IJASRM
International Journal of Advanced Scientific Research and Management, Special Issue 5, April 2019
www.ijasrm.com
ISSN 2455-6378

Solid-state lighting in favors of White Light Emitting Diode (LED): a Review

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Abstract

Solid-state light sources are in the process of profoundly changing the way humans generate light for general lighting applications. Solid-state light sources possess two highly desirable features, which set them apart from most other light sources: (i) they have the potential to create light with essentially unit power efficiency and (ii) the properties of light, such as spectral composition and temporal modulation, can be controlled to a degree that is not possible with conventional light sources such as incandescent and fluorescent lamps.

Compared with conventional lamps and backlights, white light- emitting diodes have the advantages of low power consumption, free of mercury, high response, no thermal radiation, long life-time, high stability, and so on. Typically, true white emitting LEDs are not available. White light can be generated by the combination of a blue LED chip and a yellow phosphor, YAG: Ce^{3+}. The result is a mixture of blue and yellow light that is perceived by the eyes as white. During the past few year white LEDs fabricated using near ultraviolet (n-UV) LEDs (380-420nm) coupled with red, green and blue phosphors have attracted much attention due to the advantages of colour stability and excellent colour rendering. Thus, these can be an effective tool for society and upliftment of economy of India.

Keywords: *Phosphor, White LED, chemical compounds*

1. Introduction

The solid state lighting is related to the phosphor materials. Phosphor it is a substance absorbs energy in some form or other, a fraction of the absorbed energy may be reemitted in the form of electromagnetic radiation in the visible or near visible region of the spectrum. This phenomenon is called luminescence. [Latin word'lumen' means light]. The word 'luminescence' was first used by Eilhardt Wiedemann, a German physicist in 1988. If the excitation is achieved by the bombardment with photons the corresponding process is called Photoluminescence (PL). The solid materials exhibiting luminescence property are referred to as phosphors. The phosphor materials used in LED manufacturing vary in chemical composition from application-to application and LED manufacturer-to-manufacturer, but are generally provided as a stable, low toxicity, rare earth powder, and are available from multiple suppliers worldwide [1-3].

The use of phosphors by man probably started more than 2000 years ago when they were used in fireworks to modify the colour output, but real phosphor development is a 20^{th} century phenomena starting in the 1940s, and its recent development has most of the market demand being generated by cathode ray tubes and fluorescent lighting.Phosphors used in white LED should have the following requirements - strong absorption, broad excitation spectrum , useful emission spectrum (broad) , high quantum/conversion efficiency , small thermal quenching , high chemical stability , suitable particle size and morphology , lost cost (easy synthesis and mass production) , no hazardous elements contained. However, during the last five year white LEDs have become very important lighting sources and the importance of LED Phosphors for white and coloured light generation must be considered an important market driver in the future and perhaps unfortunately, as a disruptive technology[4].

Research in LED phosphor have therefore benefited from previous efforts in understanding luminescence mechanisms , rare earth activations and combinatorial chemistry allowing fast screening of multiple compositions[5].

1.1Phosphor Applications

LEDs used display in form of mobile, laptops, monitors, LED TVs, large video screens, and lighting in residential, commercial, industrial, Plasma Municipal / Street Portable/personal Automotive and so on the growing option of the LED phosphors. Cold Cathode Fluorescence Others Fluorescent Lamps CCFL for backlight. Other uses of Phosphors are the fluorescent marking IR-VIS up or down-conversion, image intensifiers, radiation detection (scintillators) for nuclear imaging (Industrial, Safety, Medical…)CRT, PDP and CCFL LCD applications are decreasing fast.Fluorescent lighting are currently benefiting from the phase out of incandescent bulbs in many countries. However, it is expected that this phase out will ultimately benefit LEDs.

Lighting Option

Other Luminescent light

Incandescent Light | Fluorescent light | LED

Energy - 40w **10w** **1.5w**
Lifetime Hours- 1000 **10,000** **50,000**

Incandescent lamps (light bulbs) generate light by passing electric current through a resistive filament, thereby heating the filament to a very high temperature so that it glows and emits visible light over a broad range of wavelengths. The Incandescent bulbs convert less than 5% of the energy they use into visible light (with the remaining energy being converted into heat.) So the 95% of energy supplied is wasted as heat.In incandescent we used tungsten filament T= 2700-3300 Kelvin for lighting.

A fluorescent lamp or fluorescent tube is a low pressure mercury.The mercury vapor gas-discharge lamp that uses fluorescence to produce visible light. In the both the incandescent and fluorescent light are harmful to the atmosphere so the LEDs is the best lighting options because of their good quality.

LEDs are growing fast in both display (for backlighting) and general lighting applications [6].

There are three main methods of mixing colours to produce white light from an LED:

- Blue LED + green LED + red LED (color mixing; can be used as backlighting for displays)
- Near-UV or UV LED + RGB phosphor (an LED producing light with a wavelength shorter than blue's is used to excite an RGB phosphor)
- Blue LED + yellow phosphor (two complementary colors combine to form white light; more efficient than first two methods and more commonly used).

White LEDs are usually blue InGaN LEDs with a coating of a suitable material. Cerium (III) doped YAG (YAG: Ce^{3+} or $Y_3Al_5O_{12}$: $Ce^{3+)}$ is often used it absorbs the light firm the blue LED and emit in broad range from greenish to reddish, with most output in yellow.

1.2 Advantages LED: In general

LEDs emit more light per watt than incandescent light bulb. The efficiency of LED lighting fixtures is not affected by shape and size, unlike fluorescent light bulbs.LEDs can be very small (smaller than 2 mm^2) and are easily attached to printed circuit boards. It can emit light of an intended colour without using any colour filter as traditional lighting method used .This is more efficient and can lower initial costs, LEDs light up very quickly : A typical red indicator LED will achieve full brightness in under a microsecond. Its uses in communication device can have faster response time. LEDs can have a relatively long useful time. One report estimates 35,000 to 50,000 hours of useful life though time to complete failure may be longer.LEDs brings solid state components, are difficult to damage with external shock, unlike to other. LED advantages are very vast we include in this paper they are few.

1.3 White LEDs

White LEDs are labeled as solid state semiconductor lighting, which will act as future generation lighting to replace conventional lamp and backlight due to the advantages of low power consumption, free of mercury, high response, no thermal radiation, long life time, high stability and so on. Therefore, the white LEDs are promising candidates to replace conventional incandescent and fluorescent lamps in the coming future. The advanced countries in the world, such as United States, Japan, and European Union, Korea and so on, all invest a lot of resources in the research and development of white LEDs [7].

White light can be made different ways by mixing reds, greens and blues, by using an ultraviolet LED to stimulate a white phosphorsame by using a blue emitting diode that excites a yellow emitting phosphor embedded in the epoxy dome. The combination of blue and yellow makes a white emitting LED [8]. Combine with a white phosphor LED with a few amber ones, and you can create a range of different whites – form the romantic glow of a candle flame to the hot, bright light of the sun. Most "white LEDs" in the production today use a 450 - 470 nm blue GaN (gallium nitride) LED covered by a yellowish phosphor coating usually made of cerium doped yttrium aluminum garnet (YAG:Ce) crystals which have been powered and bound in a type of viscous adhesive. The LED chips emit blue light, part of which is converted to yellow by the YAG:Ce. The single crystal form the YAG:Ce is actually considered a scintillators rather than a phosphor. Science yellow light stimulates the red and green receptors of the eye, the resulting mix of blue and yellow light gives the appearance of white [9-12].

White LEDs can also be made by coating near ultraviolet (NUV) emitting LEDs with a mixture of high efficiency europium based red and blue emitting phosphors plus green emitting copper and aluminum doped zinc sulphide (ZnS:Cu,Al) [1].Typically, white light can be generated by the combination of blue LED chips and a yellow phosphor, YAG: $Ce^{3+.}$ However, the disadvantages of this method are a colour-rendering index (CRI) and high correlated colour temperature (CCT) due to red emission deficiency in the visible spectrum. During the past few years, white LEDs fabricated using near ultraviolet (n-UV) LEDs (380-420 nm) coupled with red, green and blue phosphors have attracted much attention due to advantages of colour stability and excellent colour rendering. Thus, the development of new phosphors with high quantum efficiencies for the UV LED application is highly desirable. Doped rare-earth ions have been widely reported in the application of luminescence material due to their advantages of a low synthesizing temperature and high chemical and physical stability [11].

1.3Commercial Applications

White LED Lighting is being used as an alternative to traditional lighting technology such asfluorescents, halogens, and incandescent due to a increased longevity, efficiency and efficacy. Companies such as Bridgelux, Cree, and Cooper Lighting are creating white LED lighting for businesses, commercial stores, homes, street lamps, and warehouses lighting. Bridgelux develops LED arrays for module or system development. Low-current arrays cost $4 with high-current arrays costing $50 - $75. Cree develops commercial LED modules priced from $200 to $300 with luminosity of 700-1000 lm, longevity of 35,000 hours and 90 colour rendering index (CRI). Cooper Lighting sells an LED modulecalled the Halo series that is designed to retrofit home light sockets that costs $100 with a max efficacy of 57 lm/w, luminosity of 416-793 lm, 80 CRI, and a power consumption rating of 14 W. Depending on the application, these LED systems can be accomplished by discrete arrays or single die arrays. Discrete LED arrays offer the highest efficacy with values over 100 lm/w. Complex re-flow soldering and thermal management make this type of array difficult to produce as each LED must be individually optimized. LED die arrays offer a more dynamic range of luminosity, bulk thermal management, and "plug-and-play product development."

2.aim of the research

Research aimed at the discovery of new phosphors has been dependent on the knowledge of solid-state physics and crystal chemistry. Generally, the exploration of new phosphors involves the repetition of a sequential process: 1) devising the composition of a chosen candidate sub- stance, 2) its synthesis, 3) characterization of the fluorescence of the synthesized material, 4) modification of the original composition, 5) its re-synthesis, and so on. However, it should be noted that the aforementioned process needs to be repeated several times to develop a new phosphor. Therefore, the process of discovering a new phosphor requires an enormous amount of time and effort. As a consequence, the search for new phosphors was confined to a limited composition range [14].

2.1 Method used in exploration of new phosphors

One of the effective ways of addressing the challenge is to employ generic algorithm-assisted combinatorial chemistry (GACC), which was applied to the development of heterogeneous catalysts in the recent past [15-17]. GACC has been successfully utilized by Kee-Sun Sohn's group for the exploration of new phosphors for the use in plasma displays and light-emitting diodes (LEDs) [18-21]. More recently, the same research group employed high- throughput combinatorial chemistry in combination with an advanced computational approach based on particle swarm optimization [22] , and executed a so-called particle swarm optimization-assisted combinatorial materials search (PSOCMS) to discover novel phosphors such as $Ce_{2\cdot 6}Ca_{1.4}Si1_{2}O_{4.4}N_{16.6}:Eu^{2+}$ and $La_{2.544}Ca_{1\cdot 456}Si_{12}O_{4.456}N_{16.544}:Eu^{2+}$ [23].Considerable attention has been paid to the following in both GACC and PSOCMS: 1) development of computational algorithms to make the high-throughput combinatorial screening efficient and 2) shortening of the time needed for the final identification of promising compositions. On the other hand, lesser attention has been devoted to the method of the material fabrication itself although it is crucial to establish the methodology for the reliable synthesis of phosphors, as this ensures homogeneity of compositions and uniform distribution of activators in given host compounds. In most previously reported studies based on GACC/PSOCMS as well as the synthetic studies on phosphors, researchers have primarily relied on the traditional method based on solid-state reactions. As a result, precise control of the compositions of phosphors and achievement of a homogeneous distribution of small amounts of activators in the host compounds were not possible. Another methodology involving a mineral-inspired approach in combination with the so-called solution parallel synthesis (SPS) method [24]. In the SPS method, tens of type's samples are synthesized at once under the same conditions by employing the "polymerizable complex (PC) method[25-27] or the "amorphous metal complex (AMC) method"[25-27]. This results in relatively simple and efficient screening of the phosphor candidate substances, which was difficult through conventional techniques. The PC and AMC methods are best suited for homogeneous synthesis of ceramics with complex compositions. The explored new phosphors containing silicon by focusing on silicon of Clarke number 2 and employing the SPS method. There are more than 18,000 inorganic crystalline com- pounds containing silicon, a common element [28-29]. However, since most of them are found in natural minerals, their artificial synthesis is difficult. As a result, their application as functional ceramics, e.g., phosphors, is un-common.

2.1.1 Significance of Mineral Inspired Methodology

For the exploration of a new phosphor adopt a ''mineral inspired methodology'' is good. Among different possible matrices, silicates are good candidates to serve as the host structure due to several merits such as excellent chemical and thermal stability and their abundance in nature, they constitute approximately 90% of the crust of the earth [30].Interestingly, the number of known inorganic silicates is over 14 000, most of which have been derived from natural minerals, and this substantiates the significance of the mineral inspired approach. For example, rankinite ($Ca_3Si_2O_7$), jervisite ($NaScSi_2O_6$), wastromite ($BaC_{a2}Si_3O_9$), akermanite ($Ca_2MgSi_2O_7$), anorthite ($CaAl_2Si_2O_8$), or pyrope ($Mg_3Al_2(SiO_4)_3$)], doped with a rare-earth ion, can act as an efficient phosphor [31-36]. The large number of phosphors derived from minerals evidences the fact that this ''mineral inspired methodology'' for developing a new phosphor is advantageous and less time-consuming than the combinational method developed by a generic algorithm. Apart from this approach, another fact that the needs to be documented is that, until now, the reported silicate phosphors were mainly synthesis by a conventional high temperature solid state reaction methodology,[37-40] which has some drawbacks such as the volatility and low melting point of the starting material and possible side reactions eventually fail to produce the desired compounds.

2.2 Need of the new phosphors

White-light emitting diodes, the so called next-generation solid-state lighting, offer benefits in terms of high energy efficiency, durability, reliability and safety, and, most importantly, energy saving and therefore they can replace conventional incandescent and fluorescent lamps. Owing to their reduced power use, LEDs in conjugation with renewable energy sources also offer great promise in providing lighting in remote and underdeveloped areas of the world. Towards these ends, the Optoelectronics Industry Development Association (OIDA) plans to achieve 200 lm $W^{-}1$ efficacies with good colour rendering by 2020. To achieve this goal, new phosphors with high efficiencies are the key. The most frequently used n-UV excitable blue phosphor is $BaMgAl_{10}O_{17}:Eu^{2+}$ (BAM), whose absorption in the n-UV region is poor; as a consequence, investigations into the development of a new n-UV excitable blue-emitting phosphor has become essential [30], [41-43].

LEDs that generate high-intensity white light by producing white light-emitting diodes (WLEDs). One is to use individual LEDs that emit three primary colours red, green, blue and then mixture all the colours to form white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad spectrum. White light, much in the same way a fluorescent light bulb works.

3. Conclusion

For the exploration of a new phosphor may method are involved but my study about this topics it so that the“mineral inspired methodology’’ is the best method. Because in this method we use different possible matrices, silicates are good candidates to serve as the host structure due to several merits doped with a rare-earth ion, can act as an efficient phosphor. LEDs have many advantages over incandescent light source including lower energy consumption, longer life time, improved physical robustness smaller size and faster switching. However, LEDs powerful enough for room lighting are relatively expensive and require more precise current and heat management that compact fluorescence lamp sources of comparable output. So my future works for the exploration of new phosphor by the mineral inspired methodology.

References

[1]en.wikipedia.org/wiki/Phosphor (Accessed in November 2013)

[2]www.cree.com/~/.../Lighting/.../Compositionof WhiteLEDsJul72008.pdf Composition and Supply Chain Considerations of White Lighting-Class LEDs. Mark McClear; mark_mcclear@cree.com. July 7, 2008

[3]More on rare earth elements: http://en.wikipedia.org/wiki/Rare_earth_element

[4] A. Mills, 2005,III-Vs ReviewVolume 18, Issue 3, Pages 32–34.

[5].http://www.imicronews.com/upload/Rapports/LED_Phosphor_2012_Sample.pdf

[6]Dr. K. Senthil , Sungkyunkwan University South Korea2013 International Military Science and Technology Fair

[7] W.J. Yang, May 2007” Thesis -Design, Synthesis and Luminescence Characterizations of Single-Composition Phosphors for White Light-Emitting Diodes”Hsinchu, Taiwan, Republic of China

[8] Y. Shimizu, K. Sakano, Y. Noguchi, and T. Moriguchi, 1998, Japan Patent 10-56208.

[9]www.mt*berlin*.com/frames_cryst/descriptions/led_phosphors.htm

[10] en.wikipedia.org/wiki/Light-emitting diode

[11] C.H. Huang, C. Pin Wu, T. Chen,W. R. Liu, Y. T. Yeh and Y. C. Chu , 2011, J. Mater. Chem., 21, 6869

[12] S. Lee and S. Y. Seo, 2002, J. Electrochem. Soc., 149, 158

[13]www.lrc.rpi.edu/programs/nlpip/lightinganswers/.../whiteLightMethod.as...

[14]H. Kato. J. Kim,M. Kakihan, , T. Komukai, , Y. Sato, M. Kobayashi, Y. Takatsuka , 2013, “Optics and Photonics Journal, 3, 5-12.

[15] O. V. Buyevs kaya, A. Bruckner, E. V. Baerns, 2001, Catalysis Today, Vol. 67, No. 4, pp. 369-378.

[16] D. Wolf, O. V. Buyevskaya and M. Baerns, 2000, Applied Catalysis A, Vol. 200, No. 1-2, pp. 63-77.

[17] J. S. Paul, R. Janssens, J. F. M. Denayer, G. V. Baron and P. A. Jacobs, 2005, Journal of Combinatorial Chemistry, Vol. 7, No. 3, pp. 407-413.

[18] K. S. Sohn, D. H. Park, S. H. Cho, J. S. Kwak and J. S. Kim, 2006, Chemistry of Materials, Vol. 18, No. 7, pp. 1768-1772.

[19] K. S. Sohn, D. H. Park, S. H. Cho, B. I. Kim and S. I. Woo, 2006, Journal of Combinatorial Chemistry, Vol. 8, No. 1, pp. 44-49

[20] K. S. Sohn, J. M. Lee and N. Shin, 2003, Advanced Materials,Vol. 15, No. 24, pp. 2081-2084.
[21] K. S. Sohn, B. I. Kim and N. Shin, 2004, J. Electrochem. Soc., Vol. 151, No. 12, H243-H248.
[22] Y. S. Jung, C. Kulshreshtha, J. S. Kim, N. Shin and K. S. Sohn, 2007, Chemistry of Materials, Vol. 19, No. 22, pp. 5309-5318
[23] J. Kennedy and R. Eberhart, 1995, IEEE International Conference on Neural Net-works, Perth, Vol. 4, 27 , 1942-1948.
[24] W. B. Park, Y. S. Jeong, S. P. Singh and K. S. Sohn, 2013, ECS Journal of Solid State Science and Technology, Vol. 2, No. 2, pp. R3100- R3106.
[25] Y.Suzuki and M. Kakihana, 2009, Journal of American Ceramic Society",Vol.92, Suppl., s1, pp. S168-S171.
[26] M. Kakihana, 2009, Journal of the Ceramic Society of Japan, Vol. 117, No. 8, 2009
857-862.
[27] M. Kakihana and M. Yoshimura, 1999, Bulletin of the Chemical Society of Japan, Vol. 72, No. 7, pp. 1427-1443.
[28] M. Kakihana, 1996, Journal of Sol-Gel Science and Technology, Vol. 6, No. 1, pp. 7-55.
[29] Inorganic Crystal Structure Database (ICSD), compiled by Das, 2012 Fachinformationszentrum (FIZ) Karlsruhe (in Germany) and National Institute of Standard and Technology (in United States of America).
[30] S. Ray, T. M. Chen and Y. C. Fang , 2013 RSC Advances, 2013
[31] F. Qian, R. Fu, S. Agathopoulos, X. Gu and X. Song, J..Lumin., 2012, 132, 71.
[32] S. Merlino and P. Orlandi, Period Mineral, 2006, 75, 189.
[33] S. Yao, L. Xue and Y. Yan, 2011, Opt. Laser Technol., 43,1282.
[34] L. Jiang, C. Chang, D. Mao and C. Feng, 2004, Opt. Mater., 27, 51.
[35] J. K. Park, J. M. Kim, E. S. Oh and C. H. Kim, 2005, Electrochem.Solid-State Lett., 8, H6.
[36] T. Ohagaki, A. Higashida, K. Soga and A. Yasumori, 2007, J. Electrochem. Soc.,154, J163.
[37] A. K. Sharma, C. Kulshreshtha and K. S. Sohn, 2009, Adv. Funct.Mater., 19, 1705.
[38] W. J. Yang, L. Luo, T. M. Chen and N. S. Wang, 2005, Chem. Mater., 17, 3883.
[39] W. B. Im, Y. I. Kim and D. Y. Jeon, 2006, Chem. Mater., 18, 1190.
[40] J. K. Park, K. J. Choi, J. H. Yeon, S. J. Lee and C. H. Ki, 2006, Appl. Phys. Lett., 88, 0435111.
[41] T. Hasimoto, F. Wu, J. S. Speck and S. Nakamura, 2007, Nat. Mater., 6, 568.
[42] W. B. Im, S. Brinkley, J. Hu, A. Mikhailovsky, S. P. DenBaars and R. Seshadri, 2012, Chem. Mater., 22, 2842.
[43] S. C. Allen and A. J. Steckl, 2008, Appl. Phys. Lett., 92, 1433091.