

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
16 July 2009 (16.07.2009)

(10) International Publication Number
WO 2009/088410 A3

(51) International Patent Classification:
H01L 33/00 (2006.01)

Antonio Creek Rd., Santa Barbara, California 93111 (US).

(21) International Application Number:
PCT/US2008/013280

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(22) International Filing Date:
2 December 2008 (02.12.2008)

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/969,508 4 January 2008 (04.01.2008) US

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(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,

[Continued on next page]

(54) Title: LIGHT EMITTING DEVICES WITH HIGH EFFICIENCY PHOSPOR STRUCTURES

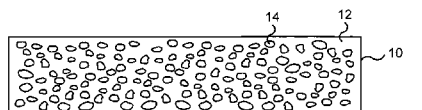


FIGURE 2

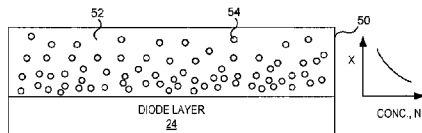


FIGURE 5A

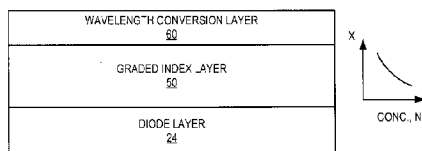


FIGURE 5B

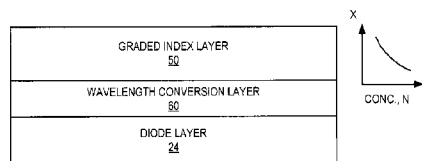


FIGURE 5C

(57) Abstract: A light emitting device includes a light emitting die (24) configured to emit light having a first dominant wavelength, and an index matched wavelength conversion structure (10, 60) configured to receive light emitted by the light emitting die (24). The index matched wavelength conversion structure (10, 60) includes wavelength converting particles (14) having a first index of refraction embedded in a matrix material (12). The matrix material (12) has a second index of refraction that may be substantially matched to the first index of refraction. The light emitting device may include a graded index layer (50) having an index of refraction that is continuously graded from a first index of refraction in a first region of the graded index layer (50) near the light emitting die (24) to a second index of refraction in the graded index layer (50) away from the light emitting die (24).



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MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI
(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR,
NE, SN, TD, TG).

— before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments (Rule 48.2(h))

Published:

— with international search report (Art. 21(3))

(88) Date of publication of the international search report:

3 September 2009

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/013280

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L33/00

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)
H01L

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 734 465 B1 (TASKAR NIKHIL R [US] ET AL) 11 May 2004 (2004-05-11) figures 1-9 column 1, line 13 - line 36 column 3, line 31 - column 9, line 31 -----	1-10, 21-23, 25, 26, 29-31, 36, 37, 42
X	US 2007/096113 A1 (INOSHITA KYOJI [JP] ET AL) 3 May 2007 (2007-05-03) figures 2-14 page 1, paragraph 5 page 2, paragraph 36 - page 9, paragraph 115 ----- -/--	1-10, 21-23, 25, 26

Further documents are listed in the continuation of Box C

See patent family annex.

* Special categories of cited documents:

A document defining the general state of the art which is not considered to be of particular relevance

E earlier document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

& document member of the same patent family

Date of the actual completion of the international search

23 March 2009

Date of mailing of the international search report

02/07/2009

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2008/013280

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/255353 A1 (TASKAR NIKHIL R [US] ET AL) 16 November 2006 (2006-11-16) the whole document -----	1-6,9, 10, 21-23, 25,26
X	US 2007/273282 A1 (RADKOV EMIL V [US] ET AL) 29 November 2007 (2007-11-29) figures 1-3 page 1, paragraph 16 - page 5, paragraph 63 -----	1-6,9, 10,21, 22,25,26
X	DE 10 2005 061828 A1 (OSRAM OPTO SEMICONDUCTORS GMBH [DE]) 4 January 2007 (2007-01-04) page 5, paragraph 29 - paragraph 30 page 8, paragraph 68 - page 12, paragraph 114 figures 1-6 -----	1,3,4, 25,26

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/013280

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.
2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-10, 21-23, 25, 26, 29, 30, 31, 36, 37, 42

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-10,21-23,25,26,29,30,31,36,37,42

A light emitting device according to claim 1, further specified by the features defined in claims 2-10, 21 or 22; or

A luminaire comprising a light emitting device as recited in Claim 1; or

A light emitting structure according to claim 25; or

A light emitting device according to claim 26; or

A light emitting device according to claim 29, further specified by the features defined in claims 30, 31, 36 or 37; or

A luminaire comprising a light emitting device as recited in Claim 29; wherein

claim 1 defines:

A light emitting device, comprising:

a light emitting die configured to emit light having a first dominant wavelength; and

an index matched wavelength conversion structure configured to receive light emitted by the light emitting die;

wherein the index matched wavelength conversion structure comprises a plurality of wavelength converting particles embedded in a matrix material, the wavelength converting particles having a first index of refraction and configured to receive at least a portion of light emitted by the light emitting die and to responsively emit light having a second dominant wavelength that is different from the first dominant wavelength, and the matrix material having a second index of refraction that is substantially matched to the first index of refraction.

1.1. claim: 1+2

The light emitting device of Claim 1, wherein the matrix material comprises silicone and has an index of refraction greater than about 1.55.

1.2. claim: 1+3

The light emitting device of Claim 1, further comprising a mounting surface, wherein the light emitting die is on the mounting surface and is between the mounting surface and the wavelength conversion structure.

1.3. claim: 1+4

The light emitting device of Claim 1, further comprising a lens on the wavelength conversion structure, wherein the lens is configured to receive light emitted by the light emitting die that passes through the wavelength conversion structure.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1.4. claim: 1+5

The light emitting device of Claim 1, further comprising:
a submount, wherein the light emitting die is on the submount; and
a lens, wherein the light emitting die is between the submount and the lens, the lens including a proximal surface near the light emitting device, a distal surface spaced apart from the light emitting device, and a side surface extending between the proximal surface and the distal surface, wherein the wavelength conversion structure is on the proximal surface, the distal surface, and/or the side surface.

1.5. claim: 1+5+6

The light emitting device of claim 5, further comprising:
a reflective layer on at least one of the proximal surface, the distal surface and/or the side surface of the lens that the wavelength conversion structure is not on.

1.6. claims: 1+7,8

The light emitting device of Claim 1, further comprising a light scattering layer configured to scatter light emitted by the light emitting die.

1.7. claims: 1+9,10

The light emitting device of Claim 1, further comprising:
a mounting surface, wherein the light emitting die is on the mounting surface; and
a housing comprising sidewalls extending away from the mounting surface, the mounting surface and the sidewalls defining an optical cavity, wherein the wavelength conversion structure is outside the optical cavity; and optionally a lens on the optical cavity.

1.8. claims: 1+21,22

The light emitting device of Claim 1, wherein the wavelength conversion structure comprises a lens positioned adjacent the light emitting die.

1.9. claim: 23

A luminaire comprising a light emitting device as recited in Claim 1.

1.10. claim: 25

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

A light emitting structure comprising a diode layer and an index matched wavelength conversion structure adhesively bonded to the diode layer, wherein the index matched wavelength conversion structure comprises a plurality of wavelength converting particles embedded in a matrix material, the wavelength converting particles having a first index of refraction and configured to receive at least a portion of light emitted by the light emitting die and to responsively emit light having a second dominant wavelength that is different from the first dominant wavelength, and the matrix material having a second index of refraction that is substantially matched to the first index of refraction.

1.11. claim: 26

A light emitting device, comprising:
a submount;
a light emitting die on the submount;
an index matched wavelength conversion structure adhesively bonded to the diode layer, wherein the index matched wavelength conversion structure comprises a plurality of wavelength converting particles embedded in a matrix material, the wavelength converting particles having a first index of refraction and configured to receive at least a portion of light emitted by the light emitting die and to responsively emit light having a second dominant wavelength that is different from the first dominant wavelength, and the matrix material having a second index of refraction that is substantially matched to the first index of refraction;
and
a lens on the wavelength conversion structure.

1.12. claims: 29,30,31,36,37

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

A light emitting device according to claim 29, further optionally comprising the additional features of any of claims 30, 31, 36 and 36+37, the additional features of claim 30 being:

the graded index layer comprises a silicone matrix including a plurality of transparent particles embedded therein, wherein the silicone matrix has a first index of refraction and the transparent particles have a second index of refraction that is higher than the first index of refraction, and wherein a concentration of the transparent particles in the silicone matrix is continuously graded from a first concentration in the first region of the graded index layer near the light emitting die to a second concentration in the graded index layer away from the light emitting die;

the additional features of claim 31 being:

an optical element having a third index of refraction that is higher than the first and second indices of refraction and that is configured to receive light emitted by the light emitting die;

wherein the optical element is between the light emitting die and the graded index layer; and

wherein the first region of the graded index of refraction is near the optical element and the second region of the graded index layer is away from the optical element, and wherein the first index of refraction is higher than the second index of refraction;

the additional features of claim 36 being:

an encapsulant material on the light emitting die, wherein the encapsulant material has a third index of refraction that is less than or about equal to the first index of refraction;

wherein the encapsulant material is between the light emitting die and the graded index layer; and

wherein the first region of the graded index of refraction is near the encapsulant material and the second region of the graded index layer is away from the encapsulant material, and wherein the first index of refraction is lower than the second index of refraction; and the additional features of claim 37 being:

an optical element on the graded index layer, wherein the optical element has a fourth index of refraction that is greater than or about equal to the second index of refraction.

1.13. claim: 42

A luminaire comprising a light emitting device as recited in Claim 29.

2. claims: 1+9+10+11,12,13

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

A light emitting device, comprising:
a light emitting die configured to emit light having a first dominant wavelength; and
an index matched wavelength conversion structure configured to receive light emitted by the light emitting die;
wherein the index matched wavelength conversion structure comprises a plurality of wavelength converting particles embedded in a matrix material, the wavelength converting particles having a first index of refraction and configured to receive at least a portion of light emitted by the light emitting die and to responsively emit light having a second dominant wavelength that is different from the first dominant wavelength, and the matrix material having a second index of refraction that is substantially matched to the first index of refraction, further comprising:
a mounting surface, wherein the light emitting die is on the mounting surface; and
a housing comprising sidewalls extending away from the mounting surface, the mounting surface and the sidewalls defining an optical cavity, wherein the wavelength conversion structure is outside the optical cavity; and
a lens on the optical cavity, wherein
details of the lens arrangement on the optical cavity are further specified.

3. claims: 1+9+10+14, 29+36+37+38

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

A light emitting device according to claim 1, further comprising:
a mounting surface, wherein the light emitting die is on the mounting surface; and
a housing comprising sidewalls extending away from the mounting surface, the mounting surface and the sidewalls defining an optical cavity, wherein the wavelength conversion structure is outside the optical cavity; and
a lens on the optical cavity; further comprising
an encapsulant material in the optical cavity, the encapsulant material having a third index of refraction that is lower than a fourth index of refraction of the lens, and
a graded index layer between the optical cavity and the lens, wherein the graded index layer has an index of refraction that is continuously graded from a lower index near the optical cavity to a higher index near the lens; or
A light emitting device according to claim 29, further comprising:
an encapsulant material on the light emitting die, wherein the encapsulant material has a third index of refraction that is less than or about equal to the first index of refraction;
wherein the encapsulant material is between the light emitting die and the graded index layer; and
wherein the first region of the graded index of refraction is near the encapsulant material and the second region of the graded index layer is away from the encapsulant material, and wherein the first index of refraction is lower than the second index of refraction; still further comprising
a lens on the graded index layer, wherein the lens has a fourth index of refraction that is greater than or about equal to the second index of refraction.

4. claim: 1+9+10+15

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

A light emitting device, comprising:
a light emitting die configured to emit light having a first dominant wavelength; and
an index matched wavelength conversion structure configured to receive light emitted by the light emitting die;
wherein the index matched wavelength conversion structure comprises a plurality of wavelength converting particles embedded in a matrix material, the wavelength converting particles having a first index of refraction and configured to receive at least a portion of light emitted by the light emitting die and to responsively emit light having a second dominant wavelength that is different from the first dominant wavelength, and the matrix material having a second index of refraction that is substantially matched to the first index of refraction, further comprising:
a mounting surface, wherein the light emitting die is on the mounting surface; and
a housing comprising sidewalls extending away from the mounting surface, the mounting surface and the sidewalls defining an optical cavity, wherein the wavelength conversion structure is outside the optical cavity; and
a lens on the optical cavity, wherein the wavelength conversion structure is between the lens and the optical cavity.

5. claim: 1+9+10+16

A light emitting device, comprising:
a light emitting die configured to emit light having a first dominant wavelength; and
an index matched wavelength conversion structure configured to receive light emitted by the light emitting die;
wherein the index matched wavelength conversion structure comprises a plurality of wavelength converting particles embedded in a matrix material, the wavelength converting particles having a first index of refraction and configured to receive at least a portion of light emitted by the light emitting die and to responsively emit light having a second dominant wavelength that is different from the first dominant wavelength, and the matrix material having a second index of refraction that is substantially matched to the first index of refraction, further comprising:
a mounting surface, wherein the light emitting die is on the mounting surface; and
a housing comprising sidewalls extending away from the mounting surface, the mounting surface and the sidewalls defining an optical cavity, wherein the wavelength conversion structure is outside the optical cavity; and
a lens on the optical cavity; further comprising a light scattering layer on the optical cavity.

6. claim: 1+17

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

The light emitting device of Claim 1, further comprising a graded index layer on the wavelength conversion structure, the graded index layer having an index of refraction that is continuously graded from a higher index of refraction near the wavelength conversion structure to a lower index of refraction away from the wavelength conversion structure.

7. claims: 1+18,19,20

The light emitting device of Claim 1, further comprising a graded index layer between the wavelength conversion structure and the light emitting die, the graded index layer having an index of refraction that is continuously graded from a higher index of refraction near the light emitting die to a lower index of refraction near the wavelength conversion structure.

8. claim: 24

A liquid crystal display backlight comprising a light emitting device as recited in Claim 1.

9. claim: 26+27

A light emitting device, comprising:

- a submount;
- a light emitting die on the submount;
- an index matched wavelength conversion structure adhesively bonded to the diode layer, wherein the index matched wavelength conversion structure comprises a plurality of wavelength converting particles embedded in a matrix material, the wavelength converting particles having a first index of refraction and configured to receive at least a portion of light emitted by the light emitting die and to responsively emit light having a second dominant wavelength that is different from the first dominant wavelength, and the matrix material having a second index of refraction that is substantially matched to the first index of refraction;
- and
- a lens on the wavelength conversion structure; further comprising:
 - a light scattering layer between the lens and the wavelength conversion structure and configured to scatter light emitted by the wavelength conversion structure.

10. claim: 26+28

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

A light emitting device, comprising:
a submount;
a light emitting die on the submount;
an index matched wavelength conversion structure adhesively bonded to the diode layer, wherein the index matched wavelength conversion structure comprises a plurality of wavelength converting particles embedded in a matrix material, the wavelength converting particles having a first index of refraction and configured to receive at least a portion of light emitted by the light emitting die and to responsively emit light having a second dominant wavelength that is different from the first dominant wavelength, and the matrix material having a second index of refraction that is substantially matched to the first index of refraction;
and
a lens on the wavelength conversion structure; further comprising:
an antireflective coating on the lens.

11. claim: 29+31+32

A light emitting device, comprising:
a light emitting die configured to emit light having a first dominant wavelength; and
a graded index layer configured to receive light emitted by the light emitting die, wherein the graded index layer has an index of refraction that is continuously graded from a first index of refraction in a first region of the graded index layer near the light emitting die to a second index of refraction in the graded index layer away from the light emitting die, wherein the first index of refraction is different from the second index of refraction; further comprising:
a lens having a third index of refraction that is higher than the first and second indices of refraction and that is configured to receive light emitted by the light emitting die;
wherein the lens is between the light emitting die and the graded index layer; and
wherein the first region of the graded index of refraction is near the lens and the second region of the graded index layer is away from the lens, and wherein the first index of refraction is higher than the second index of refraction.

12. claims: 29+31+33,34,35

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

A light emitting device, comprising:
a light emitting die configured to emit light having a first dominant wavelength; and
a graded index layer configured to receive light emitted by the light emitting die, wherein the graded index layer has an index of refraction that is continuously graded from a first index of refraction in a first region of the graded index layer near the light emitting die to a second index of refraction in the graded index layer away from the light emitting die, wherein the first index of refraction is different from the second index of refraction; further comprising:
a wavelength conversion structure having a third index of refraction that is higher than the first and second indices of refraction and that is configured to receive light emitted by the light emitting die;
wherein the wavelength conversion structure is between the light emitting die and the graded index layer; and
wherein the first region of the graded index of refraction is near the wavelength conversion structure and the second region of the graded index layer is away from the wavelength conversion structure, and wherein the first index of refraction is higher than the second index of refraction.

13. claims: 29+36+37+39,40,41

The light emitting device of Claim 29, further comprising:
an encapsulant material on the light emitting die, wherein the encapsulant material has a third index of refraction that is less than or about equal to the first index of refraction;
wherein the encapsulant material is between the light emitting die and the graded index layer; and
wherein the first region of the graded index of refraction is near the encapsulant material and the second region of the graded index layer is away from the encapsulant material, and wherein the first index of refraction is lower than the second index of refraction; further comprising a wavelength conversion structure on the graded index layer, wherein the wavelength conversion structure has a fourth index of refraction that is greater than or about equal to the second index of refraction.

14. claim: 43

A liquid crystal display backlight comprising a light emitting device as recited in Claim 29.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2008/013280

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
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