Title: LIGHT EMITTING DEVICE WITH A EU-COMPRISING PHOSPHOR MATERIAL

Abstract: Light emitting device comprising an excitation energy source to deliver a primary excitation energy and a converting element essentially comprising Eu\(^{3+}\) phosphor material to at least partly convert the primary energy into a secondary radiation whereby in the excitation spectrum of the Eu-comprising phosphor material at 298 K and 1,013 bar the maximum intensity in the wavelength range between \(\geq 460\) nm to \(\leq 470\) nm is \(\geq 5\%\) of the maximum intensity in the wavelength range between \(\geq 220\) nm to \(\leq 320\) nm. The excitation energy source can be any suitable energy source to excite a secondary light emission such as electron beam sources (e.g. electron guns in CRTs) or light sources such as organic LEDs, inorganic LEDs or laser diodes.
before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the “Guidance Notes on Codes and Abbreviations” appearing at the beginning of each regular issue of the PCT Gazette.
Light emitting device with a Eu-comprising phosphor material

The present invention is directed to light emitting devices, especially to the field of LEDs and to a light converting Eu-comprising phosphor material.

Line emitting phosphors are widely applied as red emitters in fluorescent light emitting devices and emissive displays, e.g. in fluorescent lamps, CRTs, and PDPs.

However, especially Eu-containing light emitting devices suffer from the drawback that the common Eu-doped materials such as CaS:Eu or Sr₂SIsNgIEu comprises Eu²⁺ ions, which are subject of instability due to its oxidation or reaction with other components present in the light emitting device. Another drawback of Eu²⁺ activated red-emitting phosphors according to prior art is their relatively wide emission band, which results in a low lumen equivalent. Eu³⁺ activated red-emitting phosphors show a better lifetime stability compared to Eu²⁺, but showing a strong absorption only in the UV-C and VUV spectral range, while the absorption is very weak below the low edge of the charge transfer state around 300nm. This prevents the application of Eu³⁺ for instance in phosphor-converted light emitting diodes (pcLEDs), since the emission wavelength of such efficient high brightness LEDs is within the near UV-A spectral range above 350nm or within the blue spectral range. In phosphor converted LEDs, the LED emits a primary radiation, which is at least partly converted into a secondary radiation with a longer wavelength by the light converting material, the so-called phosphor material.

It is an object of the present invention to provide a phosphor converted light-emitting device comprising a stable and efficient Eu-comprising phosphor material.

This object is solved by a light emitting device comprising an excitation
energy source to deliver a primary energy and a converting element essentially comprising Eu\(^{3+}\)-phosphor material to at least partly convert the primary energy into a secondary radiation whereby in the excitation spectrum of the Eu-comprising phosphor material at 298 K and 1,013 bar the maximum intensity in the wavelength range between \(\geq 460\) nm to \(\leq 470\) nm is \(>5\%\) of the maximum intensity in the wavelength range between \(\geq 220\) nm to \(\leq 320\) nm.

In absorption spectra, the term "intensity" denotes the amount of absorbed light (corresponding to an absorption strength). The term "essentially comprising Eu\(^{3+}\)-phosphor material" means and/or includes especially that \(>90\%\), according to another embodiment \(>95\%\) and according to another embodiment \(>98\%\) of the Eu comprised in the Eu-comprising material are in the form of Eu\(^{3+}\). The spectral (absorption and emission) properties of Eu\(^{3+}\) materials are more stable over time as compared to Eu\(^{2+}\) materials, because of the lesser tendency to be oxidized. The lower the remaining Eu\(^{2+}\) content, the better the lifetime behaviour of the Eu-phosphor material.

The excitation energy source can be any suitable energy source to excite the secondary light emission of Eu\(^{3+}\)-comprising phosphor materials such as electron beam sources (e.g. electron guns in CRTs) or light sources such as organic LEDs, inorganic LEDs or laser diodes. Therefore the primary energy can be the energy of an electron beam or the energy of a radiation. The terms "wavelength range" or more specific "UV-A spectral range" or "blue spectral range" denote energy ranges not limited only to electro-magnetic radiation energy.

With an enhanced absorption capability of the Eu-comprising phosphor material in the above-specified blue spectral range compared to state in the art materials, a light-emitting device according to the present invention could be operated efficiently with LEDs with blue primary radiation (primary energy). The absorption strength of a converting element depends on the absorption strength of the material itself and on the thickness of the converting element in primary energy, e.g. primary light energy, propagation direction. To obtain an equal absorption strength, a more effective light conversion material (high absorption strength of the material itself) for instance enables the application of thinner phosphor materials for more compact devices and/or to reduce the risk of re-absorption of the secondary emission and
following radiation-less transition leading to an enhanced efficiency of the light emitting device due to a thinner converting element. An enhancement of the blue absorption capability simultaneously also enhances the absorption capability in the near UV-A range between 350nm and 420nm. Therefore, also LEDs emitting within the UV-A A spectral range can be used to emit the primary radiation of the pcLED by using a phosphor material according to the present invention.

According to an embodiment of the present invention, in the emission spectrum of the Eu-comprising material at 298 K and 1,013 bar the peak area in the wavelength range between \( \geq 680 \text{ nm} \) to \( \leq 720 \text{ nm} \) is >15% of the peak area in the wavelength range between \( \geq 570 \text{ nm} \) to \( \leq 720 \text{ nm} \). Here, the LED shows an improved deep red emittance characteristics in that for some applications efficiencies of 100 - 200 Lumen/Watt are feasible. Additionally, the LED shows improved colour point stability due to the stability of the red emitter. The term "peak area" denotes the integral amount of light within the specified wavelength range.

According to an embodiment of the present invention, the atomic dopant level (in atom-% of the trivalent cation of the host lattice) of Eu in the Eu-comprising phosphor material is up to 20%. Higher Eu\(^{3+}\) concentration would lead to pronounced energy transfer of the absorbed energy to the surface and defect sites and thus to quenching of the Eu\(^{3+}\) luminescence, a phenomenon which is known as concentration quenching.

According to an embodiment of the present invention, the Eu-comprising phosphor material furthermore comprises a co-dopant M selected out of the group comprising Bi, In, Tl, Sb or mixtures thereof. These additional dopants are elements with a large number of electrons on d-orbitals increasing the electron density to enhance the absorption capability of Eu\(^{3+}\) within the host lattice. According to an embodiment of the present invention, the atomic dopant concentration of M (in atom-%) in the Eu-comprising material is up to 20%. Higher M\(^{3+}\) concentration would lead to pronounced energy transfer of the absorbed energy to the surface and defect sites and thus to quenching of the activator luminescence.

According to an embodiment of the present invention, the ratio of Eu (in atom-%) towards M (in atom-%) in the Eu comprising material is \( \geq 0.1:1 \) to \( \leq 10:1 \). In case that more than one co-dopant is present, the term "the ratio of Eu towards M"
means or includes especially that M represents the sum of all co-dopants as described above.

According to an embodiment of the present invention, the Eu-comprising material is selected out of the group comprising oxides, oxyhalogenides, garnets, vanadates, tungstates, borates, silicates, germanates or mixtures thereof. These materials offer a high electron density at the sites of the oxygen anions within the host lattice leading to improved absorption properties of Eu$^{3+}$.

According to an embodiment of the present invention, the Eu-comprising material is selected out of the group comprising (Gdi$_{1-x}$Lu$_{x}$)$_2$O$_3$:Eu$^2+$, (Y$_{1-x-y}$Lu$_x$,La$_y$)$_2$Al$_2$O$_4$:Eu$^2+$, Ba$_2$(Y$_{1-x-y}$Lu$_x$)$_2$Si$_4$O$_9$:Eu$^2+$, Ba$_2$(Y$_{1-x}$Lu$_x$)$_2$Ge$_4$O$_{13}$:Eu$^2+$, (Y$_{1-x}$Lu$_x$)$_2$Ge$_4$O$_{13}$:Eu$^2+$, LaOM:Eu with M = (Br, Cl, I), Na$_3$(Y$_{1-x}$Lu$_x$)$_2$O$_3$:Eu$^2+$, Cs$_3$(Y$_{1-x}$Lu$_x$)$_2$O$_3$:Eu$^2+$, Cs$_3$(Y$_{1-x}$Lu$_x$)$_2$O$_3$:Eu$^2+$, or mixtures thereof. Here, Eu$^{3+}$ is surrounded from ions with high negative charge density leading to an enhanced absorption properties in the near UV-A and blue spectral range.

A light-emitting device according to the present invention may be of use in a broad variety of systems and/or applications, amongst them one or more of the following:

- Office lighting systems
- household application systems
- shop lighting systems,
- home lighting systems,
- accent lighting systems,
- spot lighting systems,
- theatre lighting systems,
- fibre-optics application systems,
- projection systems,
- self-lit display systems,
- pixelated display systems,
segmented display systems,
warning sign systems,
medical lighting application systems,
indicator sign systems, and

decorative lighting systems
portable systems
automotive applications
green house lighting systems

The aforementioned components, as well as the claimed components and the components to be used in accordance with the invention in the described embodiments, are not subject to any special exceptions with respect to their size, shape, material selection and technical concept such that the selection criteria known in the pertinent field can be applied without limitations.

Additional details, characteristics and advantages of the object of the invention are disclosed in the subclaims, the figures and the following description of the respective figures and examples, which—in an exemplary fashion—show several embodiments of an Eu-comprising phosphor material use in a light emitting device according to the present invention as well as an LED according to embodiments of the present invention.

Fig. 1 shows an excitation spectrum of a Y₂O₃IEu material according to prior art
Fig. 2 shows an emission spectrum of the material of Fig. 1
Fig. 3 shows an excitation spectrum of a Eu-comprising material according to a first Example of a first embodiment of the present invention
Fig. 4 shows an emission spectrum of the material of Fig. 3
Fig. 5 shows an excitation spectrum of a Eu-comprising material according to a second Example of a second embodiment of the present invention
Fig. 6 shows an emission spectrum of the material of Fig. 5
Fig. 7 shows an excitation spectrum of a Eu-comprising material according to a third Example of a third embodiment of the present invention
Fig. 8 shows an emission spectrum of the material of Fig. 7
Fig. 9 shows an excitation spectrum of a Eu-comprising material according to a fourth Example of a fourth embodiment of the present invention
Fig. 10 shows an emission spectrum of the material of Fig. 9
Fig. 11 shows an emission spectrum of an LED according to a fifth Example of a fifth embodiment of the present invention
Fig. 12 shows an emission spectrum of an LED according to a sixth Example of a sixth embodiment of the present invention.

Fig. 1 and 2 refer to Y₂O₃:Eu material with a Eu-doping level of 5% (prior art Eu-component). Fig. 1 shows an excitation spectrum, Fig. 2 shows an emission spectrum. It can be clearly seen that the intensity as well as the peak area as described above is much lower than according to materials within the present invention.

While the absorption of Eu³⁺ phosphors in the UV-C and VUV spectral range is strong, it is only very weak below the low energy edge of the charge transfer state around 300nm. This prevents the application of Eu³⁺ in state of the art phosphors for phosphor converted light emitting diodes (pcLEDs), since the minimum emission wavelength for efficient high brightness LEDs is at around 370nm, which is below the strong absorption wavelength range (≤300nm) of the Y₂O₃:Eu phosphor material. The absorption lines around 395nm (⁷F₀ - ⁵D₂) and 465nm (⁷F₀ - ⁵D₂) are spin forbidden 4f-4f transitions and therefore very weak absorption lines.

The present invention describes red line emitting Eu³⁺ phosphors with relatively strong absorption of UV-A radiation and/or blue radiation due to the enhancement of the weak absorption lines at around 395nm (⁷F₀ - ⁵D₂) and 465nm (⁷F₀ - ⁵D₂). This is achieved by using lattices with a high covalency or by co-doping the host lattice by ions having the [Ar]3d¹⁰, [Kr]4d¹⁰ or [Xe]4f¹⁴5d¹⁰ electron configuration. By the application of covalent lattices or electron rich co-dopants, the spin forbidden character of the 4f-4f transitions of Eu³⁺ is relaxed to a certain extent, which results in an enhanced absorption strength of these transitions. The improved absorption properties enable the efficient application of these materials as a colour converter for organic or inorganic state of the art phosphors converted light emitting diodes with
emission wavelength in the UV-A and/or blue spectral range.

Suitable Eu-comprising phosphor materials for the absorption enhancement according to the present invention are high covalent lattices such as (Gd$_{1-x}$Lu$_x$)$_2$O$_3$:Eu, (Y$_{1-y}$Gd$_x$Lu$_y$)$_3$Al$_2$O$_3$:Eu, Ba$_2$(Y$_{1-x}$Gd$_x$Lu$_y$)$_2$i$_4$θ$_{13}$:Eu, Ba$_2$(Y$_{1-x}$

5 Gd$_x$Lu$_y$)$_2$Ge$_4$O$i_3$:Eu, (Y$_{1-y}$Gd$_x$Lu$_y$)VO$_4$:Eu, (Y$_{1-x}$Gd$_x$Lu$_y$)$_2$OCl:Eu, Ba:(Y$_{1-x}$Gd$_x$Lu$_y$)B$_2$O$i_3$:Eu, Ba$_2$(Y$_{1-x}$Gd$_x$Lu$_y$)(BO$_2$)$_3$:Eu, (Y$_{1-x}$

10 Gd$_x$Lu$_y$)$_2$Si$\theta_5$:Eu, (Ca$_{a_1}$Sr$_{a_2}$)$_3$(Y$_{1-x}$Lu$_x$Ga$_w$In$_y$)$_2$Ge$\theta_3$:Eu$_{i_2}$Eu$_z$ (a, w, x, y = 0.0 - 1.0, z = 0.0 - 0.2), (Ca$_{a_1}$Sr$_{a_2}$)$_3$(Y$_{1-x}$Lu$_x$Ga$_w$In$_y$)$_2$Ge$\theta_3$:Eu$_{i_2}$Eu$_z$ (a, v, w, x, y = 0.0 - 1.0, y,z = 0.0 - 0.2), LaOM:Eu with M=(Br,Cl,I) or mixtures thereof. Here, Eu$^{3+}$ is surrounded from ions with high negative charge density. Suitable Eu-doping levels are levels up to atomic 20%. Within these materials, Eu$^{3+}$ exhibits a strong covalent interaction with the host lattice influencing the transition probability of the spin forbidden transition in comparison to atomic transition probabilities.

The covalent interaction of Eu$^{3+}$ with the host lattices can be even more enhanced by co-doping of the host lattice with other triple positive charged ions such as Bi$^{3+}$, In$^{3+}$, Tl$^{3+}$ or Sb$^{3+}$ or mixtures thereof. For example, suitable In$^{3+}$ co-doping levels are up to atomic 10%. According to another embodiment of the present invention, the atomic dopant level of M in the Eu-comprising phosphor material is up to 5%. According to another embodiment of the present invention, the atomic dopant level of M in the Eu-comprising phosphor material is up to 1%.

According to an embodiment of the present invention, the ratio in atom% of Eu towards M in the Eu-comprising phosphor material is ≥ 0.5:1 to ≤ 5:1. According to an embodiment of the present invention, the ratio in atom% of Eu towards M in the Eu-comprising phosphor material is ≥ 1:1 to ≤ 3:1. In case that more than one co-dopant is present, the term "the ratio of Eu towards M" means or includes especially that M represents the sum of all co-dopants as described above.

The absorbed excitation energy will be released by a secondary radiation with longer wavelength. Before radiation release (electron transition from the excited to the ground state), the excited D-levels relax radiation-less to the excited D-ground state 5Do. According to the transition rules, transitions to the 7F$_2$ state are allowed, while transitions to the 7F$_4$ state leading to a deep red emission are spin forbidden. To increase light efficiency and colour rendering index a deep red emission with wavelengths
around 700nm are preferred. The high electron density of the Eu$^{3+}$-comprising phosphor materials according to the present invention also influencing the emission properties, where the spin forbidden transition $^5D_0 \rightarrow ^7F_4$ is enhanced in comparison to the allowed transition $^5D_0 \rightarrow ^7F_2$.

The following examples show the improved absorption and emission properties of Eu$^{3+}$ comprising phosphor materials according to the present invention. For a better comparison to prior art, all following samples contain the same Eu-doping level of 5atom% Eu$^{3+}$. The presence of Eu$^{3+}$ is predetermined by the material preparation. People skilled in the art know, which starting materials have to be chosen in order to prepare materials essentially comprising Eu$^{3+}$.

EXAMPLE I

Fig. 3 and 4 refer to LaOCl:Eu. Fig. 3 shows an excitation spectrum, Fig. 4 shows an emission spectrum.

In fig.3, the maximum intensity in the wavelength range between $\geq$ 460 nm to $\leq$ 470 nm is approx. 21% of the maximum intensity in the wavelength range between $\geq$ 220 nm to $\leq$ 320 nm.

In fig.4, the peak area in the wavelength range between $\geq$ 680 nm to $\leq$ 720 nm is 22% of the peak area in the wavelength range between $\geq$ 570 nm to $\leq$ 720 nm.

EXAMPLE II

Fig. 5 and 6 refer to Sr$_3$In$_2$Ge$_3$O$_7$:Eu. Fig. 5 shows an excitation spectrum, Fig. 6 shows an emission spectrum.

In fig.5, the maximum intensity in the wavelength range between $\geq$ 460 nm to $\leq$ 470 nm is approx. 25% of the maximum intensity in the wavelength range between $\geq$ 220 nm to $\leq$ 320 nm.

In fig.6, the peak area in the wavelength range between $\geq$ 680 nm to $\leq$ 720 nm is 25% of the peak area in the wavelength range between $\geq$ 570 nm to $\leq$ 720 nm.

EXAMPLE III

Fig. 7 and 8 refer to Y$_2$SiO$_5$:Eu. Fig. 7 shows an excitation spectrum, Fig. 8 shows an emission spectrum.

In fig.7, the maximum intensity in the wavelength range between $\geq$ 460 nm to $\leq$ 470 nm is approx. 11% of the maximum intensity in the wavelength range between $\geq$
220 nm to ≤ 320 nm.

In fig. 8, the peak area in the wavelength range between ≥ 680 nm to ≤ 720 nm is 21% of the peak area in the wavelength range between ≥ 570 nm to ≤ 720 nm.

EXAMPLE IV

5 Fig. 9 and 10 refer to Ca₃Ga₂Ge₃O₁₂IEu. Fig. 9 shows an excitation spectrum, Fig. 10 shows an emission spectrum.

According to an embodiment of the present invention, in the excitation spectrum of the Eu-comprising phosphor material at 298 K and 1,013 bar the maximum intensity in the wavelength range between ≥ 460 nm to ≤ 470 nm is >10% of the maximum intensity in the wavelength range between ≥ 220 nm to ≤ 320 nm.

According to another embodiment of the present invention, in the excitation spectrum of the Eu-comprising phosphor material at 298 K and 1,013 bar the maximum intensity in the wavelength range between ≥ 460 nm to ≤ 470 nm is >15% of the maximum intensity in the wavelength range between ≥ 220 nm to ≤ 320 nm.

According to an embodiment of the present invention, in the excitation spectrum of the Eu-comprising phosphor material at 298 K and 1,013 bar the maximum intensity in the wavelength range between ≥ 460 nm to ≤ 470 nm is >20% of the maximum intensity in the wavelength range between ≥ 220 nm to ≤ 320 nm as shown for example for Y₂SiO₅IEu and Ca₃Ga₂Ge₃O₁₂IEu.

According to another embodiment of the present invention, in the excitation spectrum of the Eu-comprising phosphor material at 298 K and 1,013 bar the peak area in the wavelength range between ≥ 680 nm to ≤ 720 nm is >20% of the peak area in the wavelength range between ≥ 570 nm to ≤ 720 nm as shown for example for Ca₃Ga₂Ge₃O₁₂IEu, Y₂SiO₅IEu, Sr₃In₂Ge₃O₁₂IEu and LaOCliEu. Other Eu-comprising phosphor materials can show different peak area ratios.

EXAMPLE V
Fig. 11 shows an emission spectrum of an LED according to a fifth Example of a fifth embodiment of the present invention. The LED was manufactured as follows:

A powder mixture of 20% (Y,Gd)\textsubscript{3}Al\textsubscript{5}O\textsubscript{12}:Ce and 80% Y\textsubscript{2}SiO\textsubscript{3}:Eu were suspended in a fluid silicon precursor compound. A drop of this silicon precursor was placed on a Chip emitting light of the wavelength 465 nm and the silicon polymerized. The LED is then sealed with a plastic lens.

In Fig. 11 it can be clearly seen that the resulting LED shows a good optical characteristic with a $T_c$ value of 3000K.

EXAMPLE VI

Fig. 12 shows an emission spectrum of an LED according to a sixth Example of a sixth embodiment of the present invention. The LED was manufactured as follows:

A powder mixture of 20% (Y,Gd)\textsubscript{3}Al\textsubscript{5}O\textsubscript{12}:Ce and 80% LaOChEu were suspended in a fluid silicon precursor compound. A drop of this silicon precursor was placed on a Chip emitting light of the wavelength 465 nm and the silicon polymerized. The LED is then sealed with a plastic lens.

In Fig. 12 it can be clearly seen that the resulting LED shows a good optical characteristic with a $T_c$ value of 3100K.

In other embodiments, Eu-doping levels different from 5atom% can be chosen in order to adapt for instance the converting element size or the spectral properties of the converting element to the desired application.

The particular combinations of elements and features in the above detailed embodiments are exemplary only; the interchanging and substitution of these teachings with other teachings in this and the patents/applications incorporated by reference are also expressly contemplated. As those skilled in the art will recognize, variations, modifications, and other implementations of what is described herein can occur to those of ordinary skill in the art without departing from the spirit and the scope of the invention as claimed. Accordingly, the foregoing description is by way of example only and is not intended as limiting. The invention's scope is defined in the following claims and the equivalents thereto. Furthermore, reference signs used in the description and claims do not limit the scope of the invention as claimed.

MATERIALS AND METHODS
The spectra of the Eu-comprising materials according to the present invention were measured with an in-house built spectrofluorimeter system:

The light source of this spectrofluorimeter system is a 150W Xe-lamp in an airflow-cooled housing. The lamp output is focused on the entrance slit of the excitation monochromator (Bentham) with a focal length of 0.5 m. The escaping light from the exit slit of the excitation monochromator is fed into a sample chamber and focused onto the sample material under test via several mirrors. While the sample under test is horizontal orientated the optical axis of the excitation and the emission branch are oriented vertically and nearly parallel. This geometric orientation ensures reliable and quantitative comparative measurements of different samples. The sample chamber is coupled optically to the emission monochromator (Bentham, focal length 0.5m) via a mirror system. Detection of the emitted light occurs with a thermo-electrically cooled photomultiplier tube (PMT) unit mounted to the exit slit of the emission monochromator. The system is fully computer controlled by an in-house developed software program based on DOS.

The sample under test is shaped as a powder layer of 2 mm thickness and the spot size of the excitation light beam is approx. 2x3 mm². The spectral resolution of the excitation and emission branch was in the order of 1-2 nm. A 1 nm step size was chosen for the determination of the excitation and emission spectra.
CLAIMS:

1. Light emitting device comprising an excitation energy source to deliver a primary excitation energy and a converting element essentially comprising Eu³⁺-phosphor material to at least partly convert the primary energy into a secondary radiation whereby in the excitation spectrum of the Eu-comprising phosphor material at 298K and 1,013 bar the maximum intensity in the wavelength range between ≥ 460 nm to ≤ 470 nm is ≥5% of the maximum intensity in the wavelength range between ≥ 220 nm to ≤ 320 nm.

2. The light emitting device of claim 1, whereby in the emission spectrum of the Eu-comprising phosphor material at 298 K and 1,013 bar the peak area in the wavelength range between ≥ 680 nm to ≤ 720 nm is ≥15% of the peak area in the wavelength range between ≥ 570 nm to ≤ 720 nm.

3. The light emitting device of any of the claims 1 to 3 whereby the atomic dopant level of Eu in the Eu-comprising phosphor material is up to 20%.

4. The light-emitting device of any of the claims 1 to 4 whereby the Eu-comprising phosphor material furthermore comprises a co-dopant M selected out of the group comprising Bi, In, Tl, Sb or mixtures thereof.

5. The light emitting device of any of the claims 1 to 5 whereby the atomic dopant concentration of M in the Eu-comprising phosphor material is up to 20%.

6. The light emitting device of any of the claims 1 to 6 whereby the ratio in atom% of Eu towards M in the Eu-comprising phosphor material is ≥ 0.1:1 to ≤ 10:1.
7. The light emitting device of any of the claims 1 to 7 whereby the Eu-
comprising phosphor material is selected out of the group comprising oxides,
oxyhalogenides, garnets, vanadates, tungstates, borates, silicates, germanates or
mixtures thereof

8. The light emitting device of any of the claims 1 to 8, whereby the Eu-
comprising phosphor material is selected out of the group comprising (Gdi-
Lu)\_2O\_3:Eu\_2, (Yi\_x\_yGd\_Lu\_y\_3Al\_0 i\_2:Eu\_2, Ba\_2(Yi\_xGd\_Lu\_2Si\_4θ i\_3:Eu\_2, Ba\_2(Yi\_x-
Lu)\_2Ge\_4θ i\_3:Eu\_2, (Yi\_xGd\_Lu\_y)VO\_4:Eu\_2, (Yi\_xGd\_Lu\_y)OCl:Eu\_2, Ba(Yi\_x-
Gd\_Lu\_y)BO\_3:Eu\_2, (Yi\_xGd\_Lu\_y)Si\_5:Eu\_2, (Cai\_aSr\_y)\_3(Yi\_w\_yGd\_Lu\_wGa\_In\_y)\_2Ge\_3θ i\_2:Eu\_2 (a, w, x, y = 0.0 -
1.0, z = 0.0 - 0.2), (Cai\_aSr\_y)\_3(Yi\_w\_yGa\_In\_y)\_2Ge\_3θ i\_2:Eu\_2 (a, v, w, x = 0.0 -
1.0, y, z = 0.0 - 0.2), LaOM:Eu with M = (Br, Cl, I), Na\_9[(Yi\_x-
Lu)\_2Wi\_0O\_3\_4]:Eu\_2, (Yi\_x\_yLu\_xGd\_y)[P(Mo\_3Oio)\_4]:Eu\_2 (x, y = 0.0 - 1.0, z = 0.0 -
0.2) or mixtures thereof

9. A system comprising a light emitting device according to any of the
claims 1 to 9 the system being used in one or more of the following applications:

Office lighting systems
- Household application systems
- Shop lighting systems,
- Home lighting systems,
- Accent lighting systems,
- Spot lighting systems,
- Theatre lighting systems,
- Fibre-optics application systems,
- Projection systems,
- Self-lit display systems,
- Pixelated display systems,
segmented display systems,
warning sign systems,
medical lighting application systems,
indicator sign systems, and
decorative lighting systems
portable systems
automotive applications
green house lighting systems
FIG. 1

FIG. 2
FIG. 3

FIG. 4
**INTERNATIONAL SEARCH REPORT**

**International application No**
PCT/IB2007/050068

A. CLASSIFICATION OF SUBJECT MATTER

INV. C09K11/79 C09K11/86 C09K11/66

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C09K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, CHEM ABS Data, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim</th>
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<td>TAO Y ET AL: &quot;EXAFS studies of luminescence centres in Eu&lt;3--&gt; doped nanoscale phosphors&quot; MATERIALS LETTERS, NORTH HOLLAND PUBLISHING COMPANY, AMSTERDAM, NL, vol. 28, no. 1–3, September 1996 (1996-09), pages 137-140, XP004078355 ISSN: 0167-577X the whole document</td>
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Date of the actual completion of the international search
2 May 2007

Date of mailing of the international search report
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Form PCT/ISA/210 (second sheet) (April 2005)
### DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>EP 0 304 117 A1 (PHILIPS NV [NL]) 22 February 1989 (1989-02-22) page 2, lines 12-18 examples 10,11; table 1</td>
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