Current progress and comparative study of performance of the energy saving lighting devices: a review

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Abstract. In the present scenario, rare earth activated phosphor materials are important families in luminescent materials, which is useful in various applications. Over the past few years, rare earth activated phosphor has gained a lot of attention from the society and research community due to its exceptional properties such as low cost, eco-friendly behavior, solution process ability, better PL properties, wider range of color tunability, color purity and defects tolerance etc. In this review, we first discuss energy saving lighting devices, after that, we have discussed those methods which are used to synthesize rare earth activated phosphors. We have been focusing on the modification and tailoring of the photoluminescence of phosphors, which may lead to the acquisition of new phosphors with tunable emission colors. In this review, we are discussed recently reported color tunable phosphors. At the end of the review, scope in lighting field, energy saving devices, and future scope also discussed.

Keywords: luminescent materials; color tunability; photoluminescence; energy saving devices

1. Introduction
In a last few year, the consumption of energy of light sources concerning with biasing of light source became one of the major problems for the entire world. Thus, the main demand of the world economy and the global environment is to saving energy and reduction in the carbon emission and also the environmental cycles deflecting gases. The main lighting sources are candescent and fluorescent. Due to the very low luminous efficacy of an incandescent light and very limited life-time, incandescent light source was not enough source that reference for the energy saving purposes. The fluorescent light is more efficient as compared to the incandescent but fluorescent tubes are fragile and bulky in form. Although fluorescent light has a typical color rendering index (CRI) values in the range of 80-90 CRI (CRI measures the ability of light source to reproduces colour of various object related to the sunlight) there is also problem of disposal due to the presence of mercury. In addition, because of low power or energy circulation and long lifespan, compact fluorescent lamps (CFLs) have emerged as one of the alternatives to incandescent lamps or bulbs. But CFLs require a high initial input current. 220V AC current is not sufficient to start fluorescent lamps. This requires an electronic explosion to achieve the required 600–1000 high voltage ignition spike. [1]. Also, CFLs cannot operate in humid indoor, refrigerators and microwave ovens. At the present time, the research society hopes that the widespread use of the LEDs source of light as compared to the traditional light sources will reduce power consumption and support the environment worldwide. The current lighting system promotes the development of LEDs for an additional lighting system in the modernization era. Noble prize in physics (2014) honours the researchers (I. Akasaki, H. Amano, s. Nakamura) of high efficient blue LEDs which offers not only energy saving lighting source but also accrete the interest of researchers toward LEDs
lighting and this invention of blue LEDs has led to white light sources [2]. The unique characteristics of LEDs such as compact size, long-life, good performance in cold temperature, lack of unwanted emission and ease of maintenance are very beneficial in many applications [3–5].

The development of white light-emitting diodes (w-LEDs) in display technology have gained great interest arises due to its high efficiency, low power consumption, long lifetime, and high compatibility, energy saving, eco-friendly behavior, as well as are of highly economical [3–5]. This beneficial technology is capable of replacing incandescent and fluorescent lamps. According to earlier studies, LEDs are 9 to 10 times greater than the CFLs [6]. Thus, due to the amazing and tremendous properties of LEDs, it is better than CFL lamps. Due to the potential application in the lighting and display sector, the popularity of white WLED has increased. Addition of red phosphor to a WLEDs results in the low color correlated temperature (CCT) and high CRI [7]. It is always experimentally found that the contamination phases that exist with the leading phase, could acts as a non-radioactive centre for a quenching the luminescence.

In the current scenario, the search for efficient materials is necessary to increase the qualities of the LEDs. Physical, chemical, and thermal stability are important in the search for a good host material. Nowadays, phosphors are widely used for LEDs applications [8–10]. As it is very clear, lanthanide (Rare-earth) ions are very important for the development of phosphor materials. Rare earth activated phosphor play key role due to their excellent luminescence properties. Because of the superb optical and electromagnetic properties and substance dependability they are attractive host material for the lanthanide dopant particles to synthesized phosphors, which is used for various applications such as Raman lasers, optical communications, Thermoluminescence dosimetry (TLDs), display technology, Solar Cell, and a lot more fields [11–13]. These days, the host materials with rare earth ions and incredible optical properties are generally use to prepare phosphors that are utilized for the lighting applications. In spite of the fact that WLEDs have been found to have higher color quality of light, high energy efficiency, high colour stability, and long lifespan, but the superiority of light is low. They have some obvious drawbacks because of high CCT, high CRI, value and lack of red light components [14,15]. And the purpose of this study is to construct or find phosphor materials that can overcome these shortcomings and developed advanced WLEDs. Therefore, for the development of WLEDs applications, it is very important to synthesize red-emitting phosphorus by absorbing light in the range of 360–400nm [16–18]. As per literature, there has been an increase in the demand for the manufacture and study of red-colored phosphor. High-efficiency light can be obtained by mixing red phosphor with blue and green LEDs [19,20]. The different types of LED lights are ideal for numerous applications provided a great interest in new researchers in a field of energy saving lighting devices. In such a way, the enhancement of the LEDs in recent years which are superior over the incandescent and fluorescent lamps contributes a lion’s share in the various fields especially for the energy saving purposes.

2. Importance to study of Energy Saving Lighting Devices

In this era of digitalization, LED has shown its utility in the field of lighting and has been first used as a variety of lighting applications in developing countries. The main feature of LEDs is low energy consumption and high output. It’s always observed that, a large portion of your electricity bills goes directly toward the paying for the lighting that has been consumed by you. The lighting fixtures such as bulbs, tube lights, chandeliers etc. can make a significant change in your electricity consumption if they are properly used. Your lights can play an important role in saving the energy consumption level, if you develop good lighting habits. We have created a list of the many facts that will make you understand how your lighting fixtures have been consuming the energy and how effective use of the lighting can preserve the energy. The increasing requirement of energy in our daily life is well known, we use energy in various forms in our life. In this era of modernization, we use energy from waking up in the morning to sleeping at night, such as the lighting in homes, machinery in factories, entertainment equipment, and many other things. The role of energy conservation is important in reducing climate change. In the
present work, we encourage energy saving in the field of lighting. Old lighting equipment used in our homes consumes high amounts of energy for low output yield. Therefore, we suggest the use of WLEDs for lighting, whose main reason is their quality. LEDs is one of the most energy-efficient and fast-developing lighting technologies today. Quality LED light bulbs are longer, more durable, and provide comparable or better light quality than other types of lighting. LEDs are also environmentally safe because they do not contain mercury in its components. Therefore, we suggest the use of WLEDs for lighting, whose main reason is their quality.

3. Characteristics of phosphor converted LED phosphors

3.1. Photoluminescence

It is the emission of light from any form of matter with the absorption of photon (electromagnetic radiation). It is one of the many forms of luminescence and is initiated by photon-excitation (excitation by photons). Photons having wavelength from vacuum ultraviolet (VUV) region to infrared (IR) region acts as source of excitation. The mechanism of photoluminescence is different for organic and inorganic materials.

3.2. Energy Transfer

Sometimes absorption by the activator ion is weak which leads to very weak or no PL emission. In this case, some other dopants are used to increase the absorption of the energy in the host called as sensitizer. Sensitizer absorbs energy efficiently and subsequently transfers it to activator ions, which results in intense PL emission from activator ion. Generally, trivalent rare earth ions (Eu$^{3+}$, Dy$^{3+}$, Tb$^{3+}$, Sm$^{3+}$, etc) have 4f-4f transition which are parity forbidden and therefore, their emission as well as excitation intensities are very low. But rare earth ions having allowed 4f-5d transition (Eu$^{2+}$ and Ce$^{3+}$) shows intense excitation and emission band. Therefore, rare earth ions with 4f-5d transition can be used to sensitize rare earth ions with 4f-4f transition. Also, the emission spectrum of sensitizer should match with excitation spectrum of activator i.e. special overlap is necessary condition for getting energy transfer between sensitizer and activator. There are two types interaction by which energy two ions can be possible. One is exchange interaction and second is electrostatic interaction. In exchange interaction, electron is transferred from sensitizer ion activator ion in ground state. In electrostatic interaction sensitizer induces a dipole oscillation on the activator ion by which energy is transferred.

3.3. Concentration Quenching

On increasing dopant concentration in the host lattice, luminescence intensity increases up to a certain concentration and then starts decreasing on further increase of dopant concentration. This phenomenon is called concentration quenching. Generally, concentration from 1mol% to 5mol% are optimum concentration for doping of rare earth ions. Concentration quenching occurs due to resonant energy transfer between the same ions’ species. There is one more possibility that decreases in concentration of dopant ion decrease emission intensity as decrease in the activator concentration decrease the energy stored by the ions. Therefore, it is important to determine optimum concentration of dopant which will result in maximum PL emission intensity.

3.4. CIE chromaticity coordinates

The color characteristics of light can be described by basic parameters which is known as Commission International de l'Eclairage (CIE) chromaticity coordinates [21]. The color coordinate is the key factor for practical lighting applications [22]. It is important for determination of colors through luminance parameter and two coordinates x and y. This approach provides more prominent precision in color measurement because this approach depends on the spectral power distribution (SPD) of light emitted from a colored object and considered by sensitivity curves that are estimated for the human eye. In the CIE diagram, any color can be expressed as the coordinates x and y. The colors that can be matched by mixing a given set of three primary colors (such as blue, green and red television screens) are shown on a chromaticity diagram by a triangle joining the coordinates of the three colors.
3.5. Color Retendering Intex (CRI)
In addition to CCT, CRI is an important parameter to determine the lighting quality of a light source, which is indicating the color quality and ability of color emission of the lighting source. The value of CRI value ranges from 0 to 100. The color rendering index value should be higher for white light source because the color shift is very less in this situation. If the value of the CRI is 0 then the quality of the light source is poor, similarly, if the value of the CRI is between 55–65, 65–75 and 75 –100, then the quality of the light source is fair, good and excellent, respectively.

3.6. Color correlated temperature (CCT)
A light source is, usually, specified in terms of color temperature to describe the color appearance of a light source by associating it with the temperature of an ideal blackbody radiator. Color temperature is measured in units of Kelvin (K). However, the term is limited only to light sources that are powered by thermal radiation. Incubation bulbs are good examples of light sources giving thermal radiation.

4. Synthesis methods
Luminescent and non-luminescent nano materials are used today in a various lighting applications. In the current scenario, research scholars and researchers are trying to synthesize new materials with better properties, greater functionality, and cheaper costs than the current one. Scientists commonly use different methods to gain better control over the size and composition of particles, such as solid-state reaction method, combustion method, sol gel method, co-precipitation method, wet chemical method, hydrothermal method, etc. In this section, we are discussing some synthesis methods, which are used for preparation of phosphor materials.

4.1 Solid-State Reaction Method
Solid state reaction method (SSR) is generally most popular and effective method for synthesis of materials. In this method solid precursors are used as a starting material. This method is suitable for mass production of materials such as oxides, (oxy) fluorides, (oxy) chlorides and (oxy) nitrides [23]. In the first step of this method, the precursors are weighed in appropriate proportions and then mixed and ground to obtain homogeneous solid solutions. Subsequently, the obtained powder is heated at high temperature, so that atoms or molecules can diffuse easily and complete the chemical reaction. The main advantage of SSR method is product quality like homogeneity of phase, high crystallinity, grain size of phosphors, and luminescence properties. In the last decades numerous papers are reported by SSR method. The main disadvantage of this method is expensive machineries for high heat treatment [23,24].

4.2 Sol Gel Method
The sol-gel method is an appropriate method for synthesizing luminescent materials. This method permits a superior control of the entire reactions participated during the preparation of solids. Homogenous multi-component systems can be effectively acquired. Various nitride, silicate, and sulfate materials can be synthesized by this method. In this method the materials are first measured in a fixed ratio, then the samples are taken in a beaker and mixed by a magnetic stirrer hot plate. Stirring the sample into a hot plate turns the sample into gel. After the sample is converted into gel, the wet gel can be optionally washed in another solvent, then the sample is allowed to dry in a preheated oven. The time between gel formation and its drying, also known as aging. The major benefits of this method is homogeneity of synthesized material, high purity of the samples, morphological control, variety of precursors, etc [25–27].

The stages of the Sol-Gel process [28]
- Hydrolysis of precursor (sol formation)
- Polycondensation (gelation)
- Aging
- Drying
- Calcination
4.3 Combustion Method
Combustion synthesis process is also known as self-propagating high-temperature synthesis (SHS). Combustion synthesis is a new method introduced to the production of phosphor over the last few years. This method is use for the production of both organic and inorganic by exothermic combustion reactions in solids of different nature. Synthesis of the combustion involves an exothermic reaction among metal nitrates and a fuel. The weighed starting materials was combined in mortar as per stoichiometric ratio and eventually a pasty substance was produced after the substance was moved in the muffle furnace at around 500-550°C. The flame developed with the fluffy powder was produced. This method creates the as- synthesized state of strongly crystalline powders [29]. By this method different materials are developed for different applications. In this method different types of fuels are used such as urea, citric acid, glycine, Ethylene glycol, acetic acid, hydrazine, etc. To be accountable for changing combustion mechanisms and kinetics, the choice of the appropriate fuel should be a basic parameter and therefore gives the possibility to control product characteristics. Combustion method has paid special attention for some epic advances in materials and various applications.

4.4 Co-precipitation method
This synthesis method is commonly used to produce oxide and fluoride-based phosphor materials [30]. This method can be considered a smart technique for the development of oxide and fluoride-based phosphors, because this method does not require rare earth (RE) to form oxides and fluorides. The main advantage of this technique is that it reduces the particle size of synthesized materials and does not require any special expensive equipment of synthesis. However, one of the main problems of co-precipitation processes is that this method consumes more time. Because the elimination of ions coming from the precursor salts used for this requires frequent washing. In addition, this method also requires post-fabrication thermal treatment for the successful synthesis of oxides and fluorides phosphors. From which the water molecules can be ejected from the obtained product. Therefore, chemical co-precipitation techniques demand calcination to obtain crystalline phosphors.

5. Recently Reported Color Tunable Phosphors
5.1. K$_2$TaO$_5$F$_3$:Mn$^{4+}$
Yang Zhou et al. reported red emitting Mn$^{4+}$ activated K$_2$TaO$_5$F$_3$ phosphor, which has been successfully synthesized by two-step synthesis method [31]. It crystalizes as cubic structure with a space group Fm$ar{3}$m, confirm from Rietveld method. By refine authors are found lattice parameters as a = 6.305 (4) Å, c = 8.917 (6) Å, Z = 2 and V = 354.57(5) Å$^3$. PL excitation bands have been obtained at 360nm and 460nm for synthesized phosphors, these excitation bands are a perfect match with the InGaN chip blue and Se ultraviolet light, which is suitable for WLEDs. In addition, the intensity of the blue excitation band (460 nm) in the PL excitation spectra is higher than the ultraviolet excitation band (360 nm). So, this red emitting phosphor can be efficiently excited by blue light InGaN chip. Under 360nm and 460nm excitation, PL emission spectra are observed, the synthesized phosphor emits narrow band red emission band at 630 nm. Yang Zhou et al. fabricated warm white-WLEDs by using a blue LED chip with combination of Y$_3$Al$_5$O$_{12}$:Ce$^{3+}$ yellow phosphors and the red emitting K$_2$TaO$_5$F$_3$: Mn$^{4+}$ phosphor. The fabricated WLEDs revealed excellent color features such as CCT = 3488 K, Ra = 93.0, R9 = 90.0. All these results revealed the synthesized phosphor may be potential red emitting phosphor for WLEDs lighting [31].

5.2. BaNb$_2$O$_6$: Eu$^{3+}$
A novel Eu$^{3+}$ doped BaNb$_2$O$_6$ phosphor was reported by Amit K. Vishwakarma and M. Jayasimhadri [32]. The prepared phosphor was successfully prepared via SSR method. The synthesized Eu$^{3+}$ doped BaNb$_2$O$_6$ phosphor revealed orthorhombic crystal structure and irregular morphology. PL studies suggest that under 466nm PL excitation, analyzed emission spectra revealed various emission peaks at
579 nm, 592 nm, 614 nm, 657 nm, 704 nm wavelengths, which are ascribed due to $^5D_0 \rightarrow ^7F_J$ (J = 0, 1, 2, 3 and 4) transitions of Eu$^{3+}$ ions [32]. The calculated value of the optical band gap and color purity of red emission was found to be 3.37 eV and 99.5%.

5.3. Eu$^{3+}$ activated La$_2$(MoO$_4$)$_3$ down conversion phosphors

Yatish et al [33] reported Eu$^{3+}$ activated La$_2$(MoO$_4$)$_3$ down conversion phosphors by SSR method. In this research paper, the authors have tried to increase the photoluminescence intensity through doping of phosphate, sulfate, and vanadate ions, as shown in Figure 1. In this work authors are observed 467 nm excitation wavelength in the Eu$^{3+}$ doped La$_2$(MoO$_4$)$_3$ phosphor. This synthesized phosphors also represents intense red color at 614 nm monitored under 467 nm excitation wavelength, which is attributed due to the $^5D_0 \rightarrow ^7F_2$ transition of Eu$^{3+}$ ion. It was also seen that maximum intensity observed at 1 mol% concentration of Eu$^{3+}$ ions. The crystallinity and morphological behavior were improved in the presence of phosphate, sulfate, and vanadate ions and photoluminescence properties were also increased. It is clear from the figure, the enhancement in PL intensity at 535 nm emission wavelength has minimum and at 614 nm emission wavelength has maximum. It has also been reported by the authors that when Molybdanate ions are replaced by vanadate ions, the increase in intensity of photoluminescence is maximum. Reportedly, it was observed that the increase in PL intensity is near about two times to its original intensity [33].

![Figure 1](image-url) Comparative study of PL emission intensities with doping of phosphate, sulfate, and vanadate ions in the La$_2$(MoO$_4$)$_3$:1 mol% Eu$^{3+}$ monitored at 467 nm. “Reprinted and copyright permission obtained from Elsevier publication [33].”

5.4. BaSiF$_6$:Ce$^{3+}$, Eu$^{2+}$ phosphor

A R. Kadam et al. [34] studied energy transfer mechanism in BaSiF$_6$:Ce$^{3+}$, Eu$^{2+}$ phosphor, which is synthesized by solution combustion method. In this work, temperature during synthesis is low at 500 ± 20°C and urea is used as a fuel material. In the investigation, crystal structure, phase purity, morphological, structural and luminescence properties were studied. Under 300 nm excitation, Ce$^{3+}$ activated BaSiF$_6$ phosphor gives broad emission band in the UV region peaking at 325 nm, 344 nm and 377 nm, which can be attributed to the 4f-5d transition of Ce$^{3+}$ ions. Further, BaSiF$_6$:Eu$^{2+}$ phosphor also gives broad emission band in blue color region centered at 445 nm, and ascribed to the d-f transition of Eu$^{2+}$ ions. After that PL excitation (PLE) spectrum was observed for BaSiF$_6$:Ce$^{3+}$, Eu$^{2+}$ phosphor under at 440 nm. The PLE exhibits broad band in the UV region centered at 362 nm that is broader than the individual PLE spectrum of Ce$^{3+}$ and Eu$^{2+}$. On the co-doping of Ce$^{3+}$, Eu$^{2+}$ in BaSiF$_6$ phosphor, PL emission intensity increased with variation of Eu$^{2+}$ ions after 0.5 mol% Eu$^{2+}$ concentration emission intensity decreased owing to the concentration quenching. As shown in Figure 2, the intensity of the
blue emission is increased by about 5.8-fold compared to the individual Eu$^{2+}$ blue emission which confirms the energy transferred from Ce$^{3+}$ to Eu$^{2+}$ [34].

Figure 2: (A) PL emission spectra of BaSiF$_6$:0.7mol%Ce$^{3+}$, xmol%Eu$^{2+}$ phosphor under 362nm excitation (B) Energy level Ce$^{3+}$ and Eu$^{2+}$. “Reprinted and copyright permission obtained from Elsevier publication [34].”

5.5. Gd$_2$GeO$_5$ (GGO):Bi$^{3+}$, Eu$^{3+}$ phosphors

Recently, Qi Sun et al. [35] studied color tunable Gd$_2$GeO$_5$ (GGO):Bi$^{3+}$, Eu$^{3+}$ phosphors and energy transfer mechanism for light-emitting diodes. In this work, authors are synthesized GGO: Bi$^{3+}$, Eu$^{3+}$ phosphors via solid state reaction method. The PL emission spectrum of the GGO: Bi$^{3+}$, Eu$^{3+}$ phosphors exhibits emission at 453 nm due to the $^{3}$P$_{1}$$rightarrow$$^{1}$S$_{0}$ allowed transition of the Bi$^{3+}$ ions and the several sharp red emission bands are observed due to the $^{5}$D$_{0}$$rightarrow$$^{7}$F$_{J}$ (J = 0, 1, 2, 3, 4) transitions of the Eu$^{3+}$ ions. Further, PL emission spectra realized blue-red tunable color emission monitored under 321 nm UV excitation. The occurrence of Bi$^{3+}$ and Eu$^{3+}$ on the PLE spectra clearly indicated energy transfer of the Bi$^{3+}$$rightarrow$Eu$^{3+}$. In this study, GGO:0.05Bi$^{3+}$,0.12Eu$^{3+}$ phosphors exhibited high IQE and good thermal stability. As per investigation, the authors are concluded that synthesized GGO:0.05Bi$^{3+}$,0.12Eu$^{3+}$ phosphors is a reliable product for plant growth LEDs and white LEDs [35].

6. Scope of Lighting Devices

The innovation of smart lighting technology gives a particular scope with respect to the energy effectiveness, accommodation and security. This may include devices with high efficiency and robotic control that allow changes based on conditions, such as the availability of sunlight at various locations, to accomplish some stylish or easy effects. This includes task lighting, supplement lighting and general lighting etc. The innovation of Smart lighting empowers families and clients to distantly control cooling, warming, lighting and apparatuses, limiting superfluous light and energy use as well [35–37]. This ability saves energy and gives a more noteworthy degree of comfort and convenience. Next to the customary lighting businesses, the future accomplishment of lighting will require the association of various partners and furthermore partner networks. Likewise, the idea of deep light involves using basic light from the sun to reduce man-made light customers and turning off the light when people leave the room [38].

Based on earlier studies, it is known that the lighting control system is based on an intelligent network, which controls lighting using at least one central computing device. This system establishes correspondence between input and output. Lighting control systems are commonly used for a variety of applications such as lighting outside of indoor, outdoor, modern, commercial, and private locations [39]. The lighting control system controls the light with precision and supplies the lighting as needed. Continuous task lighting alludes to expanded luminescence to better accomplish a particular action.
However, the luminance level is not the key level controlling visibility. Contrast is an important lighting parameter that determines the quality of the light source. Visibility of the light source is reduced if the contrast of the light source is at work. Therefore, in any workplace, lighting is the main purpose of the assignment. The overall lighting can be diminished on the grounds that task lighting gives focused light where required. There are other examples of the use of light in machinery where a particular work area required enlightenment, and in workshops, where an undertaking light may enlighten the real working territory. The main function of light is done in medicine and medical procedure, as a dentist's lamp as well as in examination and operation light. The main advantage of the lighting control system is the ability to control individual light sources or groups of light sources from a single user device. Also, such a capacity to control various light sources from a user device permits complex or challenges lighting scenes to be made. The room may have various scenes pre-set and every one making for various exercises in the room. The major satisfaction of lighting control system is decrease in the energy utilization. Longer lamp life is additionally picked up when darkening and turning off lights when not being used. The remote lighting control systems gives extra advantages including diminished establishment costs as well as expanded adaptability over where turns off and sensors might be put [39, 40].

7. Future Challenges to Lighting Devices
Various research reports on lighting devices have shown that light can similarly affect concentration, inventiveness, joint effort, and ultimately efficiency, which has accelerated its selection in commercial lands. Human-centric lighting has been around for five years or more but its definition is still unclear. The term itself is a bit of a misnomer in the sense that most lighting has been focused on humans, long before lighting even became electric. The current revolution in lighting is not about simple illumination, nor efficiency or even LEDs. Human-driven lighting has been around for a very long time or all the more yet its definition is as yet indistinct. The term itself is somewhat of a misnomer as in most lighting has been centered around people, well before lighting even got electric. The current unrest in lighting isn’t about straightforward brightening, nor efficiency or even LEDs. In 2017, the Memory Workplace Survey reported that a natural light originated as the best type of light for an office. "Perhaps it is peculiarly surprising that abundant natural light had the best difference, contrasting with those more than six times the number of respondents who believed natural light guide fixation. Conditioned by evolution to respond to the tone and rhythm of sunlight, natural light is the ideal form of light that benefits employee concentration and therefore productivity". The new world of light is about people. Before introducing new lighting systems, businesses should focus on increasing the level of natural light in the work environment using windows or an improved office format. At a time when natural light is unimaginable, LEDs provide ideal qualities compared to the other options. Effectiveness, cost-effective and ecological benefits of LEDs are evident. However, by better supporting the worker, enterprise workers can bring a lot of value through health, focus, collaboration, and ultimately productivity. This is why LEDS is very important in the field of lighting.

8. Concluding Remark
Energy utilization from lighting accounts to 20% of worldwide energy production, given the worldwide energy emergency, has led to the progress of pc-WLEDs as an ideal green light source for the next generation lighting industry due to their outstanding benefits. With the fast improvement of modern science and technology, emerging stringent technical and practical demands have become strict criteria for PC-WLEDs, both with respect to their luminous efficiency and tuning emission colors. Demand for lighting applications is increasing day by day, but at the same time, it is also a rapidly growing source of greenhouse gas emissions. LEDs have high energy-saving efficiency in light sources and they encourage new energy savings in the market with current technology. And so there is no doubt, a global reduction in greenhouse gas emissions can be achieved by lighting LEDs and low-cost lighting with a better environment. LEDs can achieve high quality lighting at low energy consumption. At the present
time, the development of LED has gained great popularity in the research society for lighting. Developing countries as well as developed countries also recognized the potential of LED and promoted its use. LED has cleared the way for rapid various developments in innovation. Currently, LEDs are not just limited to lighting needs but are gaining deep respect for their vast applications in various fields. The changing requirements led to various adjustments to the LED system and this led to the move from well-established semiconductor materials science. Lighting updated in this way will be more energy-efficient depending on the use of the devices and their combination may be the best. The overall study of rare-earth activated phosphors has led to amazing developments in recent years. In the field of lighting, several rare-earth activated phosphors have been reported that are suitable for WLEDs application and their results indicate that they have met all the criteria required for lighting purpose. They also gives advantages in the field of optical communications. In the next generation, Due to the dual applications of rare earth activated phosphors, in the near future it is expected that WLEDs lighting system can be used as a new type of lighting system with network and intelligent features that can reduce consumption of lighting energy.

9. References

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