce material requirements and enable production of various shapes to accommodate solid state lighting devices for different applications. Forged heatsinks such as the one shown in FIGURE 30 (Fig. 3 of U.S. Patent No. 8,476,812) offer substantial benefits over cast heatsinks for LED lighting devices. FIGURE 30 (Fig. 4 of U.S. Patent No. 8,476,812) illustrates a top perspective view of the forged heatsink as shown in FIGURE 30. Forged heatsinks offer greater thermal conductivity due to higher density and lower porosity than cast heatsinks. Cast aluminum heatsinks are typically characterized by a thermal conductivity of about 180 W/mK. Forged aluminum heatsinks have a thermal conductivity of about 180-210 W/mK. Aluminum is the most common material used for heatsinks. Aluminum heatsinks are formed in various shapes by casting, extrusion, or machining techniques. Forging offers greater flexibility in manufacturing heatsinks with a variety of shapes and potential lower cost in high-volume production.

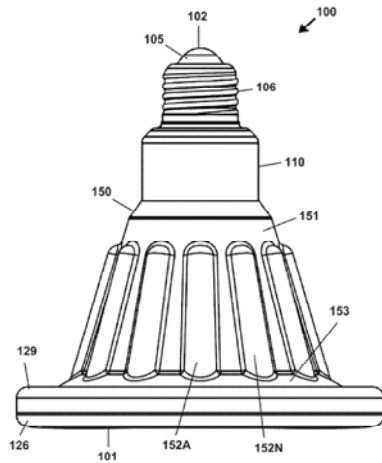


FIG._3

Figure 30: Figure 3 of U.S. Patent No. 8,476,812
(Source: U.S. Patent & Trademark Office)

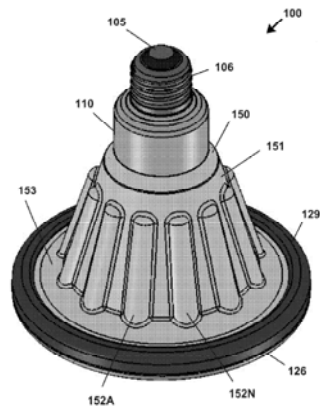


FIG._4

Figure 31: Figure 3 of U.S. Patent No. 8,476,812
(Source: U.S. Patent & Trademark Office)

Forging is a manufacturing process involving pressing, pounding, or squeezing of metal to produce high density and high strength parts known. Forging may be performed hot or cold. Hot would involve preheating the metal work piece to desired temperature below its melting point before the metal is

worked on. Forging is different from the casting or foundry process as metal used for forging is neither melted or poured. Forging uses hammers which pound metal into shape with controlled high pressure impact strikes or presses which squeeze metal into shape vertically with controlled high pressure.

FIGURE 30 (Fig. 4 of U.S. Patent No. 8,476,812) is a cross sectional view of a second conventional impression die forging apparatus that includes a header die and a gripper die composed of fixed die and movable die portions, with a work piece disposed between the header die and gripper die.

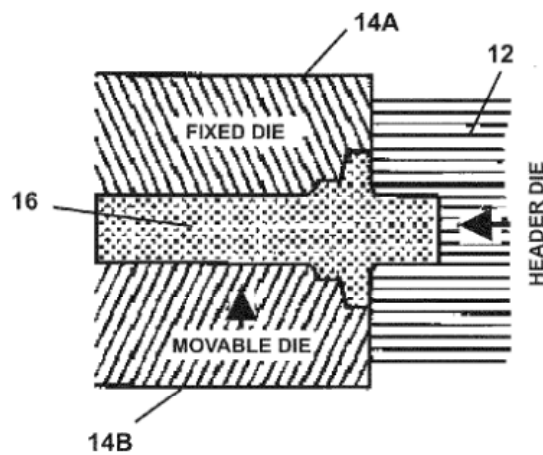


FIG. 2
(RELATED ART)

Figure 32: Figure 2 of U.S. Patent No. 8,476,812
(Source: U.S. Patent & Trademark Office)

Impression die forging involves forming metal to a desired shape and size using preformed impressions (recesses or cavities) in specifically prepared dies that exert three dimensional control on the workpiece. A die is typically formed of material that is harder than the workpiece.

The heatsink is formed by impression die forging using at least two dies. At least one impression die may include separable portions that has thermal conductivity of 200 W/mK or higher. The forged heatsink includes a frustoconical outer surface and multiple protrusions that project radially outward from the outer surface. The protrusions provide increased surface area to enhance heat dissipation.

The protrusions are convex with curved inner surface. They can be solid with varying thickness from base to outer tip. The protrusions can be oriented longitudinal, lateral, or, diagonal. The forged heatsink has multiple fins each having a cross sectional area that decreases with increasing distance from a center of gravity from the forged heatsink.

The forged heatsink has a profile that varies in at least two deminsions. The heatsink has a wall thickness that varies in at least two dimensions. Such variations permit the are of the heatsink nearest to the LED-light heat source to be thicker, and areas of the extremities (farther from the heat source) to be thinner to maximize heat transfer and minimize material weight and cost. The forged heatsink can be designed to have flared transition portions that extend between the frustoconical outer surface and a radial lip of increased thickness relative to the surface. The lip defines multiple cavities each to include an associated heatpipe. The forged heatsink is electrically isolated from the LED-light emitting heat source. Each heatpipe is arranged to conduct heat from the gap, which is open to the cavity of the reflector, into the heatsink. The cavities may be formed as part of the process of forging the heatsink or can be

formed after the forging process such as drilling. The heatpipes may be inserted into the cavities. The forged heatsink is formed as a single piece or formed in multiple parts that are joined together using joining techniques such as welding and brazing. FIGURES 33 and 34 illustrate the forged heatsink describe above.

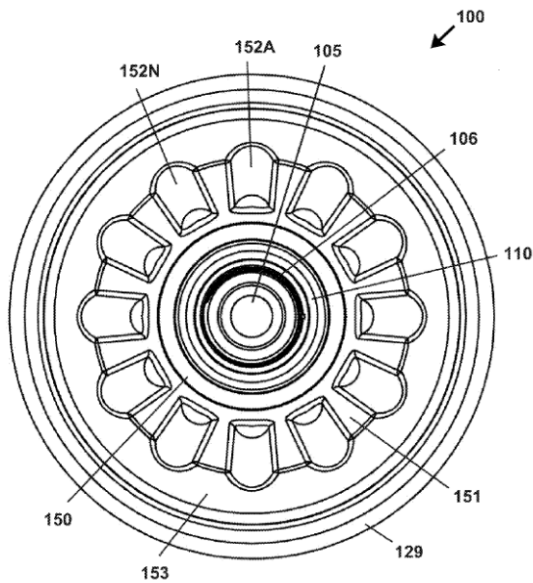


FIG. 6

Figure 33: Figure 6 of U.S. Patent No. 8,476,812
(Source: U.S. Patent & Trademark Office)

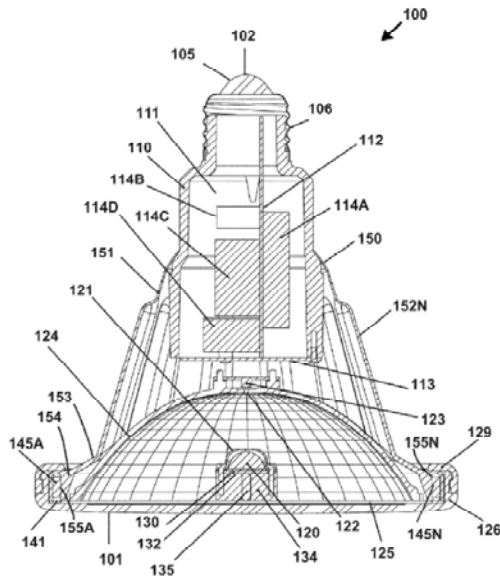


FIG. 7

Figure 34: Figure 7 of U.S. Patent No. 8,476,812
(Source: U.S. Patent & Trademark Office)

In operation of the LED-light device, electrical current is delivered through connectors to a longitudinal circuit board, LED components, and a lateral circuit board. Conductive traces or wires supply current to the LED-light device. Light from the LED travels through the diffuser to the reflector which reflects a portion of light emitted from the LED towards end of the LED-light assembly and lens and exits the device. Heat from the LED and reflector is radiated into the reflector cavity and also conducted through the conductive slug aided by the central heatsink. Heat from the cavity and gap is received by the radial lip aided by the operation of the lateral heatpipes and conducted into the frustoconical outer surface and protrusions to be dissipated into the environment. The forged heatsink is in thermal communication with the LED via intermediate heat transfer components.

6.0 CONCLUSION

Patents and published patent applications are valuable resources to students, engineers, and researchers for learning about technology. This thesis investigated the ability to learn about a technology through disclosures made in published patent applications and issued patents. This thesis shows that patents are valuable resources for learning about technology by using patents to learn about and describe LED lighting technology.

An effective method for using published patent applications and patents to learn about technology that was also used to write this thesis is as follows:

1. Go to www.uspto.gov
2. Click on Quick Search hyperlink located under USPTO Patent Full-Text and Image Database (PatFT).
3. Under Query, enter a search term in Term 1 – a broad technology term that would bring up patents that the researcher is interested in. For example, “LED Light.”
4. Select the Field of Search for the search term. For example, “Abstract.”
5. For a more targeted search, enter a second search term in Term 2 – a more narrow term that would narrow the search results but still capture the patents that the researcher is interested in. For example, enter the name of a company that is in the technology field that the researcher is interested in.

6. Select the Field of Search for the second search term. For example, "Assignee."
7. Alternatively, for a broader search, choose the "OR" option between Term 1 and Term2, and enter an alternative search term in Term 2 – an alternative technology term that would also capture the patents that the researcher is interested in. For example, "Light Emitting Diodes."
8. Select the field of Search for the second search term. For example, "Abstract."
9. Run the search, click on and review the abstracts and figures of each of the published patent applications or patents that the search returned. Perform a more detailed review of the patent if the abstract reveals what the researcher is interested in.
10. Click on and review the abstracts and figures of the published patent applications and patents that are listed under Related U.S. Patent Documents for additional patent applications and patents that may be of interest. Perform a more detailed review of the patent if the abstract reveals what the researcher is interested in.
11. Click on and review the abstracts and figures of the published patent applications and patents that are listed under References Cited for additional patent applications and patents that may be of interest. Perform a more detailed review of the patent if the abstract reveals what the researcher is interested in.

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5. U.S. Patent No. 7,213,940, Public Pair
6. EP 2413360 A2, <https://www.google.com/patents/EP2413360A2>
7. U.S. Patent Application Publication NO. 2013/0170199, Public Pair
8. U.S. Patent No. 8,360,604, Public Pair
9. U.S. Patent Application Publication No. 2013/0140974, Public Pair
10. U.S. Patent No. 8,476,812, Public Pair