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Strategy for the exploration of new phosphors by Mineral Inspired Methodology coupled with Compositional Tuning

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Abstract: White LEDs are labelled 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. Currently available phosphor in the market mainly they are high correlated colour temperature, low Colour Rendering Index, synthesis process is difficult. Phosphor-converted white light-emitting diodes for indoor illumination need to be warm white (i.e., correlated colour temperature, 4000 K) with good colour rendition (i.e., colour rendering index 80). For the synthesis of new phosphor, the concept, as well as the methodology of using a mineral-inspired approach in combination with solution parallel synthesis (SPS) for exploration of new phosphors among Na/K, Sr (Ba)/Sc-silicate along with the artificial library, is reported. Moreover, the compositional tuning of the properties of extended solids through solid solution; sometimes referred to as the game of x and y, as, for example, in $K_{1-x}Na_xSr_{1-y}Ba_yScSi_2O_7$ is also demonstrated. Our expected out come to develop new phosphor using mineral inspired methodology for develop high luminous efficiency and CRI of the phosphor.

Keywords:- Phosphor, SPS method, chemical compound, etc.

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INTRODUCTION

Phosphor-When 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 are used in white LEDs. [1-4] White LEDs are labelled 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

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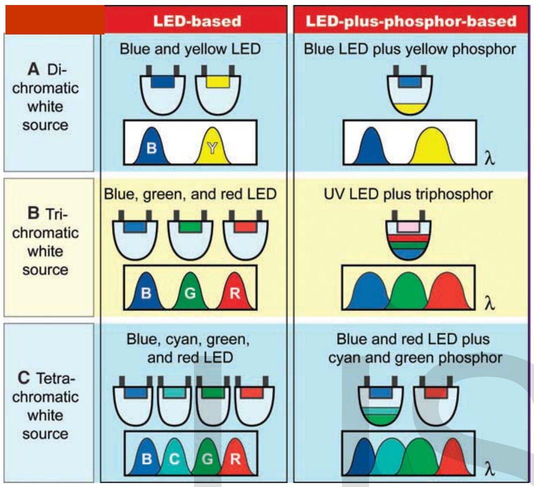
countries in the world, such as United States, Japan, and European Union, Korea and so on, all invest a lot of resources in the research and development of white LEDs. [5] Most "white LEDs" in the production today use a 450 nm - 470 nm blue GaN (gallium nitride) LED covered by a yellowish phosphor coating usually made of cerium doped yttrium aluminium 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. In 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. 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. [6-11] In the US alone, for example, fluorescent lights consume around 200 terawatts-hours of electricity annually. If these lights were all replaced with 200 lm/W TLEDs, the US would use around 100 terawatts-hours less energy (equivalent to 50 medium sized power plants) saving more than US$12 billion and also preventing around 60 million metric tons of CO_2 from being released into the atmosphere. So LED is the energy saving as well as the environmental friendly.

Method used in White LEDs

White light could be generated by several methods, such as two-wavelength white light method use blue LED + yellow phosphor, yellow ZnSe substrate + blue CdZnSe. This type of white light formation LED not produce by other because blackness of their patent. Another method three wavelength white light use red, green, and blue, ultraviolet LED + Red, green, and blue phosphors, and another combination blue LED and red and green phosphors. Utilizing the colour-complementary theory, one can use the blue LED to couple with yellow-emitting phosphor or yellow-emitting ZnSe substrate collocated with blue-emitting CdZnSe film. The former concept is claimed in the patents of Nichia and Osram, and the latter one belongs to Sumitomo Electric Industries' right (Japan). The methods of no patent blocked still include several types: one is the combination of red, green, and blue chips, whose cost is so high that it disagrees with high throughput; the others are ultraviolet (UV) LED coupled with red, green, and blue phosphors, or blue LED coupled with red and green phosphors. Therefore, the investigation of UV and blue LED-converting phosphors is the key point of developing white LEDs. [7] [12]



DRAWBACKS

White light emission can be generated by UVLED coupled with red, green, and blue phosphors or blue LED coupled with red and green phosphors. However, it is very difficult to find combinatorial phosphors with the same optimal excitation wavelength and material degradation rate. The transitions of an activator with *f-d* or *d-d* electron configurations are affected by host lattice and for this reason the optimal excitation wavelength of an activator is different with host lattice. Besides, the transitions of an activator with *f-f* electron configurations are hardly affected by host lattice, so the excitation spectrum exhibits sharp peaks and the position of optimal excitation peak shows no obvious changes. For example, the characteristic optimal excitation peak of Tb^{3+} is at 378 nm, and that of Eu^{3+} is at 394 nm. Furthermore, the extreme difference in material stability and degradation between different host phosphors will produce colour aberration. As a result, the excitation-wavelength restriction and colour aberration will be shown in combinatorial phosphors for white LEDs. In addition to the energy savings and positive environmental effects promised by solid-state lighting, solid-state sources in particular, LED-based sources offer what was inconceivable with conventional sources: controllability of their spectral, spatial, temporal, and polarization properties as well as their colour temperature. Technologies currently emerging are expected to enable tremendous benefits in lighting, automobiles, transportation, communication, imaging, agriculture, and medicine.

MOTIVATION

The motivation for the developing the new phosphor is its properties such as long operation time, energy saving compact size, save money, lower temperature, environment family, mercury free and so on. Owing to their reduced power use, LEDs in conjugation with renewable energy sources also offer great promise in providing

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lighting in remote and underdeveloped areas of the world. The luminous efficiency of a light source is a key metric for energy savings considerations. It gives the luminous flux in lumens (light power as perceived by the human eye) per unit of electrical input power. Luminous efficiencies of 425 lm/W and 320 lm/W could potentially be achieved with dichromatic and trichromatic sources, respectively, if solid-state sources with perfect characteristics could be fabricated. Perfect materials and devices would allow us to generate the optical flux of a 60-W incandescent bulb with an electrical input power of 3 W. Besides luminous efficiency, colour rendering is an essential figure of merit for a light source used in illumination.

For the synthesis of new phosphor by "Mineral Inspired Methodology" based on searching natural mineral containing Si from "American Mineral Society Database" is best method. In this method Substitution of one element of a particular composition by similar sized isovalent ion. For example the substitution of transition metal ions by similar sized and isovalent ions (Fe^{2+}, Cu^{2+}) by Mg^{2+} and (Ti^{4+} by Zr^{4+}). The table listed below show the name of mineral with their original composition and change their composition new phosphor is developed.

OUTCOME

Our expected outcome is much spared we wanted to change the important properties of the phosphor converting white LEDs such as colour rendering index, correlated colour temperature, luminous efficiency, quantum efficiency. Above properties of the already developed phosphor is not sufficient so we want to increase it by exploration of new phosphor by mineral inspired methodology. The large number of phosphors derived from minerals evidences the fact that this 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, [13–15] which has some drawbacks such as the volatility and low-melting point of the starting materials and possible side reactions eventually fail to produce the desired compounds.

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Name of Mineral	Original compositions of Minerals	Artificial Composition inspired by Natural Mineral	
		Standard Composition	Solid solutions
Armstrongite	**$CaZrSi_6O_{15}.2.5H_2O$**	**$CaZrSi_6O_{15}$**	**$(Ca,Sr)ZrSi_6O_{15}$**
Benitoite	**$BaZrSi_3O_9$**	**$BaZrSi_3O_9$**	**$(Ba,Sr)ZrSi_3O_9$**
Calciohilairite	**$CaZrSi_3O_9.H_2O$**	**$CaZrSi_3O_9$**	**$(Ca,Sr)ZrSi_3O_9$**
Cataplelite	**$Na_2ZrSi_3O_9.\ 2H_2O$**	**$Na_2ZrSi_3O_9$**	**$(Na, Li)_2ZrSi_3O_9$**
Elpidite	**$Na_2ZrSi_6O_{15}.3H_2O$**	**$Na_2ZrSi_6O_{15}$**	**$(Na,K)_2ZrSi_6O_{15}$**
Parakeldyshite	**$Na_2ZrSi_2O_7$**	**$Na_2ZrSi_2O_7$**	**$(Na,K)_2ZrSi_2O_7$**
Terskite	**$Na_4ZrSi_6O_{16}.2H_2O$**	**$Na_4ZrSi_6O_{16}$**	**$(Na, Li)_4ZrSi_6O_{16}$**
Aenigmatite	**$Na_2Fe_5TiSi_6O_{20}$**	**$Na_2Mg_5ZrSi_6O_{20}$**	**$(Na, Li)_2Mg_5ZrSi_6O_{20}$**
Titanite	**$CaTiSiO_5$**	**$CaZrSiO_5$**	**$(Ca, Sr)ZrSiO_5$**
Natisaite	**Na_2TiSiO_5**	**Na_2ZrSiO_5**	**$(Na_2, K)ZrSiO_5$**

The large number of phosphors derived from minerals evidences the fact reaction methodology 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.

CONCLUSION

The most recent record is just over 300 lumen/watt for regular light bulbs and close to 70 for fluorescent lamps. As about one fourth of world electricity consumption is used for lighting purposes, the highly energy-efficient LEDs contribute to saving the Earth's resources. So exploration of new phosphor for the fabrication of phosphor converted LED (pc-LED) is highly desirable.

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