

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
20 September 2007 (20.09.2007)

PCT

(10) International Publication Number
WO 2007/105853 A1

(51) International Patent Classification:
B32B 27/20 (2006.01)

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(21) International Application Number:
PCT/KR2006/004389

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, 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, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, 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, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(22) International Filing Date: 26 October 2006 (26.10.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10-2006-0023832 15 March 2006 (15.03.2006) KR

(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, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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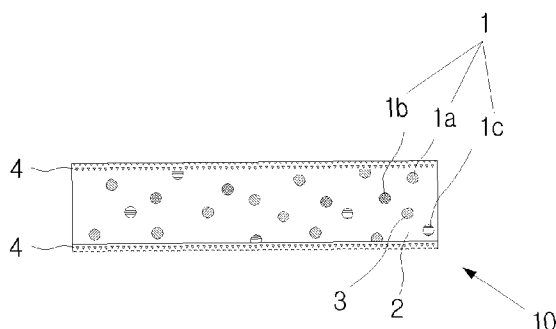
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Published:

— with international search report

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.

(54) Title: PHOTOLUMINESCENT SHEET



(57) Abstract: A photoluminescent sheet is disclosed. A photoluminescent sheet that includes a matrix resin layer, which is a thermosetting resin; a phosphor, which is included in the matrix resin layer and which converts the wavelength of light emitted from a blue LED; a curing agent, which is included in the matrix resin layer and which cures liquid thermosetting resin; and an additive, which is included in the matrix resin layer and which disperses the phosphor uniformly within the matrix resin layer, can implement white light from light having wavelengths corresponding to blue color.

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Description

PHOTOLUMINESCENT SHEET

Technical Field

- [1] The present invention relates to a photoluminescent sheet, more particularly, to a photoluminescent sheet capable of implementing white light from the blue light of an LED (light emitting diode).

[2]

Background Art

- [3] Various types of lighting equipment are used for providing light in the nighttime or in an indoor space and for spotlighting objects. Such lighting equipment provides light by receiving electrical energy from an electrical power source and converting it to light energy, where incandescent light bulbs or fluorescent tubes are generally used. However, incandescent light bulbs and fluorescent tubes entail high power consumption and heat emission, and due to their short durability of about six months, there is a need for frequent replacement.
- [4] In addition, fluorescent tubes use mercury, which is a carcinogenic substance, and may thus be subject to regulations, and when fluorescent tubes are used for direct lighting, the flickering of the light source may cause weakened eyesight. There are also several other drawbacks, including the requirement of large installation spaces, and difficulties in installation and color adjustment, etc.
- [5]
- [6] As an alternative to such conventional lighting devices, much research has been focused on lighting devices using LED's (light emitting diodes). An LED has a semi-permanent durability of about one hundred thousand hours, and since it uses light having a longer wavelength than that of ultraviolet rays, it is harmless to the human body.
- [7] LED's can be grouped, according to the wavelength of the light emitted, into blue LED's, white LED's, and ultraviolet LED's, etc. However, ultraviolet LED's and white LED's not only require complicated fabricating processes, but also incur much higher fabricating costs, such that their use is substantially limited. Thus, there is being developed a photoluminescent sheet for implementing white colors with inexpensive blue LED's. Such lighting equipment may be used for a backlight unit in a cell phone, etc.
- [8]
- [9] However, since the conventional photoluminescent sheet is formed by kneading an inorganic phosphor with a thermoplastic resin as the matrix resin using a two-axis

extruder, it is difficult to obtain uniform mixing of the phosphor in the resin sheet, which causes severe non-uniformity in luminance and color coordinates.

[10] Also, since the conventional color conversion sheet was fabricated by extrusion molding a colored pellet, in which a matrix resin and a phosphor were kneaded, identical extrusion-molding conditions produced only identical forms of color conversion sheet, to result in low applicability.

[11] Furthermore, thermoplastic resins such as polycarbonate or polymethylmethacrylate resin, etc., used for the matrix resin were limited in application, because they are high in brittleness and may easily break, as in the photograph of Fig. 1, and because they are low in heat-resistance (120°C or lower) and may easily undergo plastic deformation at high temperatures.

[12]

Disclosure of Invention

Technical Problem

[13] An aspect of the present invention aims to provide a photoluminescent sheet which can implement white light using inexpensive blue LED's, and which has high resistance to heat, brittleness, and humidity.

[14] Another aspect of the invention aims to provide a photoluminescent sheet in which the surface of the photoluminescent sheet is deformed for light diffusion, and in which wetting, which occurs due to contact when stacking with other sheets, is prevented.

[15]

Technical Solution

[16] One aspect of the invention provides a photoluminescent sheet that includes a matrix resin layer, which is a thermosetting resin; a phosphor, which is included in the matrix resin layer and which converts the wavelength of light emitted from a blue LED; a curing agent, which is included in the matrix resin layer and which cures liquid thermosetting resin; and an additive, which is included in the matrix resin layer and which disperses the phosphor uniformly within the matrix resin layer.

[17] The photoluminescent sheet may be fabricated, according to usage, as a luminance-enhancing photoluminescent sheet, luminance- and chromaticity-enhancing photoluminescent sheet, or a chromaticity-enhancing photoluminescent sheet. These may be fabricated in the following composition ratios.

[18] When a diffusing agent is not included, a luminance-enhancing photoluminescent sheet may be fabricated to include 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, and 1 ~ 90 parts by weight of the yellow phosphor, per 100 parts by weight of the silicone resin;

[19] or a luminance- and chromaticity-enhancing photoluminescent sheet may be

fabricated to include 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 1 ~ 30 parts by weight of the green phosphor, 0.1 ~ 60 parts by weight of the yellow phosphor, and 1 ~ 30 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.

[20] Also, a chromaticity-enhancing photoluminescent sheet may be fabricated to include 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 1 ~ 65 parts by weight of the green phosphor, and 1 ~ 65 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.

[21] Meanwhile, a diffusing agent may be added to the photoluminescent sheet, where the diffusing agent facilitates the refraction of light from the light source to increase the excitation rate of the phosphor and make it more uniform. Such a photoluminescent sheet may have the following composition ratios for various uses.

[22] A luminance-enhancing photoluminescent sheet may be fabricated to include 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 5 ~ 15 parts by weight of the diffusing agent, and 1 ~ 90 parts by weight of the yellow phosphor, per 100 parts by weight of the silicone resin;

[23] or a luminance- and chromaticity-enhancing photoluminescent sheet may be fabricated to include 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 5 ~ 15 parts by weight of the diffusing agent, 1 ~ 30 parts by weight of the green phosphor, 0.1 ~ 60 parts by weight of the yellow phosphor, and 1 ~ 30 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.

[24] Also, a chromaticity-enhancing photoluminescent sheet may be fabricated to include 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 5 ~ 15 parts by weight of the diffusing agent, 1 ~ 50 parts by weight of the green phosphor, and 1 ~ 50 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.

[25] Meanwhile, a protective film may be attached to a surface of the matrix resin layer. The protective film is a transparent layer, which protects the matrix resin layer for increased resistance to heat and humidity.

[26] The surface of the protective film may have uneven levels. This is for the functions of diffusion and anti-wetting. Minute balls for preventing wetting may be attached to the surface of the protective film, to prevent wetting when another sheet is placed in contact with the photoluminescent sheet.

Brief Description of the Drawings

[27] Fig. 1 is a photograph of a photoluminescent sheet according to prior art.

[28] Fig. 2 is a cross-sectional view of a photoluminescent sheet according to a first disclosed embodiment of the present invention.

- [29] Fig. 3 is a photoluminescent spectra graph of three types of photoluminescent sheets according to a second disclosed embodiment of the present invention.
- [30] Fig. 4 is a graph illustrating the relation between diffusing agent concentration and luminance in a photoluminescent sheet according to a third disclosed embodiment of the present invention.
- [31] Fig. 5 is a flowchart illustrating a method of fabricating a photoluminescent sheet according to a fourth disclosed embodiment of the present invention.
- [32] Fig. 6 is a schematic diagram illustrating a method of fabricating a photoluminescent sheet according to a fourth disclosed embodiment of the present invention.
- [33] Fig. 7 is a photograph of a photoluminescent sheet according to a fourth disclosed embodiment of the present invention.
- [34] Fig. 8 is a photograph for reliability testing for a photoluminescent sheet according to prior art.
- [35] Fig. 9 is a photograph for reliability testing for a photoluminescent sheet according to a fourth disclosed embodiment of the present invention.
- [36] Fig. 10 is a cross-sectional view of a photoluminescent sheet according to a fifth disclosed embodiment of the present invention.
- [37] Fig. 11 is a photograph of a photoluminescent sheet having minute balls attached, according to a fifth disclosed embodiment of the present invention.
- [38] Fig. 12 is a cross-sectional view of a photoluminescent sheet according to a sixth disclosed embodiment of the present invention.
- [39] Fig. 13 is a cross-sectional view of a photoluminescent sheet according to a seventh disclosed embodiment of the present invention.
- [40]
- [41] <Description of Reference Numerals for Key Components>
- [42] 1a: yellow phosphor 1b: red phosphor
- [43] 1c: green phosphor 1: phosphor
- [44] 2: matrix resin layer 3: diffusing agent
- [45] 4: protective film 5: minute ball
- [46] 10: photoluminescent sheet 20: silicone liquid
- [47]

Mode for the Invention

- [48] Embodiments of the invention will be described below in more detail, with reference to the accompanying drawings, where the same reference numerals are used for the same or corresponding components, and redundant descriptions are omitted.
- [49]
- [50] Fig. 2 is a cross-sectional view of a photoluminescent sheet according to a first

disclosed embodiment of the present invention. In Fig. 2 are illustrated a yellow phosphor 1a, red phosphor 1b, green phosphor 1c, phosphor 1, matrix resin layer 2, diffusing agent 3, protective film 4, and photoluminescent sheet 10.

[51] The photoluminescent sheet 10 shown in Fig. 2 has the function of transforming the light of a blue LED, having a wavelength of 400 nm ~ 500 nm, into white light. Basically, it has the form of a thin matrix resin layer 2 having a phosphor dispersed within.

[52] Although it is not shown in Fig. 2, a curing agent and an additive may be included inside the matrix resin layer 2. The curing agent is used for curing liquid thermosetting resin, and the additive is used for dispersing the phosphor uniformly within the liquid thermosetting resin. The diffusing agent 3 is for increasing the excitation rate of the phosphor and making it more uniform. The protective film 4 is for protecting the matrix resin layer 2.

[53]

[54] The materials used in certain embodiments of the invention are described as follows.

[55]

[56] - Matrix Resin Layer 2

[57] In embodiments of the invention, the matrix resin layer 2 is composed of a thermosetting resin, which may be a silicone resin. While thermoplastic resin is easy to handle, it is high in brittleness and low in humidity-resistance, making it difficult to use in a photoluminescent sheet 10. Thus, in embodiments of the invention, thermosetting resin is used, which involves more complicated processes.

[58] Silicone resin has good flexibility, and has superior adhesion when printed on a film. Desirable properties for silicone resin applicable to an embodiment of the invention include a light transmittance of 85% or higher, a viscosity of 3000 cP or higher, and a drying (curing) temperature of 120 °C or lower. Also, adequate mixing with the phosphor 1, etc., may be preferable, as well as low volatility and good adhesion with the protective film 4. Such silicone resin is commercially available, for example, the silicone resin system of LS4326 (silicone resin) - LS4326A (curing agent) - LS4326C (curing accelerator) - toluene or xylene (70%, viscosity controller or solvent), or the silicone resin system of CF5010 (silicone resin) - SO400 (curing agent) - silicone oil (viscosity controller or solvent), etc., from Dow Corning Corporation.

[59] Since such silicone resin generally has an antifoaming agent already added, the problem of bubbling, which may occur in screenprinting applications, can be resolved. Thus, the silicone resin generally referred to below may be regarded not so much as pure silicone resin, but as silicone resin containing small amounts of materials for improving the properties of the silicone resin. This is because it is difficult to obtain

pure silicone resin in the market, and because silicone resin generally referred to by those skilled in the art is the kind sold by silicone resin manufacturers.

[60]

[61] - Phosphor 1 and Diffusing Agent 3

[62] Materials mixed into the silicone resin for light excitation and/or diffusion are as follows.

[63] An inorganic phosphor is used for the phosphor 1. A typical light-excitation inorganic phosphor is composed by doping $Y_3Al_5O_{12}$ (YAG) with cerium, where $Y_3Al_5O_{12}$ (YAG) is a material of the garnet group. For example, the light-excitation inorganic phosphor may be $(Y_{1-x-y}Gd_xCe_y)_3Al_5O_{12}$ (YAG:Gd,Ce), $(Y_{1-x}Ce_x)_3Al_5O_{12}$ (YAG:Ce), $(Y_{1-x}Ce_x)_3(Al_{1-y}Ga_y)_5O_{12}$ (YAG:Ga,Ce), $(Y_{1-x-y}Gd_xCe_y)_3(Al_{5-z}Ga_z)_5O_{12}$ (YAG:Gd,Ga,Ce), or $(Gd_{1-x}Ce_x)SC_2Al_3O_{12}$ (GSAG), etc.

[64] In general, a YAG-based phosphor is represented as $(Y_{1-x-y}Gd_xCe_y)_3(Al_{1-z}Ga_z)_5O_{12}$ (where $x+y \leq 1$; $0 \leq x \leq 1$; $0 \leq y \leq 1$; $0 \leq z \leq 1$). The main wavelengths of the light emitted by the phosphor 1 vary according to the material set forth above. Ce^{3+} light emission from a garnet composition can provide a variety of colors from green (~ 540 nm; YAG:Ga,Ce) to red (~ 600 nm; YAG:Gd,Ce), without losses in light efficiency. In an embodiment of the invention, $(Y, Gd, Ce)_3(Al, Ga)_5O_{12}$ from Daejoo Electronic Materials Co. Ltd., and $Y_3Al_5O_{12}:Ce$ from Phosphor Technology, Ltd., were used. Also, a typical inorganic phosphor for emitting dark red light is $SrB_4O_7:Sm^{2+}$. Sm^{2+} mainly contributes to producing wavelengths of a red color. This dark red inorganic phosphor in particular absorbs radiation from the entire visible light range of 600 nm or lower, and emits radiation having wavelengths of 650 nm or higher. For improved luminance, a $SrS:Eu$ based phosphor of wavelengths around 620nm from Phosphor Technology, Ltd., is used. Also, a typical inorganic phosphor for emitting green light is $SrGa_2S_4:Eu^{2+}$. This green inorganic phosphor absorbs light of 500 nm or lower, and emits radiation having a main wavelength of 535 nm. Also, a typical inorganic phosphor for emitting blue light is $BaMg_2Al_{16}O_{27}:Eu^{2+}$. This blue inorganic phosphor absorbs light of 430 nm or lower, and emits radiation having a main wavelength of 450 nm.

[65] The yellow phosphor does not necessarily have to be YAG-based, and any one of TAG-based ($Tb_3Al_5O_{12}$) or Silicate-based ($Sr_2SiO_4:Eu$) phosphors may also be used. Further, the red phosphor may also be selected from among $CaS:Eu$, $SrS:Eu$, and $SrB_4O_7:Sm$, while the green phosphor may also be $SrGa_2S_4:Eu$.

[66] The diffusing agent 3, which performs the function of scattering or diffusing light to make the light uniform, is divided mainly into a transparent diffusing agent and a white diffusing agent. Examples of a transparent diffusing agent include organic transparent diffusing agents such as acrylic resin, styrene resin, and silicone resin, etc., and inorganic transparent diffusing agents such as synthetic silica, glass beads, and

diamond, etc. Typical examples of the white diffusing agent include silicon dioxide (SiO_2), titanium dioxide (TiO_2), zinc oxide (ZnO), barium sulfate (BaSO_4), calcium sulfate (CaSO_4), magnesium carbonate (MgCO_3), aluminum hydroxide (Al(OH)_3), and inorganic oxides containing clay, etc.

[67] The size and concentration of the diffusing agent 3 material are major factors that determine the degree of scattering of light emitted from a light source. If the diffusing agent 3 is too small in size, the light diffusion efficiency may be lowered, while too much of the diffusing agent 3 may lower the light transmissivity. In an embodiment of the present invention, the best results were obtained with sizes of SiO_2 from 5 to 7 μm . Also, desirable results for light diffusion and transmissivity were obtained when the concentration of the diffusing agent 3 was 13 %.

[68] As in the case of the diffusing agent 3, the size of the phosphor 1 material is also restricted. A size of 5 ~ 7 μm may be suitable for the phosphor 1, as an excessively small size reduces the light excitation efficiency, while an excessively large size lowers the light transmissivity and uniformity of the thin film.

[69] However, the diffusing agent 3 is not of critical importance, as it is possible to sufficiently diffuse light by deforming the surfaces of the photoluminescent sheet 10.

[70]

[71] - Protective Film 4

[72] A colorless transparent synthetic resin, which has high light transmissivity, may be used for the protective film 4 in an embodiment of the invention, which includes, but is not limited to, polyethylene terephthalate (PET), polyethylene naphthalate, acrylic resin, polycarbonate, and polystyrene, etc. Among these, a polyethylene terephthalate (PET) film is superior in terms of transparency, and has high strength and flexibility. When heat resistance and chemical resistance are required, it may be preferable to use polycarbonate for the protective film 4. Preferably, a film having a thickness of 5 ~ 50 μm may be used for the protective film 4. This is because a film having a thickness of 5 μm or lower is difficult to handle, while a film having a thickness of 50 μm or higher has lower light transmissivity.

[73] Meanwhile, since a polymer screen used in screenprinting is low in mechanical strength, it may be preferable to use a stainless-steel screen. The mesh size of the screen may be appropriately adjusted according to the printing thickness and grid size. In an embodiment of the invention, a screen having a mesh size of 50 ~ 120 was used.

[74]

[75] - Other Materials

[76] A curing agent cures liquid-phase silicone. While various types of curing agents may be used, the CF5010, CD7657, DC9800, LS4326, and DC2013 products from Dow Corning Corporation are generally used.

[77] Also, one or more solutions selected from a dispersing agent for dispersing the phosphor 1 within the liquid silicone, a surface-defect-preventing agent, and a fluidity-enhancing additive may be used as additives. When such additives are not used, the phosphor 1 lumps together, to decrease the efficiency of the photoluminescent sheet 10. Products from BYK Gmbh of Germany (BYK-333, BYK-306, BYK-310, BYK-w940, BYK-110, BYK-2001, BYK-410) are mainly used for the additives. Of course, any of a variety of products and substances may be used for the above curing agent and additives according to usage.

[78] In addition, an anti-precipitating agent, a binder, or antifoaming agent, etc., may be used for better mixing between the liquid silicone resin and the phosphor 1 and optionally the diffusing agent 3, to fabricate a uniform sheet or to prevent the occurrence of bubbles.

[79] The fabrication of a photoluminescent sheet 10, using the silicone resin, additives, and phosphor 1 set forth above will be described below, for the cases where a diffusing agent 3 is added and where a diffusing agent 3 is not added, for 100 parts by weight of the silicone resin.

[80]

[81] Tables 1 and 2 list the composition ratios for photoluminescent sheets; Table 1 for the case of adding a diffusing agent, and Table 2 for the case of not using a diffusing agent.

[82]

[83] Table 1

Composition Ratio of Photoluminescent Sheet with Diffusing Agent

	Silicone(parts by weight)	Curing Agent	Additive	Diffusing Agent	GreenPh osphor	YellowP hosphor	RedPhos phor
Luminance-Enhancing Photoluminescent Sheet	100	0.05~5	0.1~15	5~15	0	1~90	0
Luminance- and Chromaticity-Enhancing Photoluminescent Sheet	100	0.05~5	0.1~15	5~15	1~30	0.1~60	1~30
Chromaticity-Enhancing Photoluminescent	100	0.05~5	0.1~15	5~15	1~50	0	1~50

Sheet							
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[84]

[85]

Table 2

Composition Ratio of Photoluminescent Sheet without Diffusing Agent

	Silicone(parts by weight)	Curing Agent	Additive	GreenPh osphor	YellowP hospor	RedPhos phor
Luminance-Enhancing Photoluminescent Sheet	100	0.05~5	0.1~15	0	1~90	0
Luminance- and Chromaticity-Enhancing Photoluminescent Sheet	100	0.05~5	0.1~15	1~30	0~60	1~30
Chromaticity-Enhancing Photoluminescent Sheet	100	0.05~5	0.1~15	1~65	0	1~65

[86]

[87]

As in Tables 1 and 2, three main types of photoluminescent sheet may be fabricated. Each of the photoluminescent sheets may be referred to, according to its characteristics, as a luminance-enhancing photoluminescent sheet, a luminance- and chromaticity-enhancing photoluminescent sheet, and a chromaticity-enhancing photoluminescent sheet.

[88]

[89]

The luminance-enhancing photoluminescent sheet uses only the yellow phosphor, among the various phosphors. Thus, when blue light is irradiated onto the photoluminescent sheet, the light that passes the yellow phosphor material displays a low peak at around 550 nm, which is the wavelength region of yellow light, while the blue light that does not pass the yellow phosphor material displays a high peak at around its original 450 nm. This arrangement of wavelengths provides enhanced luminance. On the other hand, since white light requires a suitable combination of red, green, and blue light, the light implemented by the luminance-enhancing photoluminescent sheet may be lacking in chromaticity.

[90]

However, since the light emitted from blue LED's generally does not have high luminance, it may be preferable to use a luminance-enhancing photoluminescent sheet

to ensure maximum luminance for light passing the photoluminescent sheet.

- [91] When a diffusing agent is added, as in Table 1, the luminance-enhancing photoluminescent sheet may be fabricated including 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 5 ~ 15 parts by weight of the diffusing agent, and 1 ~ 90 parts by weight of the yellow phosphor, per 100 parts by weight of the silicone resin. When the diffusing agent is not added, as in Table 2, the luminance-enhancing photoluminescent sheet may be fabricated including 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, and 1 ~ 90 parts by weight of the yellow phosphor, per 100 parts by weight of the silicone resin.

[92]

- [93] Meanwhile, the chromaticity-enhancing photoluminescent sheet is for implementing white light. In particular, the chromaticity-enhancing photoluminescent sheet is used in lighting devices, and this type of sheet may be preferable in indoor spaces for everyday living, in order to reduce fatigue to the eyes.

- [94] The chromaticity-enhancing photoluminescent sheet uses a green phosphor and a red phosphor, from among the various phosphors. White light is implemented when wavelengths of blue, green, and red colors are suitably combined. Thus, when blue light is irradiated onto the photoluminescent sheet, the light that passes the red phosphor material displays a peak at around the wavelengths for red colors, and the light that passes the green phosphor material displays a peak at around the wavelengths for green colors, while the blue light that does not pass any of the phosphor materials displays a peak at around the wavelengths for blue colors, such that the lights blend together to implement white light.

- [95] When a diffusing agent is added, as in Table 1, the chromaticity-enhancing photoluminescent sheet may be fabricated including 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 5 ~ 15 parts by weight of the diffusing agent, 1 ~ 50 parts by weight of the green phosphor, and 1 ~ 50 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.

- [96] When the diffusing agent is not added, the chromaticity-enhancing photoluminescent sheet may be fabricated including 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 1 ~ 65 parts by weight of the green phosphor, and 1 ~ 65 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.

[97]

- [98] The luminance- and chromaticity-enhancing photoluminescent sheet combines the advantages and disadvantages of the luminance-enhancing photoluminescent sheet and the chromaticity-enhancing photoluminescent sheet. That is, the luminance- and chromaticity-enhancing photoluminescent sheet has the advantage of increasing both

the luminance and the chromaticity concurrently.

[99] When a diffusing agent is added, the luminance- and chromaticity-enhancing photoluminescent sheet may be fabricated including 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 5 ~ 15 parts by weight of the diffusing agent, 1 ~ 30 parts by weight of the green phosphor, 0.1 ~ 60 parts by weight of the yellow phosphor, and 1 ~ 30 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.

[100] When the diffusing agent is not added, the luminance- and chromaticity-enhancing photoluminescent sheet may be fabricated including 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 1 ~ 30 parts by weight of the green phosphor, 0.1 ~ 60 parts by weight of the yellow phosphor, and 1 ~ 30 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.

[101]

[102] Analyzing the photoluminescent spectra of the three types of photoluminescent sheets set forth above may yield the graph shown in Fig. 3. As illustrated in Fig. 3, a peak is formed for the luminance-enhancing photoluminescent sheet across a broad range, while high peaks are formed in the blue, red, and green wavelength regions for the chromaticity-enhancing photoluminescent sheet.

[103]

[104] Meanwhile, with respect to forming the three types of photoluminescent sheets set forth above, the reasons for limiting the composition ranges are explained below.

[105]

[106] - Effect of the Curing Agent

[107] When the content of the curing agent is 0.05 % or lower, there is almost no curing at all of the silicone resin after printing, and even when there is a curing effect, the curing time is increased to several hours or several days, to cause a lack of productivity. On the other hand, when the content of the curing agent is 5 % or higher, the curing occurs too quickly, such that the curing may occur during the printing process for fabricating the photoluminescent sheet.

[108] When the curing occurs too early, the curing may occur while the printing is being performed, such that the thickness of the photoluminescent sheet is increased. This may cause serious process changes of altered color coordinates, and may incur serious problems in the reproduction of the fabrication process.

[109]

[110] - Effect of the Additives

[111] One or more of a dispersing agent, a surface-defect-preventing agent, and a fluidity-enhancing additive may be mixed in for use as additives. When the amount of additives is below 0.1 weight%, there may be serious separation and aggregation

between phosphor material after the photoluminescent sheet is fabricated, to make it difficult to form a uniform surface light source, and when the amount of additives is 15 weight% or higher, reverse effects may occur, such as those listed below in Table 3.

[112]

[113] Table 3

Types and Effects of Additives

Type of Additive	Product Name	Effect	Reverse Effect when Used Excessively
Dispersing Agent	BYK110,180,12001	prevents ag- gregation, reduction in luster, color changes, color separation, and pre- cipitation, etc.	flowing effect on print surface (non-uniformity in film surface)
Surface-Defect- Preventing Agent	BYK310,333	prevents color separation, surface fluidity, crater effect, surface slip foaming, etc.	delayed curing, weakened adhesion, and lowered surface fluidity, when used excessively, in the case of BYK333
Fluidity-Enhancing Additive	BYK940,410	prevents flow pre- cipitation of surface	flowing effect on print surface

[114]

[115] As shown in Table 3, excessive use of the dispersing agent may create a flowing effect on the print surface, to cause non-uniformity in the surface of the film (photoluminescent sheet). In the case of the surface-defect-preventing agent, when the BYK333 is added in an excess amount, the curing may be delayed, the adhesion may be weakened, and the surface fluidity may be lowered, while in the case of the fluidity-enhancing additive, an excess amount may cause a flowing effect on the print surface.

[116]

[117] - Effect of the Diffusing Agent

[118] In the case where a diffusing agent is added in the sheet, the relation between the composition of the diffusing agent and luminance is as shown in Table 4 and the graph of Fig. 4. (Table 4 and the graph of Fig. 4 are results of experiments on the luminance-enhancing photoluminescent sheet and the chromaticity-enhancing photoluminescent sheet.)

[119] When the amount of the diffusing agent is 5 parts by weight or less per 100 parts by weight of the silicone resin, there is almost no increasing effect at all on luminance, and when the amount is 15 parts by weight or more, there is a trend of decreasing luminance. Thus, a suitable amount may be selected from the range of 5 ~ 15 parts by weight.

[120]

[121] Table 4

Diffusing Agent Concentration(per 100 parts by weight of silicone resin)	Luminance-Enhancing Photoluminescent Sheet(cd/m ²)	Chromaticity-Enhancing Photoluminescent Sheet(cd/m ²)
0	2830	1909
7	2831	1868
9	2898	1908
11	3021	1978
13	3001	2012
15	2871	1900

[122]

[123] - Effect of the Phosphor

[124] As phosphors may have varying light emission and color coordinate properties according to the manufacturer, it is difficult to establish a fixed composition, and thus the phosphors have a wide range of compositions.

[125] In the case of a luminance-enhancing photoluminescent sheet, there is almost no excitation of the phosphor material with less than 1 part by weight per 100 parts by weight of the silicone resin, and as the light from the blue LED light source occupies the major portion of the resulting light, the light is of a generally blue color. With 90 parts by weight or more, the color coordinates are beyond white and are more of a yellow shade, and while the greater content of phosphors typically lead to the higher luminance in the fabrication of phosphor sheets, there is almost no luminance increase for 90 parts by weight or more.

[126] In the case of a luminance- and chromaticity-enhancing photoluminescent sheet, a composition of 1 part by weight of the green phosphor, 0.1 parts by weight of the yellow phosphor, and 1 part by weight of the red phosphor or less, per 100 parts by weight of the silicone resin, causes almost no excitation of the phosphor material at all, so that the light is of a generally blue color, and there is almost no luminance increase for 30 parts by weight of the green phosphor, 60 parts by weight of the yellow

phosphor, and 30 parts by weight of the red phosphor or more.

[127] In the case of a chromaticity-enhancing photoluminescent sheet, there is almost no excitation of the phosphor material with less than 1 part by weight of the green phosphor and 1 part by weight of the red phosphor per 100 parts by weight of the silicone resin, so that the light is of a generally blue color, and there is almost no luminance increase for 50 parts by weight of the green phosphor and 50 parts by weight of the red phosphor or more. When a diffusing agent is not used, the green phosphor may be used up to 65 parts by weight, and the red phosphor may be used up to 65 parts by weight.

[128] A method of fabricating the photoluminescent sheet considering the range of composition ratios set forth above will be described below. Fig. 5 is a flowchart illustrating a method of fabricating a photoluminescent sheet according to a fourth disclosed embodiment of the present invention, and Fig. 6 is a schematic diagram illustrating a method of fabricating a photoluminescent sheet according to the fourth disclosed embodiment of the present invention. In Fig. 6 are illustrated a protective film 4, a photoluminescent sheet 10, and silicone liquid 20.

[129]

[130] - Method of Fabrication

[131] The curing agent, the phosphor, and optionally the diffusing agent are mixed and stirred into the silicone resin of a gel form, and the viscosity is adjusted by means of silicone oil, etc., at which the silicone liquid is fabricated. Afterwards, it is printed onto the protective film by screenprinting, slit coating, or roll coating, etc., and dry-cured to fabricate the photoluminescent sheet 10. While the photoluminescent sheet 10 may also be used after removing the protective film 4, it is generally preferable to leave the protective film 4 attached, for protection.

[132]

[133] Examining the fabrication method in more detail,

[134] A liquid silicone resin was fabricated by sequentially adding the silicone resin, and 0.5 parts by weight of the curing agent and 2 parts by weight of the curing accelerator per 100 parts by weight of the silicone resin. For the liquid silicone resin fabricated in the manner set forth above, 13 parts by weight of the phosphor and 13 parts by weight of SiO_2 (5 ~ 7 μm in diameter) as the diffusing agent were mixed into the liquid silicone resin and stirred using a revolving and orbiting stirrer to fabricate a silicone liquid 20. Next, the mixed silicone liquid described above was coated, using screenprinting, onto a protective film 4 (made of polyethylene) having a double-layer structure, of which the first layer has a thickness of 10 ~ 25 μm and the second layer has a thickness of 20 ~ 100 μm , as the printing surface. After curing in an infrared drier at 120 °C, the protective film 4 was separated, to fabricate a photoluminescent sheet

based on an embodiment of the invention.

[135] However, instead of separating the protective film 4, another layer of protective film 4 may further be stacked. This may increase the heat- and humidity-resistance of the photoluminescent sheet 10.

[136]

[137] The photoluminescent sheet according to an embodiment of the invention has superior flexibility, such that it only bends and does not break. Fig. 7 is a photograph (without the protective film 4) of the photoluminescent sheet according to the fourth disclosed embodiment of the present invention, which shows how the photoluminescent sheet has no cracks on the surface.

[138] In prior art, a film was produced from thermoplastic resin by extruding and pulling, without a protective film. Reliability testing performed on such conventional thermoplastic resin in a high temperature (80 ~ 85 °C) and high humidity (80 ~ 85 %) atmosphere provides the results shown in the photograph of Fig. 8. As in the photograph, the surface phosphors were separated and lost, while the phosphor material itself was also deteriorated, such that there was a serious reduction in luminance.

[139] However, with the present embodiment, silicone resin was used, which is a kind of thermosetting resin, the results of which are no losses or deterioration of surface phosphors, as seen in the photograph of Fig. 9, and thus almost no reduction in luminance.

[140] Moreover, when a protective film 4 was stacked, there were no deterioration or reduction in luminance even in a high temperature and high humidity environment.

[141]

[142] Meanwhile, when a sheet of a different type from the photoluminescent sheet is stacked, the sheets adhere together to cause a wetting phenomenon. Therefore, there may be a need to separate each of the sheets by a minute distance. An embodiment will be described below which provides an improvement in this matter.

[143] Fig. 10 is a cross-sectional view of a photoluminescent sheet according to a fifth disclosed embodiment of the present invention, and Fig. 11 is a photograph of the photoluminescent sheet having minute balls attached, according to the fifth disclosed embodiment of the present invention. In Fig. 10 are illustrated a phosphor 1, a matrix resin layer 2, a diffusing agent 3, protective films 4, minute balls 5, attachment layers 6, and a photoluminescent sheet 10.

[144] The fifth disclosed embodiment of the invention is characterized by attaching minute balls 5 on the surfaces of the photoluminescent sheet 10. When the minute balls 5 are evenly dispersed and attached on the surfaces of the photoluminescent sheet 10, the wetting phenomenon caused by close adhesion of the surfaces may be avoided,

even when different types of sheets are placed on the upper and lower surfaces.

[145] Preferably, the minute balls 5 may also be made from resin, and it may be preferable to use a transparent material, so as not to lower the luminance. While the minute balls 5 may be attached directly on the surfaces of the photoluminescent sheet 10, coating an attachment layer 6 on the outer surface may prevent the minute balls 5 from becoming detached and may allow a stable manner of attachment.

[146] Fig. 11 is a photograph seen from above of the fifth disclosed embodiment of the invention, where minute balls are dispersed over and attached onto the surface of the photoluminescent sheet.

[147]

[148] Fig. 12 is a cross-sectional view of a photoluminescent sheet according to a sixth disclosed embodiment of the present invention. In Fig. 12 are illustrated a phosphor 1, a matrix resin layer 2, a diffusing agent 3, protective films 4, and a photoluminescent sheet 10.

[149] In the sixth disclosed embodiment, the surfaces of the protective film 4 have been treated to have roughness. This is in order to effectively diffuse light. That is, light incident on the matrix resin layer 2 passes a protective film 4 twice, where the roughness of the protective films 4 allows the paths of the light to be widely dispersed. Thus, this photoluminescent sheet 10 may be used without a diffusion agent 3. In addition, the rough surface of the protective film 4 also prevents the wetting phenomenon caused by close adhesion of the surfaces, when a different type of sheet is placed on the outer surfaces.

[150]

[151] Fig. 13 is a cross-sectional view of a photoluminescent sheet according to a seventh disclosed embodiment of the present invention. A phosphor 1, a matrix resin layer 2, a diffusing agent 3, protective films 4, minute balls 5, and a photoluminescent sheet 10 are illustrated. In this embodiment, minute balls 5 are attached on the outer surfaces of the protective films 4, which are made to have roughness, as in the sixth disclosed embodiment of Fig. 12, to enhance the function of preventing wetting.

[152] While the present invention was described in detail with reference to the particular embodiments, the embodiments are merely for the purpose of illustration, and are not to limit the invention. It is to be appreciated by those skilled in the art that various embodiments may be conceived without departing from the spirit of the present invention.

[153]

Industrial Applicability

[154] According to aspects of the invention set forth above, a photoluminescent sheet is provided which can reliably implement white light from the light of blue LED's.

[155]

Claims

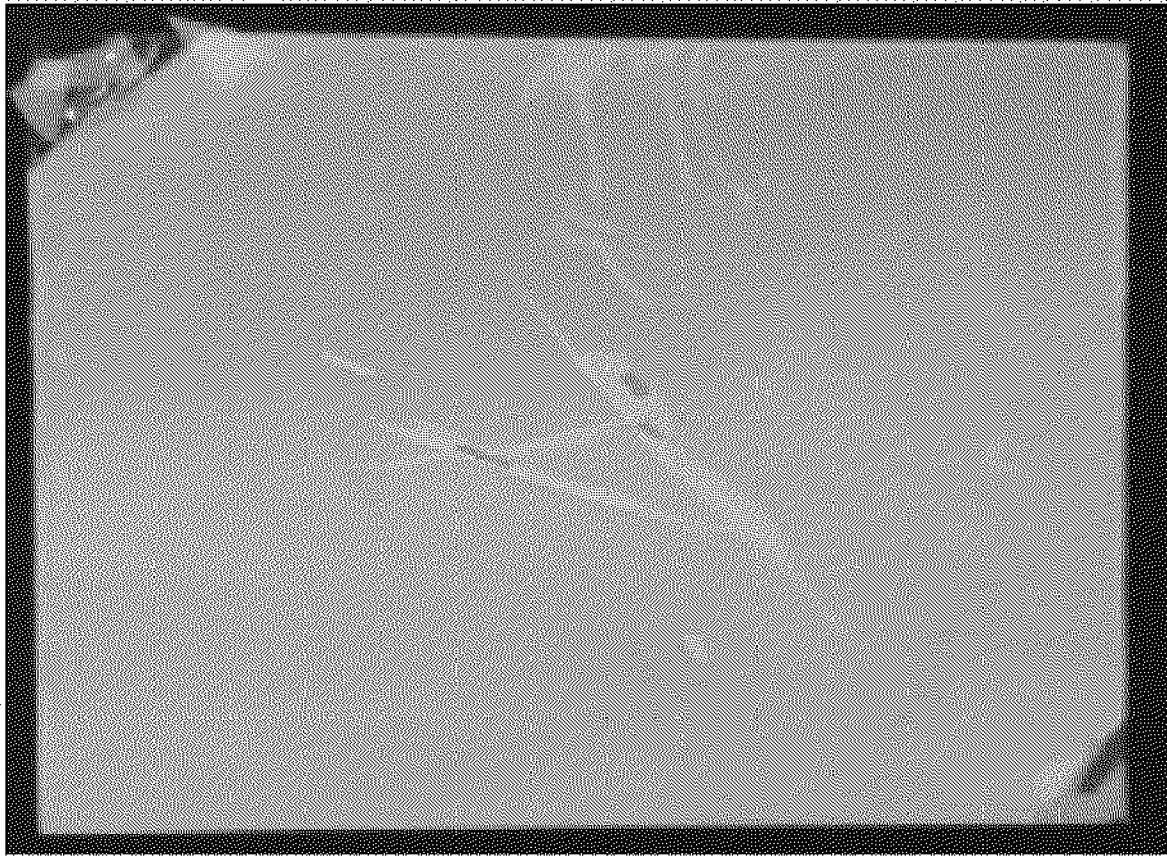
- [1] A photoluminescent sheet comprising:
a matrix resin layer of thermosetting resin;
a phosphor, included in the matrix resin layer, capable of converting a wavelength of light emitted from a blue LED;
a curing agent, included in the matrix resin layer, capable of curing liquid thermosetting resin; and
an additive, included in the matrix resin layer, capable of dispersing the phosphor uniformly within the matrix resin layer.
- [2] The photoluminescent sheet of claim 1, wherein the thermosetting resin is silicone resin, and the phosphor is a yellow phosphor,
the photoluminescent sheet comprising 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, and 1 ~ 90 parts by weight of the yellow phosphor, per 100 parts by weight of the silicone resin.
- [3] The photoluminescent sheet of claim 1, wherein the thermosetting resin is silicone resin, and the phosphor comprises a green phosphor, a yellow phosphor, and a red phosphor,
the photoluminescent sheet comprising 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 1 ~ 30 parts by weight of the green phosphor, 0.1 ~ 60 parts by weight of the yellow phosphor, and 1 ~ 30 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.
- [4] The photoluminescent sheet of claim 1, wherein the thermosetting resin is silicone resin, and the phosphor comprises a green phosphor and a red phosphor,
the photoluminescent sheet comprising 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 1 ~ 65 parts by weight of the green phosphor, and 1 ~ 65 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.
- [5] The photoluminescent sheet of claim 1, wherein the thermosetting resin is silicone resin, a diffusing agent capable of refracting light is added to the silicone resin, and the phosphor comprises a yellow phosphor,
the photoluminescent sheet comprising 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 5 ~ 15 parts by weight of the diffusing agent, and 1 ~ 90 parts by weight of the yellow phosphor, per 100 parts by weight of the silicone resin.
- [6] The photoluminescent sheet of claim 1, wherein the thermosetting resin is silicone resin, a diffusing agent capable of refracting light is added to the silicone resin, and the phosphor comprises a green phosphor, a yellow phosphor, and a

red phosphor,

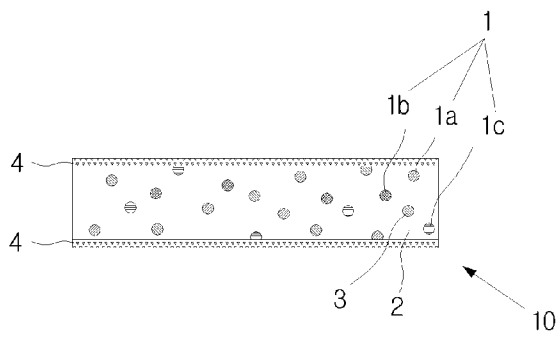
the photoluminescent sheet comprising 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 5 ~ 15 parts by weight of the diffusing agent, 1 ~ 30 parts by weight of the green phosphor, 0.1 ~ 60 parts by weight of the yellow phosphor, and 1 ~ 30 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.

- [7] The photoluminescent sheet of claim 1, wherein the thermosetting resin is silicone resin, a diffusing agent capable of refracting light is added to the silicone resin, and the phosphor comprises a green phosphor and a red phosphor, the photoluminescent sheet comprising 0.05 ~ 5 parts by weight of the curing agent, 0.1 ~ 15 parts by weight of the additive, 5 ~ 15 parts by weight of the diffusing agent, 1 ~ 50 parts by weight of the green phosphor, and 1 ~ 50 parts by weight of the red phosphor, per 100 parts by weight of the silicone resin.
- [8] The photoluminescent sheet of claim 1, wherein a protective film is attached to a surface of the matrix resin layer.
- [9] The photoluminescent sheet of claim 8, wherein minute balls for preventing wetting are attached to a surface of the protective film.
- [10] The photoluminescent sheet of claim 8, wherein a surface of the protective film has roughness.

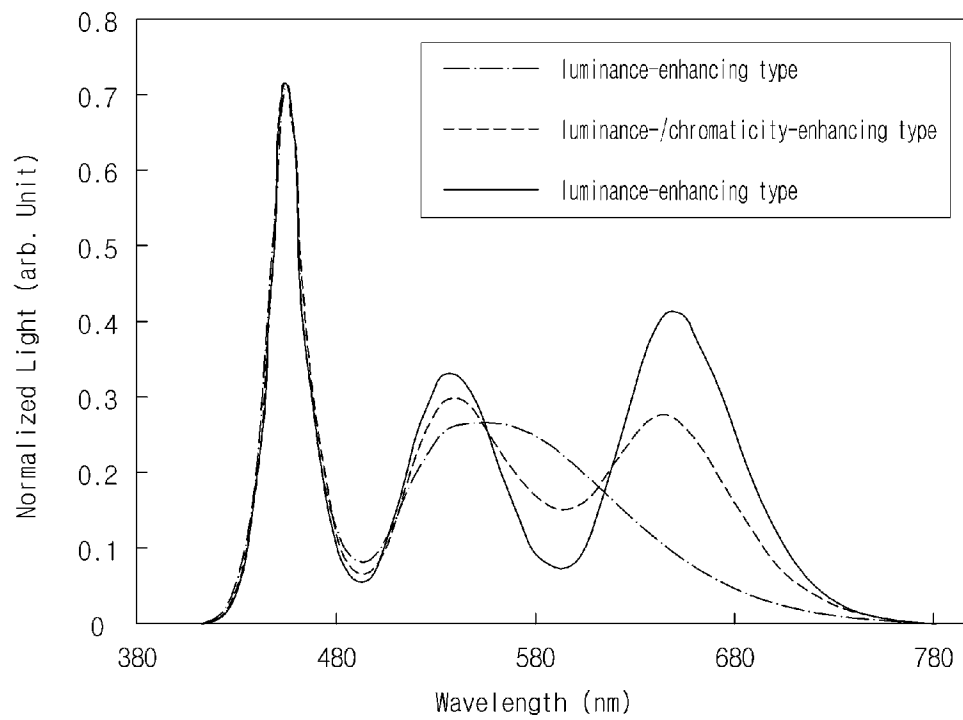
[Fig. 1]



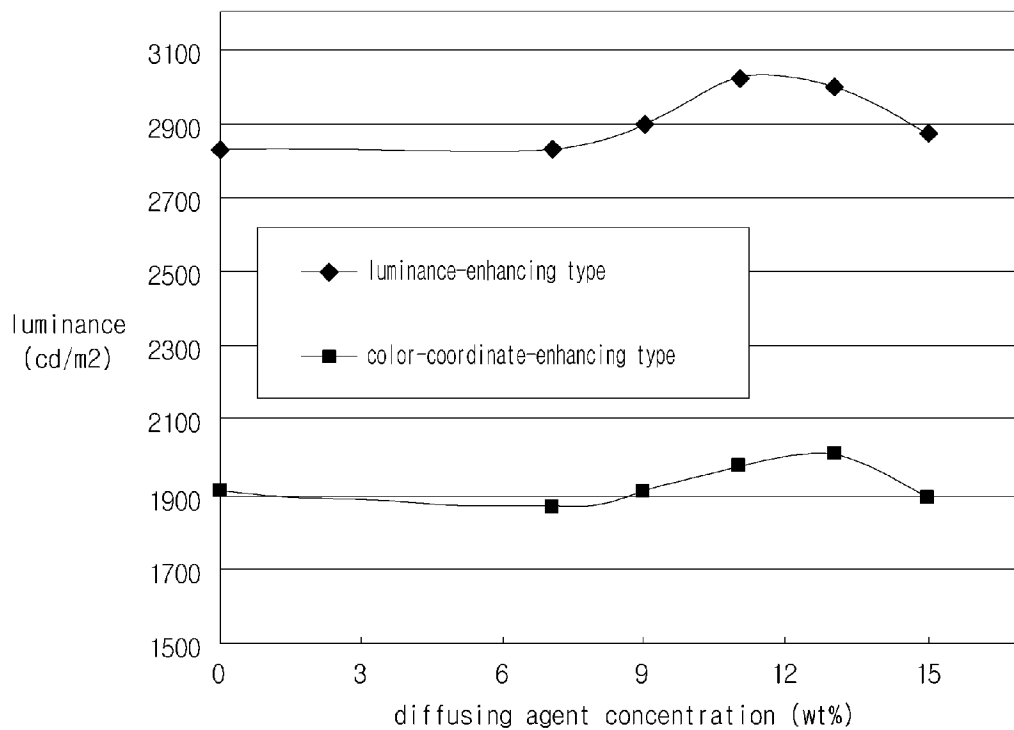
[Fig. 2]



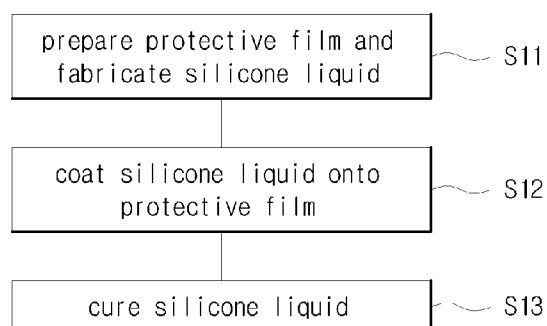
[Fig. 3]



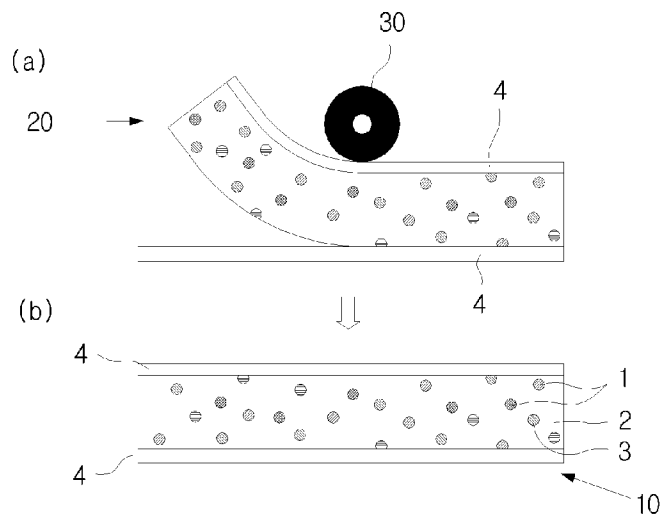
[Fig. 4]



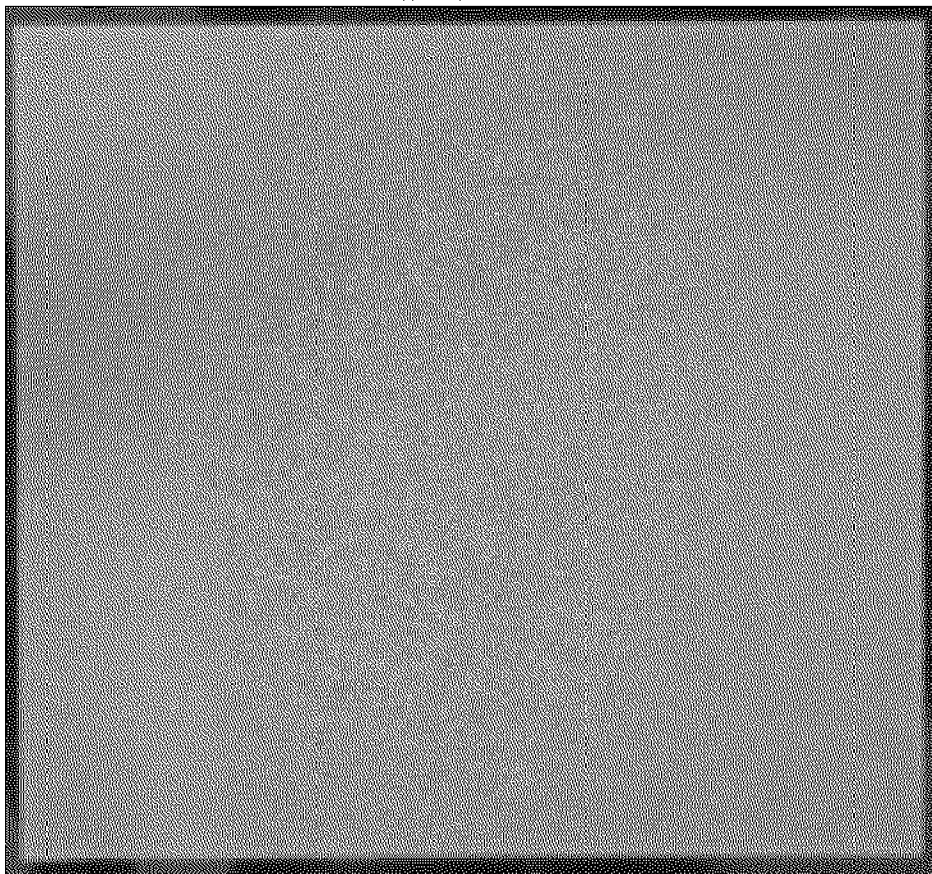
[Fig. 5]



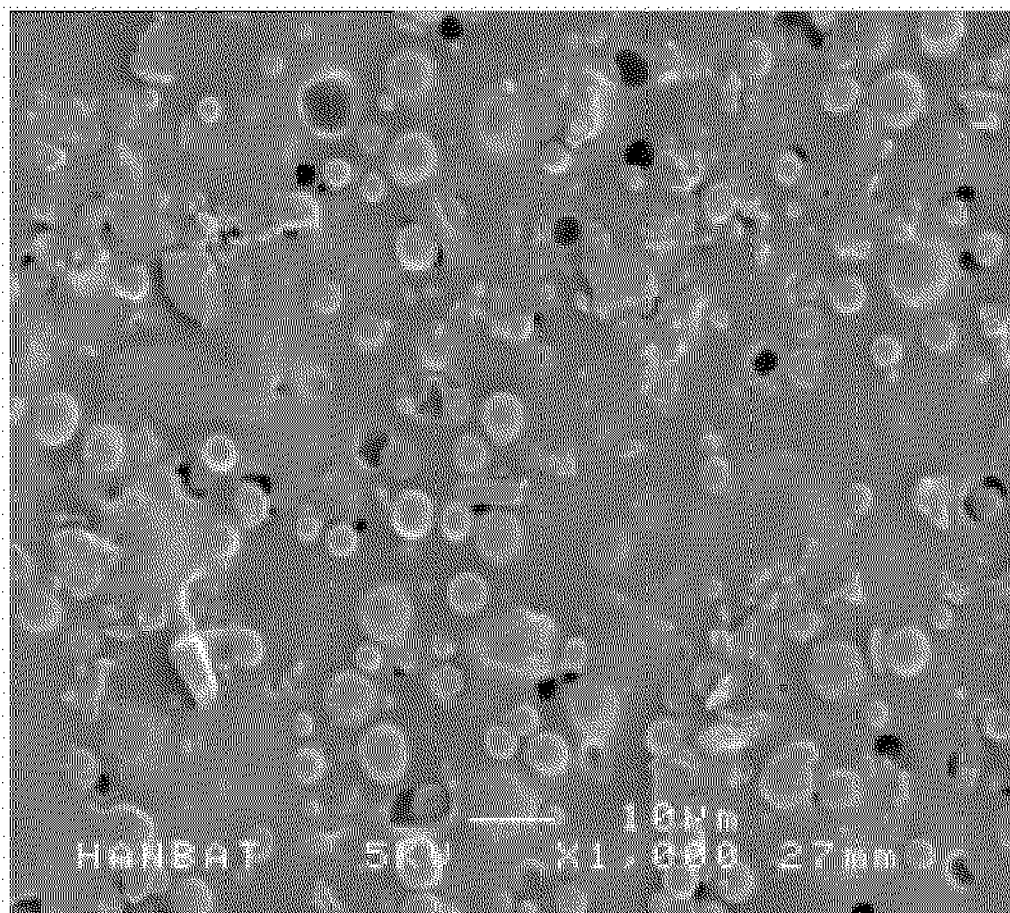
[Fig. 6]



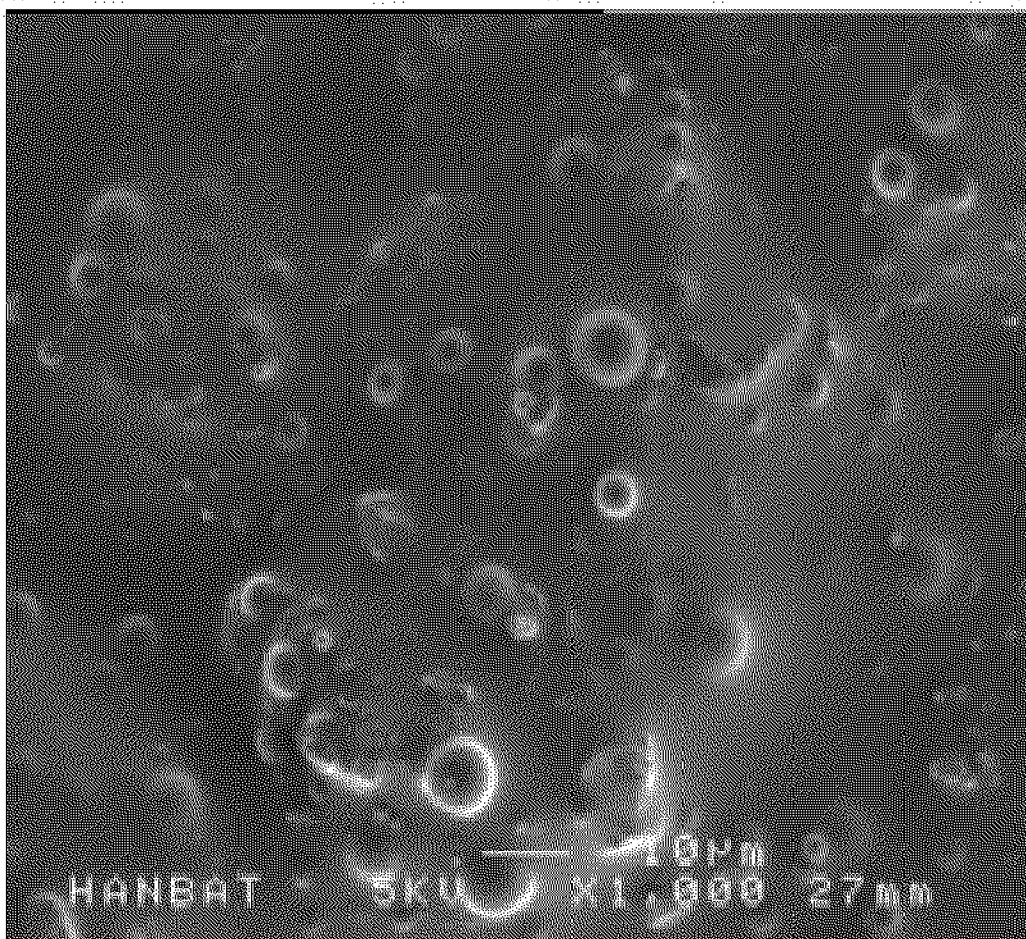
[Fig. 7]



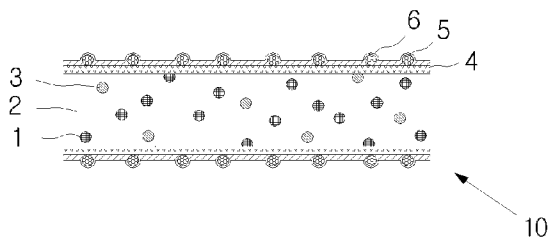
[Fig. 8]



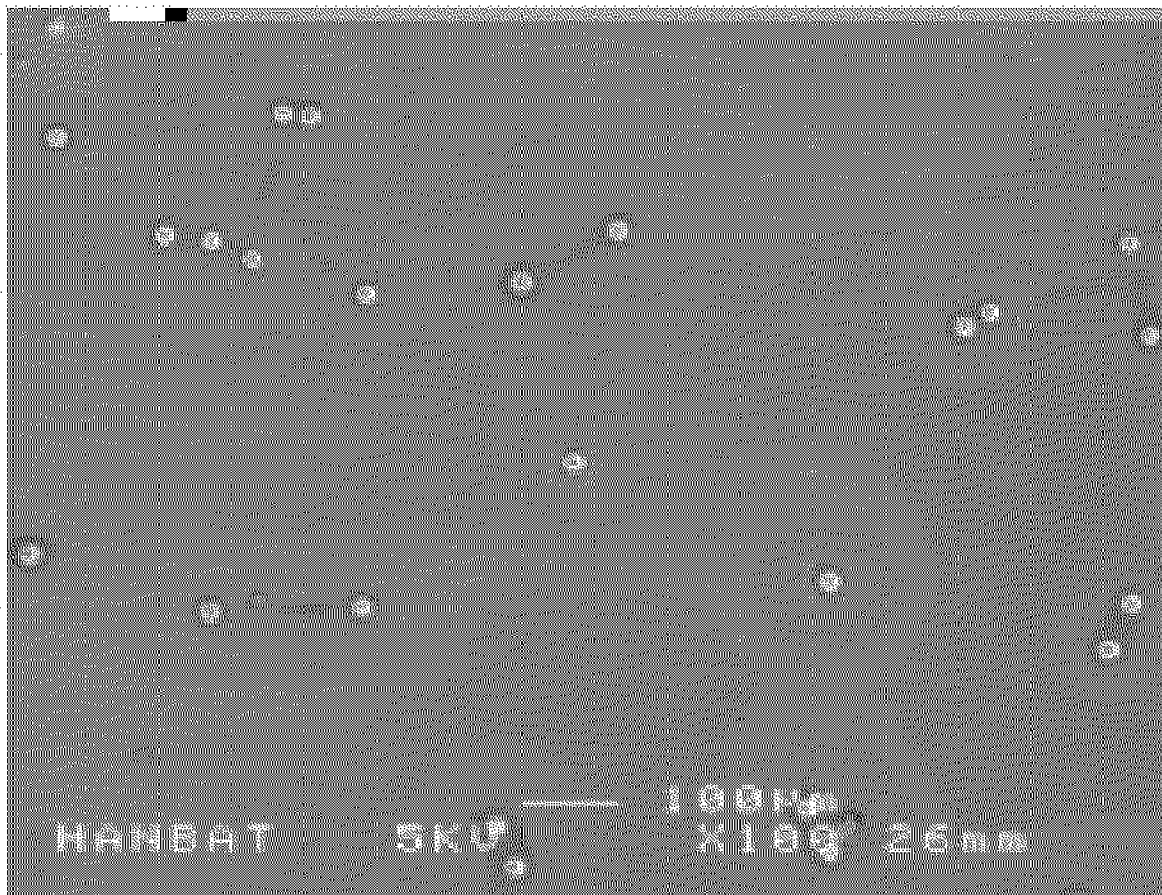
[Fig. 9]



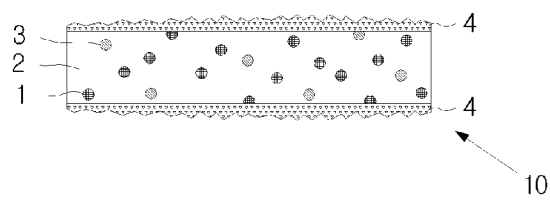
[Fig. 10]



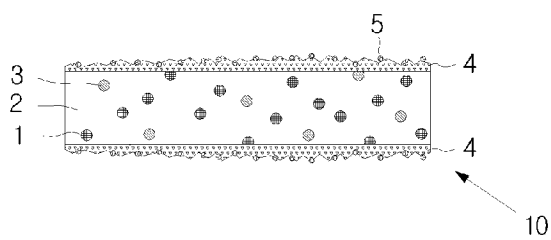
[Fig. 11]



[Fig. 12]



[Fig. 13]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2006/004389**A. CLASSIFICATION OF SUBJECT MATTER*****B32B 27/20(2006.01)i***

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)

IPC 8 : B32B 27/20

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

KR,JP IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS (KIPO internal) "photoluminescent" "phosphor"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6569786 B1, (Omniglow Corporation), 27 May 2003 (27.05.2003) see Figure 2 and claims 1 and 7	1-10
A	US 6395408 B1, (Pioneer Plastics Corporation), 28 May 2002 (28.05.2002) see columns 5 and 6, and claims 1 and 12	1-10
A	US 4927681, (Pioneer Electronic Corporation), 22 May 1990 (22.05.1990) see columns 5 and 6, and Figure 1	1-10



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

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"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

22 JANUARY 2007 (22.01.2007)

Date of mailing of the international search report

22 JANUARY 2007 (22.01.2007)

Name and mailing address of the ISA/KR

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Facsimile No. 82-42-472-7140

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LEE, Young Jae

Telephone No. 82-42-481-8305



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2006/004389

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US6569786	27.05.2003	US6569786B1 US6569786BA	27.05.2003 27.05.2003
US6395408	28.05.2002	AT336372E AU199735036B2 AU3503697A1 AU715838B2 BR9710695A CA2259388AA CA2259388C CA2259388C CN1091027C CN1228732 CN1228732A DE69736518C0 DK0907502T3 EP00907502B1 EP907502A1 EP907502B1 EP907502A4 ES2129018T1 GR99300016T1 HK1020549A1 IL127766A0 IL127766A1 JP12515078 JP2000515078T2 KR1020000022267 NZ333538A US2002127430A1 US2002127430AA US6395408B1 US6395408BA US6596416BB W09800289A1	15.09.2006 21.01.1998 21.01.1998 10.02.2000 11.01.2000 08.01.1998 20.09.2005 08.01.1998 18.09.2002 15.09.1999 15.09.1999 28.09.2006 23.10.2006 16.08.2006 14.04.1999 16.08.2006 17.10.2001 01.06.1999 28.05.1999 03.11.2006 28.10.1999 26.08.2001 14.11.2000 14.11.2000 25.04.2000 29.09.2000 12.09.2002 12.09.2002 28.05.2002 28.05.2002 22.07.2003 08.01.1998
US4927681	22.05.1990	EP00354601A3 EP00354601B1 EP0354601A2 EP354601A2 EP354601A3 EP354601B1 JP02050328 JP2050328A2 JP2904434B2 US05063556 US4927681A US5063556A	29.05.1991 06.07.1994 14.02.1990 14.02.1990 29.05.1991 06.07.1994 20.02.1990 20.02.1990 14.06.1999 05.11.1991 22.05.1990 05.11.1991