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Hamada et al. (43) **Pub. Date: Apr. 14, 2005**(54) **ORGANIC ELECTROLUMINESCENCE
DEVICE AND LUMINANCE MATERIAL****Publication Classification**(76) Inventors: **Yuji Hamada**, Nara (JP); **Tsuyoshi
Tsujioka**, Osaka (JP)(51) **Int. Cl.⁷** **H05B 33/14**(52) **U.S. Cl.** **428/690**; 428/917; 313/504;
313/506

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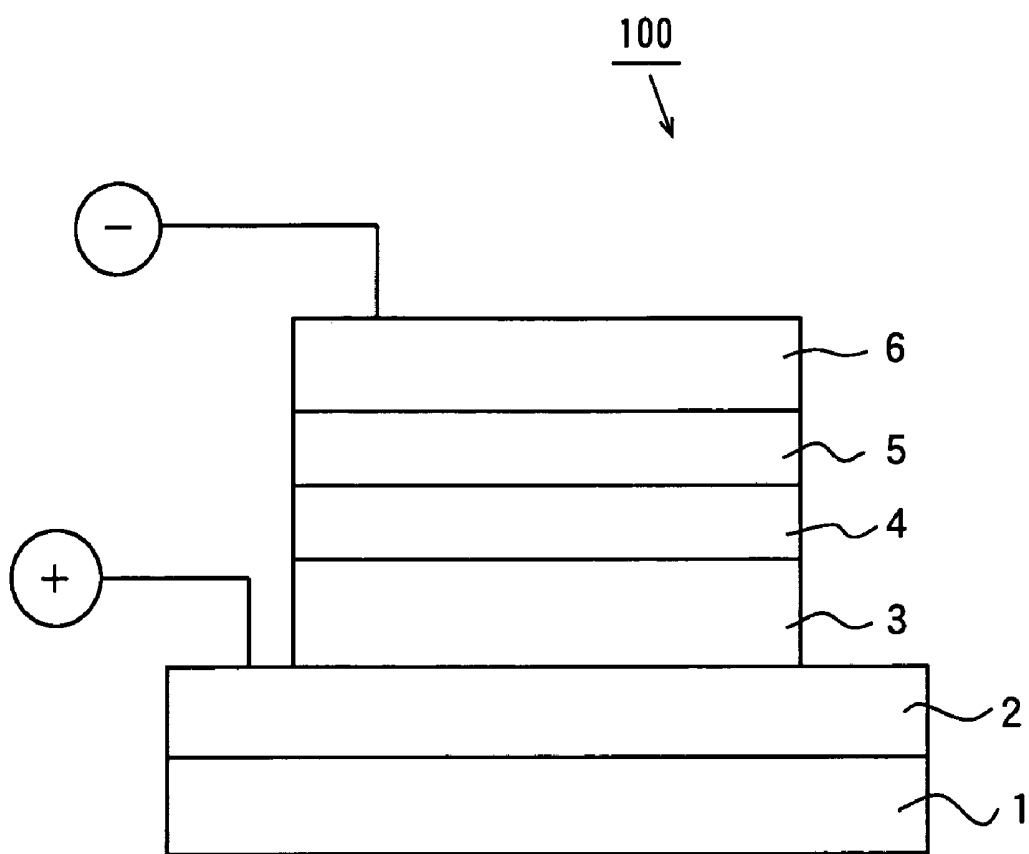
McDermott Will & Emery**600 13th Street NW****Washington, DC 20005-3096 (US)**(57) **ABSTRACT**(21) Appl. No.: **10/479,734**(22) PCT Filed: **Jun. 4, 2002**(86) PCT No.: **PCT/JP02/05522**(30) **Foreign Application Priority Data**

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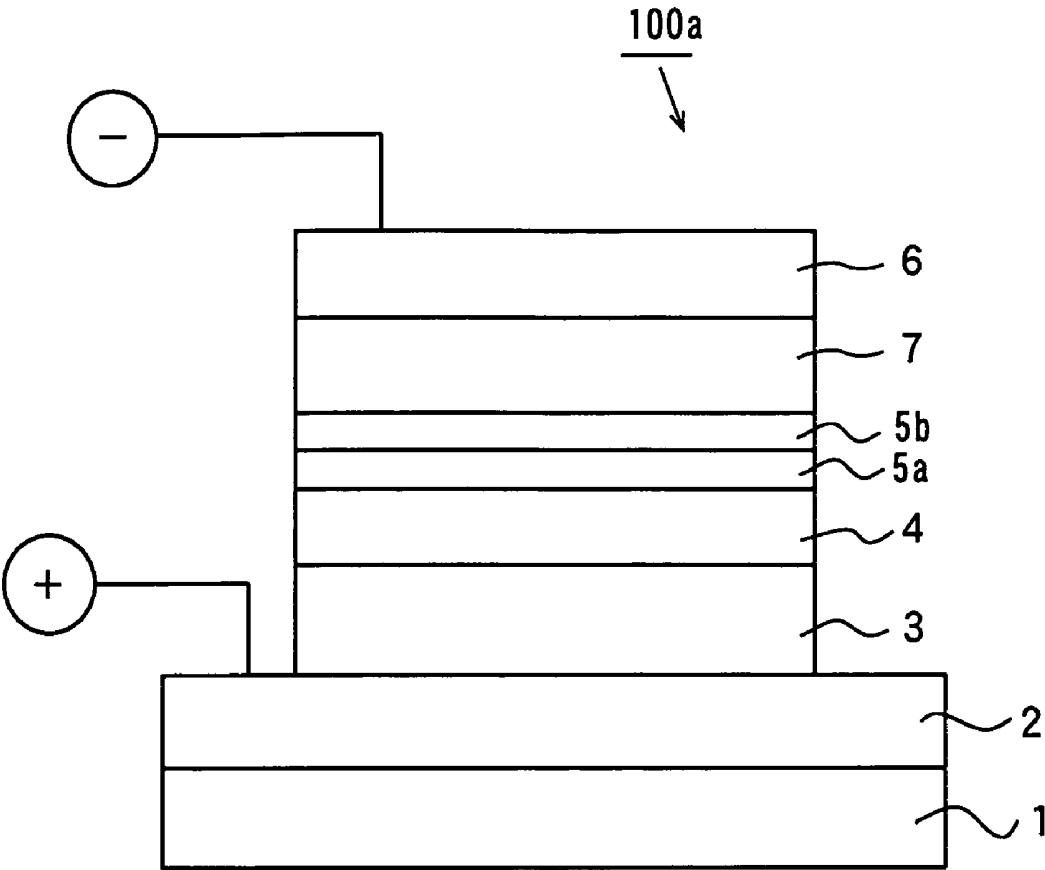
Jun. 3, 2002 (JP) 2002-161323

An organic EL device is provided which is capable of providing high luminance and high luminous efficiency. In an organic EL device, a hole injecting electrode lies on a glass substrate, and a hole injecting layer, a hole transporting layer, and a light emitting layer are sequentially formed thereon. An electron injecting electrode lies on the light emitting layer. The light emitting layer contains a host material, a light emitting dopant, and a first light-emission assisting dopant. The first light-emission assisting dopant is composed of a rubrene derivative.

F i g . 1



F i g . 2



ORGANIC ELECTROLUMINESCENCE DEVICE AND LUMINANCE MATERIAL

TECHNICAL FIELD

[0001] The present invention relates to an organic electroluminescent device and luminescent material.

BACKGROUND ART

[0002] Organic electroluminescent devices (hereinafter referred to as organic EL devices) are new self-emitting devices of great prospects. The organic EL devices have a stacked structure in which a carrier transporting layer (an electron or hole transporting layer) and a light emitting layer are sandwiched between a hole injecting electrode and an electron injecting electrode.

[0003] An electrode material having a large work function, such as gold or ITO (indium-tin oxide), is used to form the hole injecting electrode, and an electrode material having a small work function, such as Mg (magnesium) or Li (lithium), is used to form the electron injecting electrode.

[0004] The hole transporting layer, light emitting layer, and electron transporting layer are formed of organic materials. A material having p-type semiconductor properties is used to form the hole transporting layer and a material having n-type semiconductor properties is used to form the electron transporting layer. The light emitting layer is formed of a fluorescent or phosphorescent organic material which, too, has a carrier transporting property, as an electron or hole transporting property.

[0005] The hole injecting electrode, hole transporting layer, light emitting layer, electron transporting layer, and electron injecting electrode are stacked in this order to form an organic EL device.

[0006] The functional layers, i.e. the hole transporting layer, electron transporting layer, and light emitting layer, may each be composed of a plurality of layers, or may be omitted, depending on the organic materials used.

[0007] For example, Chihaya Adachi et al., Appl. Phys. Lett., Vol. 55, pp. 1489-1491 (1989) discloses a device structure that has only two organic layers, light emitting and electron transporting layers, between the hole injecting electrode and electron injecting electrode. In this device, the light emitting layer made of a luminescent material called NSD has a good hole transporting property, so that the light emitting layer can act also as a hole transporting layer.

[0008] C. W. Tang et al., Appl. Phys. Lett., Vol. 51, pp. 913-915 (1987) discloses a device structure that has two organic layers: hole transporting and light emitting layers. In this case, tris(8-hydroxyquinolino)aluminum (hereinafter referred to as Alq) in the light emitting layer performs two functions: light emitting and electron transporting functions.

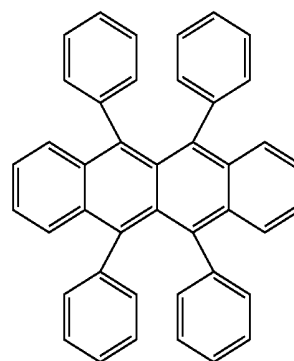
[0009] S. A. VanSlyke et al., Appl. Phys. Lett., Vol. 69, pp. 2160-2162 (1996) discloses a device structure that has three organic layers: a hole injecting layer, hole transporting layer, and light emitting layer. In this case, the hole injecting layer, made of copper phthalocyanine, serves like a hole transporting layer; thus the entire device includes two hole transporting layers.

[0010] In this way, the stacked structure of the electron transporting layer, hole transporting layer and light emitting layer can be freely designed, depending on the organic materials used.

[0011] Organic EL devices can be used to obtain visible light from blue to red, by properly selecting organic material of the light emitting layer. Therefore a full-color display can be implemented by using monochromatic organic EL devices individually emitting red, green or blue light, i.e. the three primary colors of light (RGB).

[0012] Among red, green and blue lights obtained with organic EL devices, green light and blue light are stable. On the other hand, it is difficult to obtain light with high luminance and high luminous efficiency in the range from red to orange. Therefore developing full-color displays requires red-emitting organic EL devices with good color purity, high luminous efficiency, and high luminance.

[0013] JP2000-164362, A suggests a method in which rubrene having the molecular structure represented by Formula (15) below is used as a light-emission assisting dopant. While this method offers improved red color purity, it fails to provide sufficient luminous efficiency and sufficient luminance.



RUBRENE

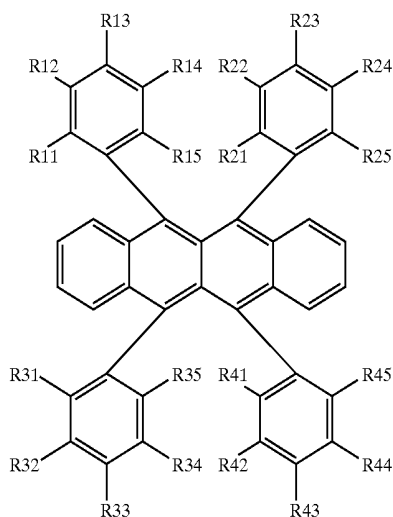
(15)

DISCLOSURE OF THE INVENTION

[0014] An object of the invention is to provide an organic EL device capable of providing high luminance and high luminous efficiency.

[0015] Another object of the invention is to provide a luminescent material capable of providing high luminance and high luminous efficiency.

[0016] According to one aspect of the invention, an organic electroluminescent device includes a hole injecting electrode, an electron injecting electrode, and a light emitting layer provided between the hole injecting electrode and the electron injecting electrode, wherein the light emitting layer contains a rubrene derivative having a molecular structure represented by Formula (1):



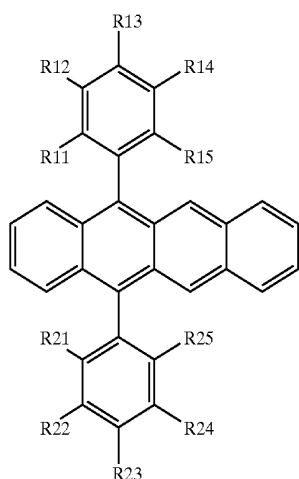
(1)

[0017] wherein R11-R15, R21-R25, R31-R35 and R41-R45 are the same or different and each represent a hydrogen atom or a substituent, where the structure in which all are hydrogen atoms is excluded. Adjacent two of R11-R15, adjacent two of R21-R25, adjacent two of R31-R35, and adjacent two of R41-R45 may be bonded together to form rings. Adjacent three of R11-R15, adjacent three of R21-R25, adjacent three of R31-R35, and adjacent three of R41-R45 may be bonded together to form rings.

[0018] Because the light emitting layer contains a rubrene derivative having a molecular structure represented by Formula (1), the organic electroluminescent device of the invention provides high luminance and high luminous efficiency.

[0019] According to another aspect of the invention, an organic electroluminescent device includes a hole injecting electrode, an electron injecting electrode, and a light emitting layer provided between the hole injecting electrode and the electron injecting electrode, wherein the light emitting layer contains a rubrene derivative having a molecular structure represented by Formula (2):

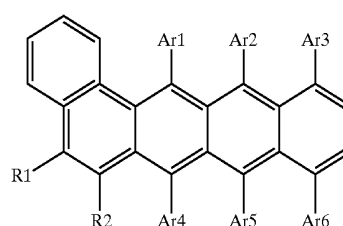
(2)



[0020] wherein R11-R15 and R21-R25 are the same or different and each represent a hydrogen atom or a substituent. Adjacent two of R11-R15 and adjacent two of R21-R25 may be bonded together to form rings. Adjacent three of R11-R15 and adjacent three of R21-R25 may be bonded together to form rings.

[0021] Because the light emitting layer contains a rubrene derivative having a molecular structure represented by Formula (2), the organic electroluminescent device of the invention provides high luminance and high luminous efficiency.

[0022] According to still another aspect of the invention, an organic electroluminescent device includes a hole injecting electrode, an electron injecting electrode, and a light emitting layer provided between the hole injecting electrode and the electron injecting electrode, wherein the light emitting layer contains a rubrene derivative having a molecular structure represented by Formula (3):

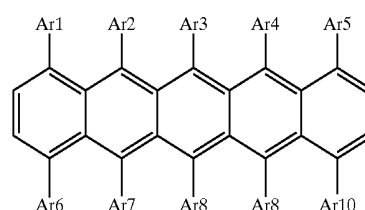


(3)

[0023] wherein Ar1-Ar6 are the same or different and each represent a hydrogen atom or a substituent. R1 and R2 are the same or different and each represent a hydrogen atom or a substituent. Adjacent R1 and R2 may be bonded together to form a ring.

[0024] Because the light emitting layer contains a rubrene derivative having a molecular structure represented by Formula (3), the organic electroluminescent device of the invention provides high luminance and high luminous efficiency.

[0025] According to a further aspect of the invention, an organic electroluminescent device includes a hole injecting electrode, an electron injecting electrode, and a light emitting layer provided between the hole injecting electrode and the electron injecting electrode, wherein the light emitting layer contains a rubrene derivative having a molecular structure represented by Formula (4):

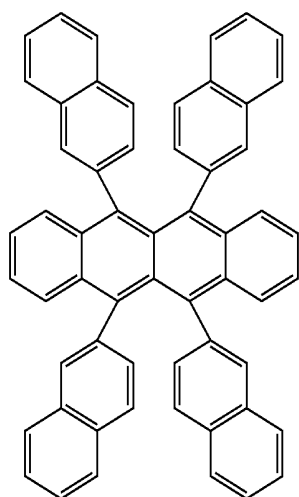


(4)

[0026] wherein Ar1-Ar10 are the same or different and each represent a hydrogen atom or a substituent.

[0027] Because the light emitting layer contains a rubrene derivative having a molecular structure represented by Formula (4), the organic electroluminescent device of the invention provides high luminance and high luminous efficiency.

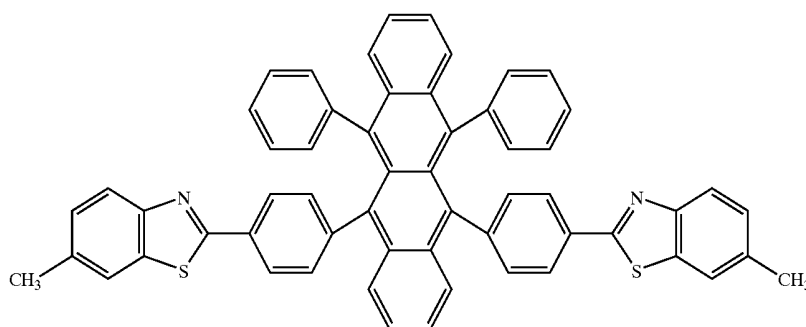
[0028] The rubrene derivative may be 5,6,11,12-tetrakis(naphth-2-yl)-naphthacene having a molecular structure represented by Formula (A1):



(A1)

[0029] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

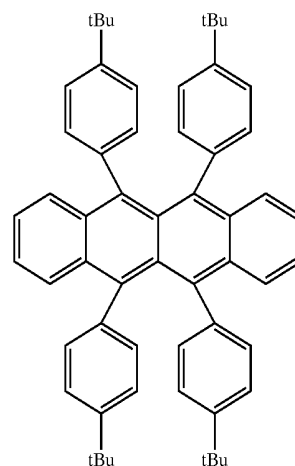
[0030] The rubrene derivative may be 5,12-bis(4-(6-methylbenzothiazole-2-yl)phenyl)-6,11-diphenylnaphthacene represented by Formula (A2):



(A2)

[0031] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

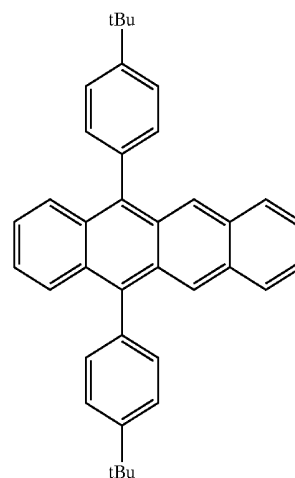
[0032] The rubrene derivative may be 5,6,11,12-tetrakis(4-tert-butylphenyl)-naphthacene represented by Formula (A3):



(A3)

[0033] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

[0034] The rubrene derivative may be 5,12-bis(4-tert-butylphenyl)-naphthacene represented by Formula (A4):

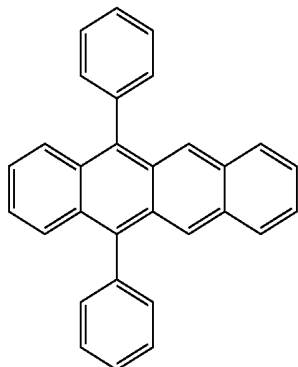


(A4)

[0035] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

[0036] The rubrene derivative may be 5,12-diphenylnaphthacene represented by Formula (A5):

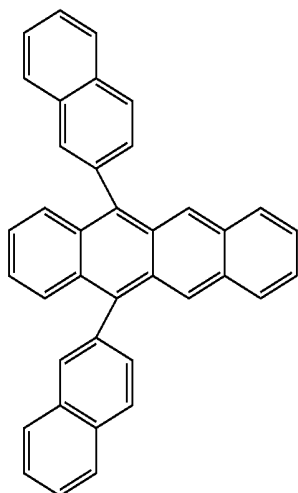
(A5)



[0037] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

[0038] The rubrene derivative may be 5,12-bis(naphth-2-yl)naphthacene represented by Formula (A6):

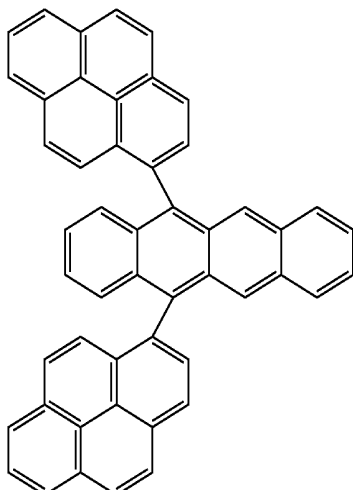
(A6)



[0039] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

[0040] The rubrene derivative may be 5,12-bis(pyrene-1-yl)naphthacene represented by Formula (A7):

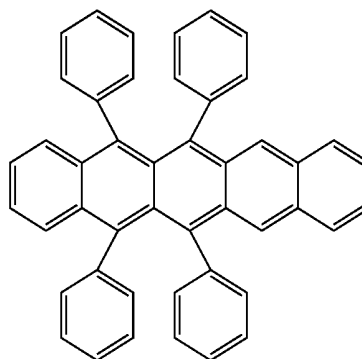
(A7)



[0041] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

[0042] The rubrene derivative may be 5,6,13,14-tetrakisphenyl-pentacene represented by Formula (A8):

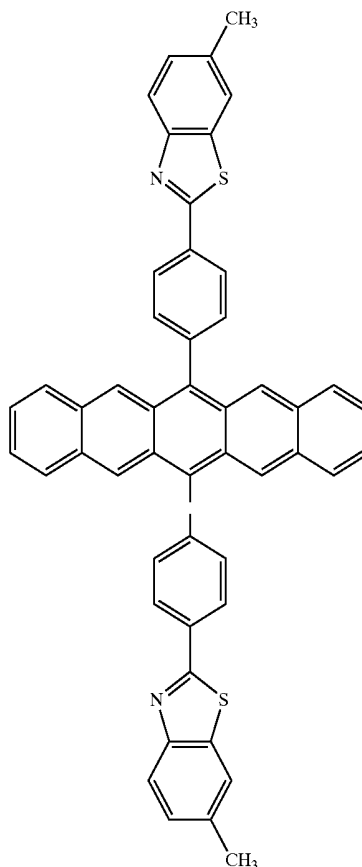
(A8)



[0043] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

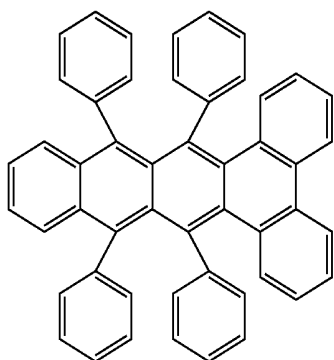
[0044] The rubrene derivative may be 6,13-bis(4-(6-methylbenzothiazole-2-yl)phenyl)-pentacene represented by Formula (A9):

(A9)



[0045] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

[0046] The rubrene derivative may be 5,6,11,12-tetrakisphenyl-1,2-benzo-(3,4-benzo-)naphthacene represented by Formula (A10):



(A10)

[0047] This enables higher luminance and higher luminous efficiency than when the light emitting layer contains rubrene.

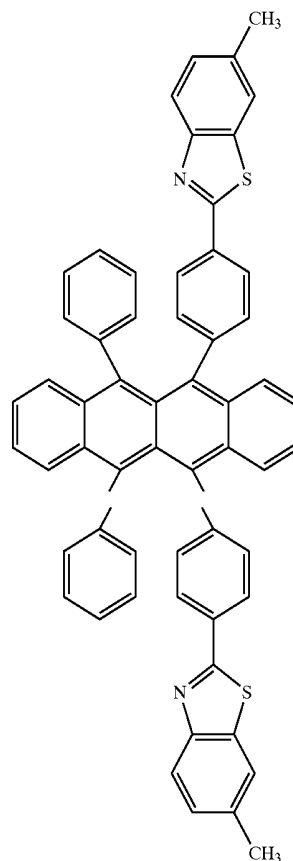
[0048] The light emitting layer may contain a host material, a light emitting dopant, and a first light-emission assisting dopant, with the first light-emission assisting dopant being composed of a rubrene derivative. The first light-emission assisting dopant serves to transfer excitation energy to the light emitting dopant. Using any of the rubrene derivatives shown above as the first light-emission assisting dopant enhances the luminance and luminous efficiency.

[0049] The light emitting layer may further contain a second light-emission assisting dopant. The second light-emission assisting dopant serves to adjust the balance of carriers flowing in the light emitting layer. Using the second light-emission assisting dopant further enhances the luminance and luminous efficiency.

[0050] The light emitting layer may contain a host material and a light emitting dopant, with the light emitting dopant being composed of a rubrene derivative. Using any of the rubrene derivatives shown above as the light emitting dopant enhances the luminance and luminous efficiency.

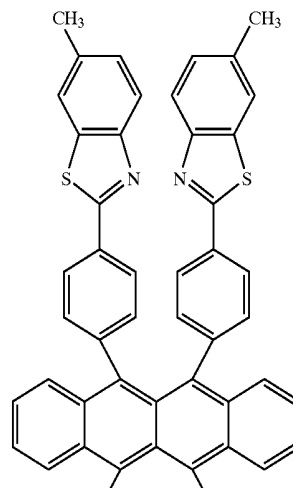
[0051] The content of the light emitting dopant may be not less than 0.1 percent by weight nor more than 50 percent by weight, with respect to the host material. This causes the light emitting dopant to act not as a host but as a dopant.

[0052] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C1) and a second light emitting layer that contains a luminescent material that emits blue light.

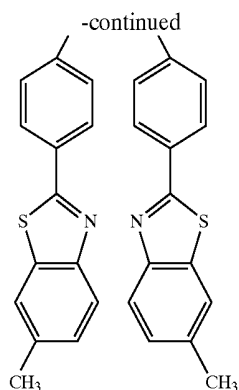


(C1)

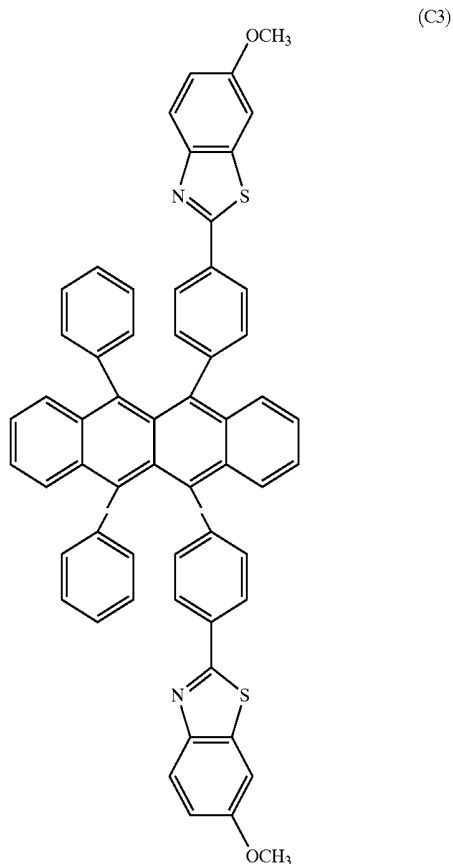
[0053] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C2) and a second light emitting layer that contains a luminescent material that emits blue light.



(C2)

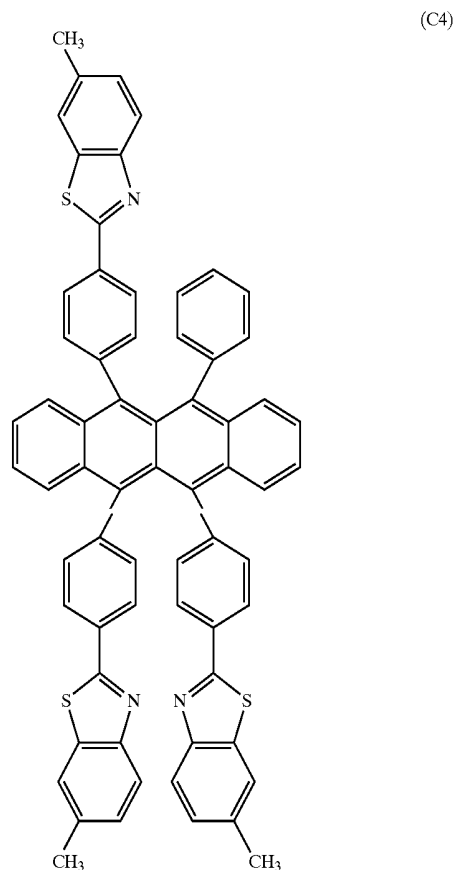


[0054] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C3) and a second light emitting layer that contains a luminescent material that emits blue light.

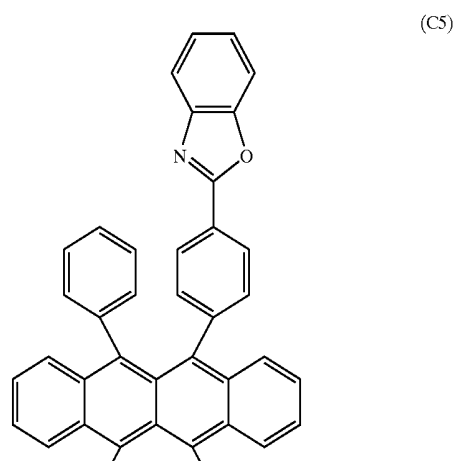


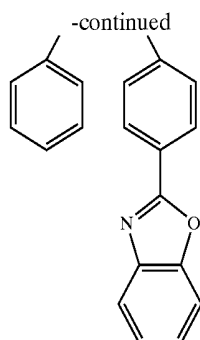
[0055] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C4)

and a second light emitting layer that contains a luminescent material that emits blue light.

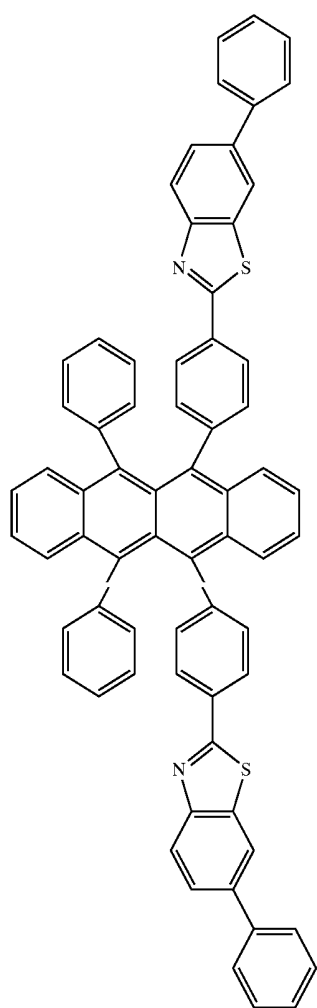


[0056] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C5) and a second light emitting layer that contains a luminescent material that emits blue light.





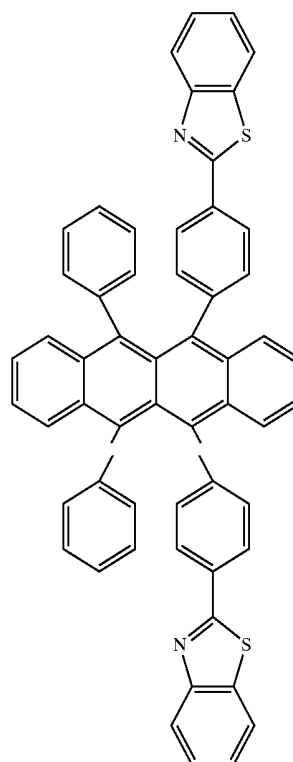
[0057] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C6) and a second light emitting layer that contains a luminescent material that emits blue light.



(C6)

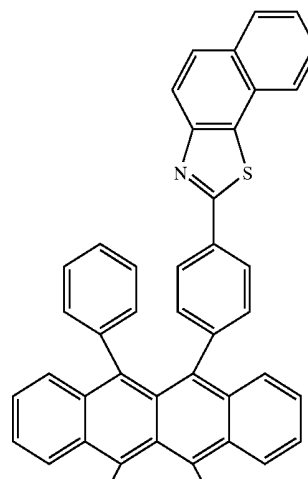
[0058] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may

include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C7) and a second light emitting layer that contains a luminescent material that emits blue light.

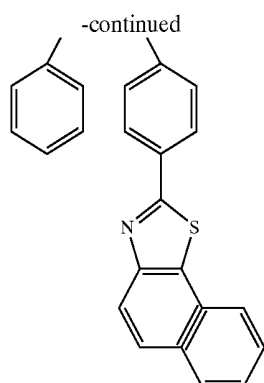


(C7)

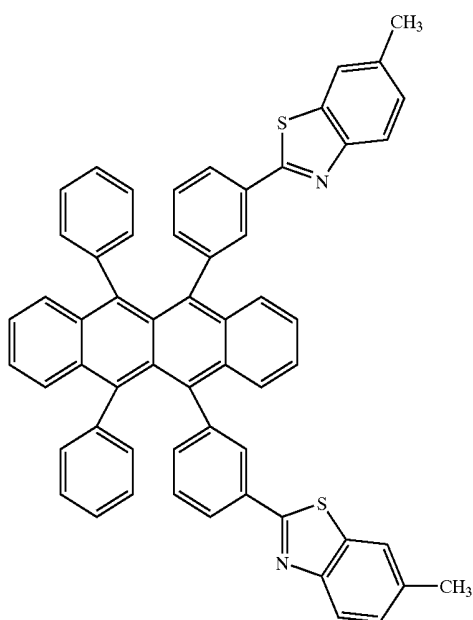
[0059] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C8) and a second light emitting layer that contains a luminescent material that emits blue light.



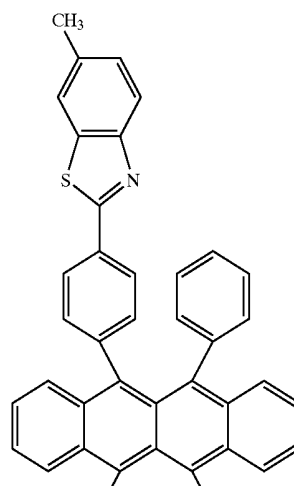
(C8)



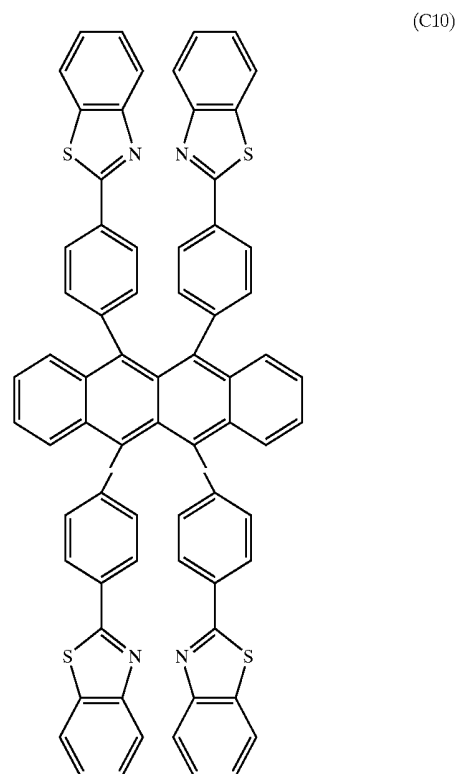
[0060] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C9) and a second light emitting layer that contains a luminescent material that emits blue light.

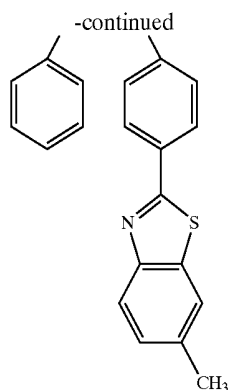


[0062] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C11) and a second light emitting layer that contains a luminescent material that emits blue light.

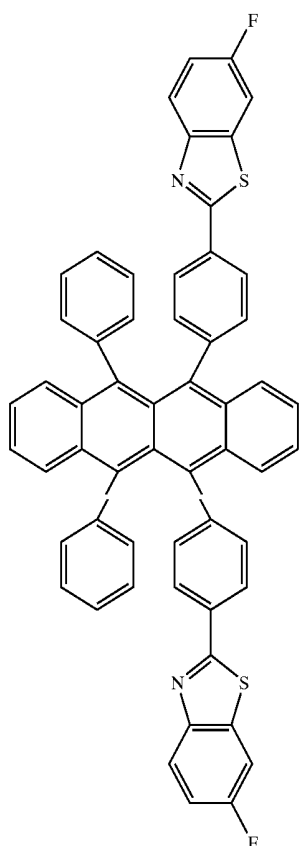


[0061] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C10) and a second light emitting layer that contains a luminescent material that emits blue light.





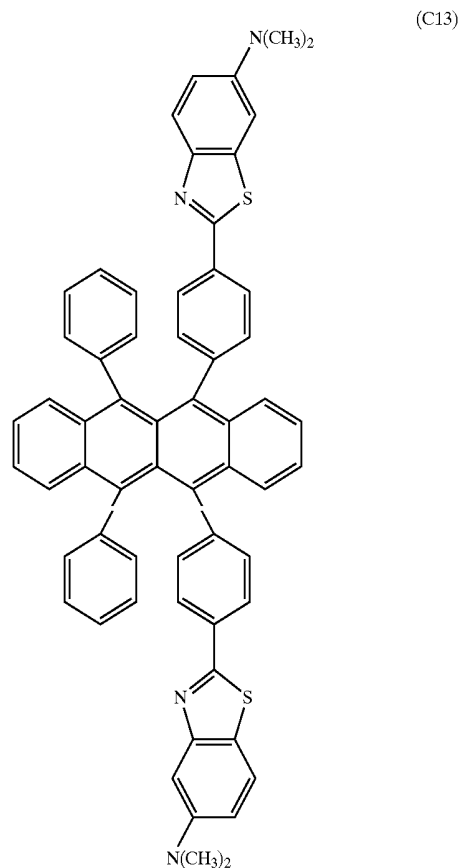
[0063] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C12) and a second light emitting layer that contains a luminescent material that emits blue light.



(C12)

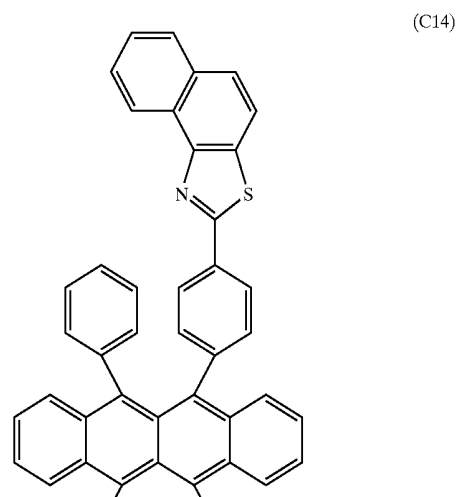
[0064] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C13)

and a second light emitting layer that contains a luminescent material that emits blue light.

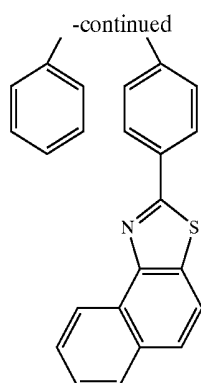


(C13)

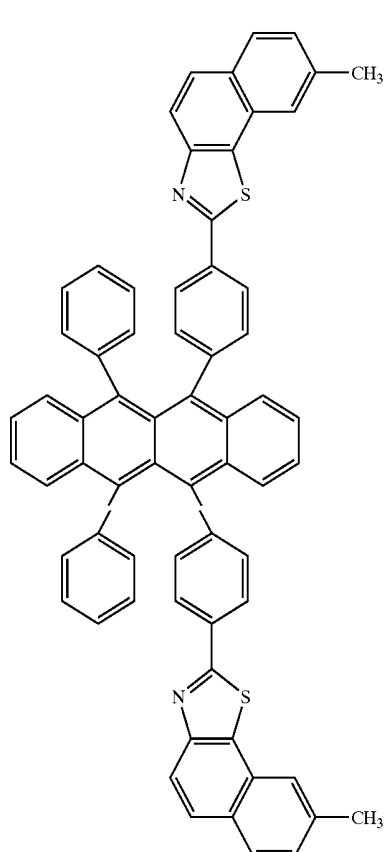
[0065] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C14) and a second light emitting layer that contains a luminescent material that emits blue light.



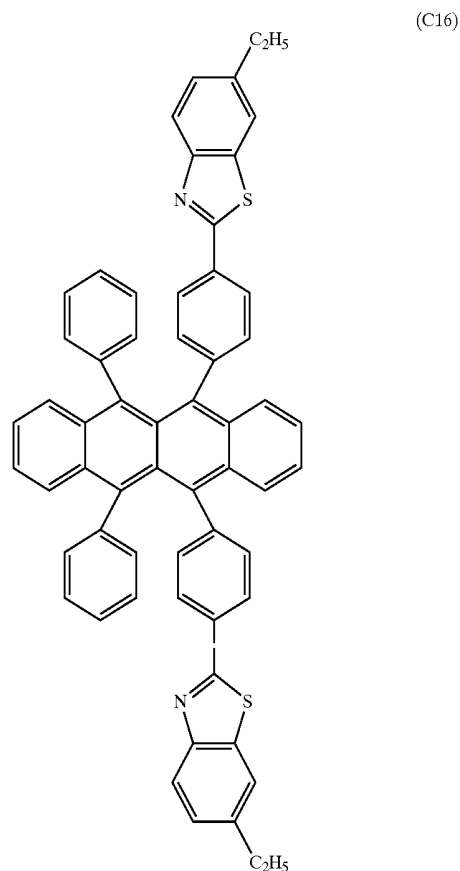
(C14)



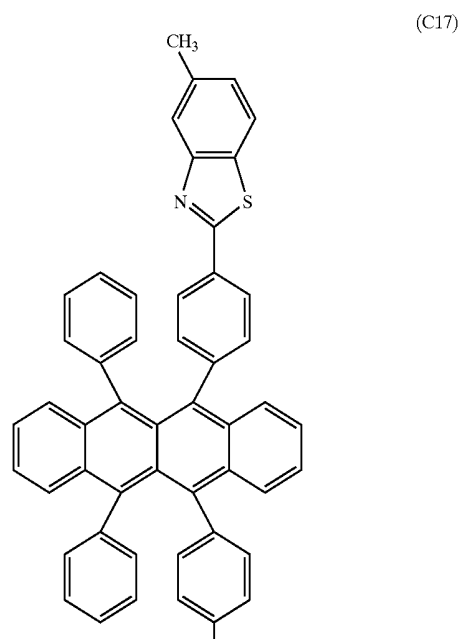
[0066] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C15) and a second light emitting layer that contains a luminescent material that emits blue light.



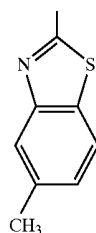
[0067] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C16) and a second light emitting layer that contains a luminescent material that emits blue light.



[0068] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C17) and a second light emitting layer that contains a luminescent material that emits blue light.

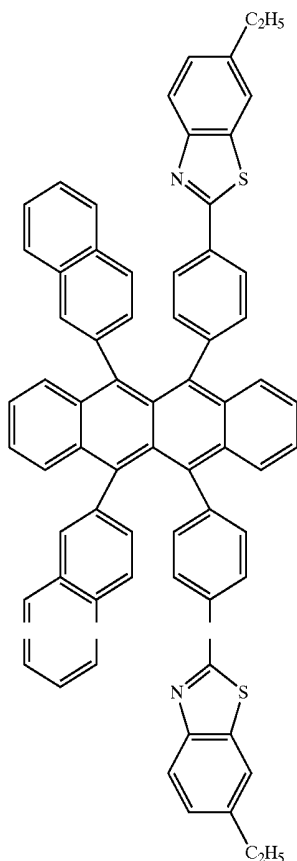


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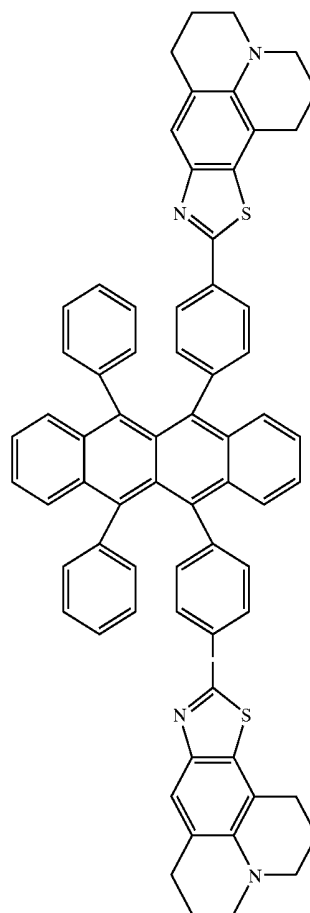
[0069] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C18) and a second light emitting layer that contains a luminescent material that emits blue light.

(C18)



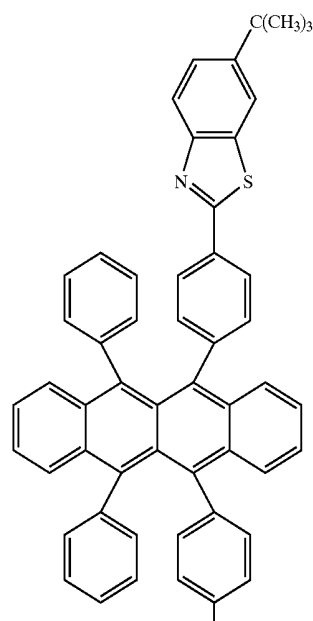
[0070] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C19) and a second light emitting layer that contains a luminescent material that emits blue light.

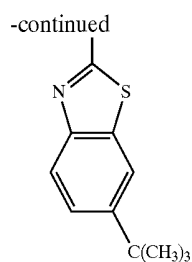
(C19)



[0071] In an organic electroluminescent device having a light emitting layer between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains a compound having a molecular structure represented by Formula (C20) and a second light emitting layer that contains a luminescent material that emits blue light.

(C20)



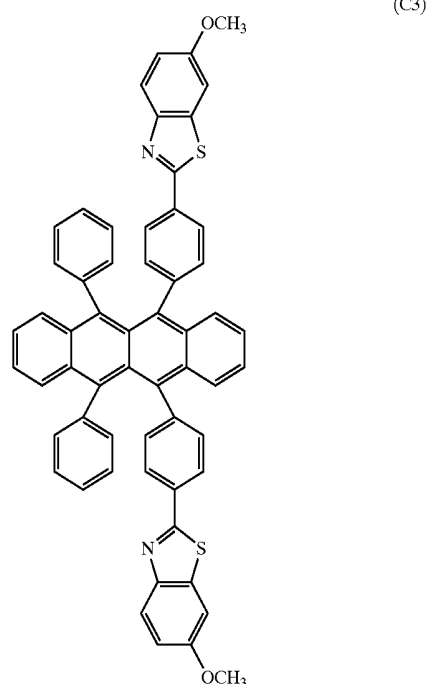
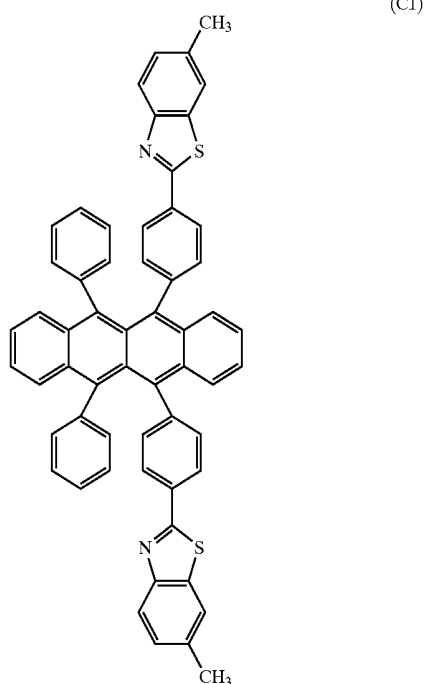
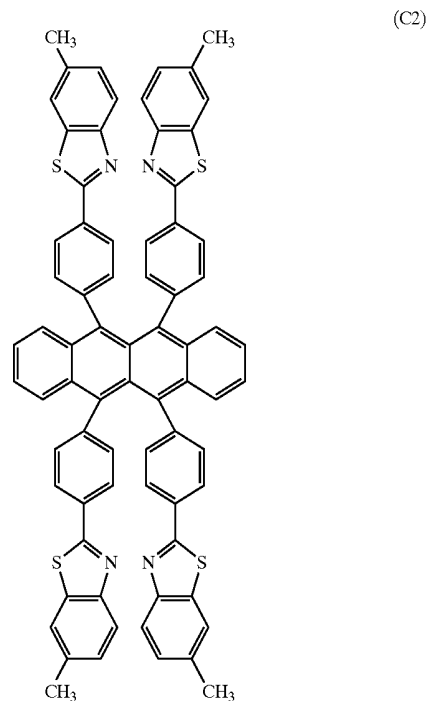


[0072] The luminescent materials having the molecular structures represented by Formulas (C1)-(C20) are capable of emitting orange or yellow light with high luminance and high luminous efficiency, and so the first light emitting layer emits orange or yellow light and the second light emitting layer emits blue light. Then, because of the complementary relation between orange or yellow and blue, the organic electroluminescent device is capable of emitting white light.

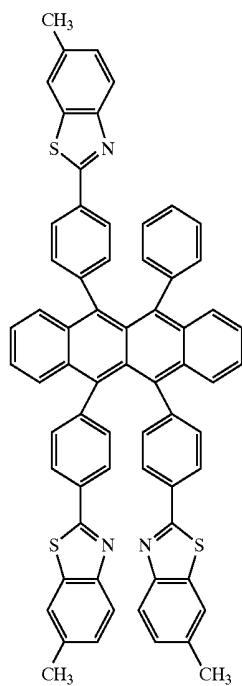
[0073] Preferably, the second light emitting layer contains an anthracene derivative as a host material and a perylene derivative as a light emitting dopant. This allows the second light emitting layer to efficiently emit blue light.

[0074] In an organic electroluminescent device having a light emitting layer provided between a hole injecting electrode and an electron injecting electrode, the light emitting layer may include a first light emitting layer that contains at least one compound selected from the group consisting of compounds having molecular structures represented by Formulas (C1)-(C20) and at least one compound selected from the group consisting of compounds represented by Formulas (A4)-(A7), (A10), and (C21)-(C27), and a second light emitting layer that contains a luminescent material that emits blue light.

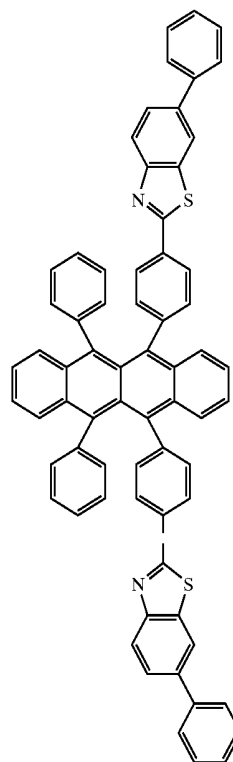
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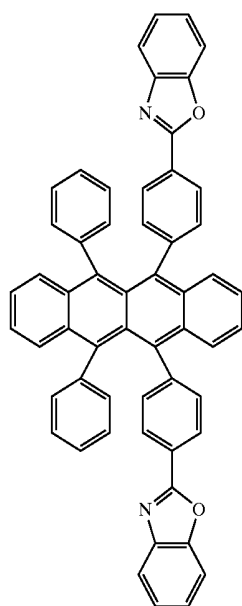
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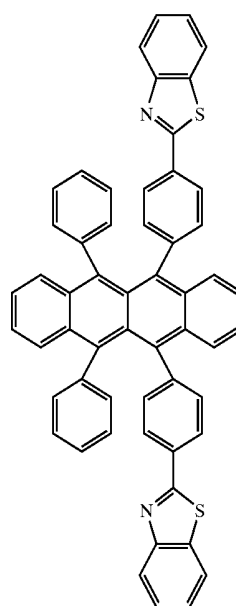
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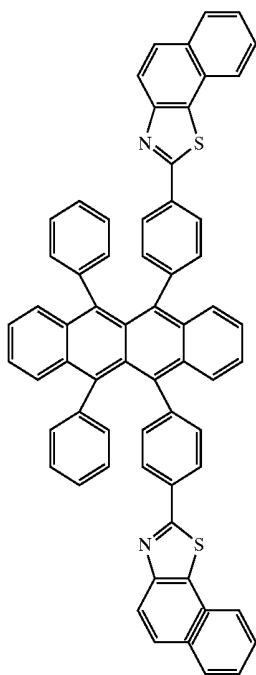
(C5)



(C7)

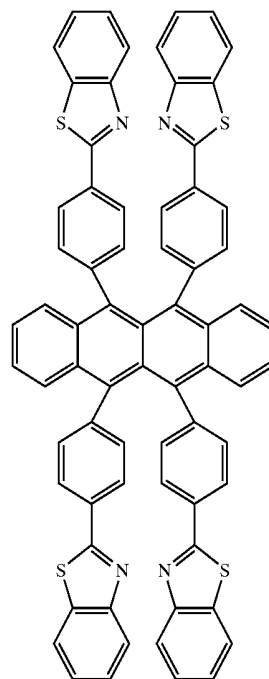


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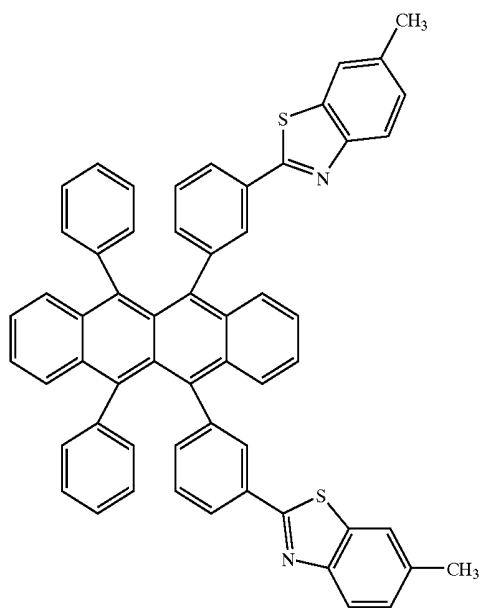


(C8)

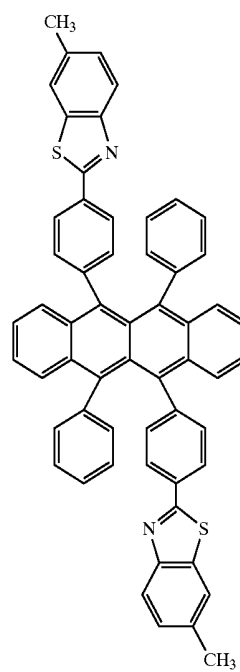
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(C10)

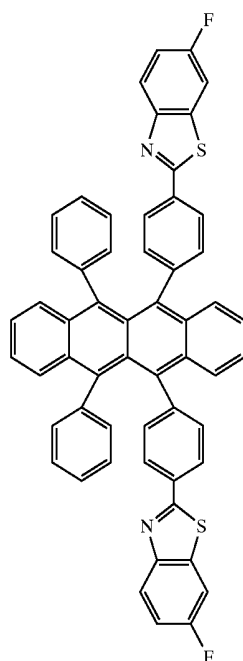


(C9)



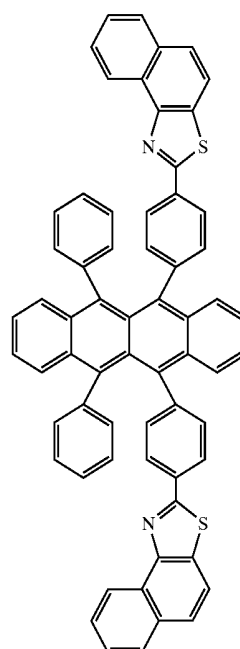
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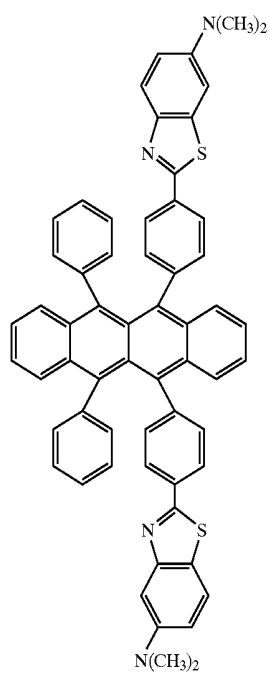
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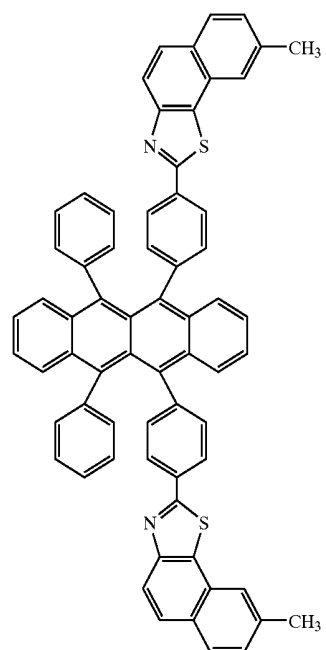


(C14)

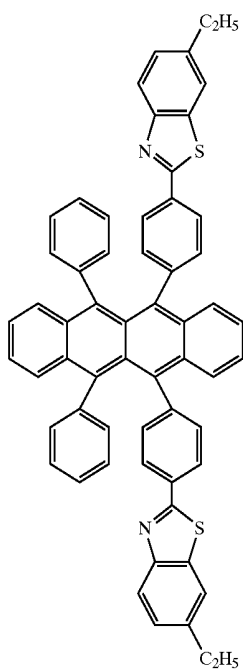
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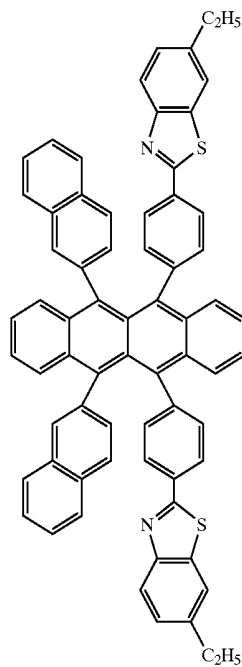
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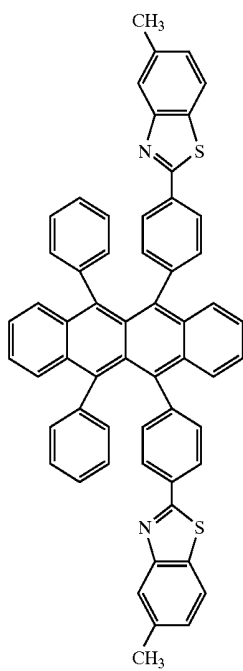
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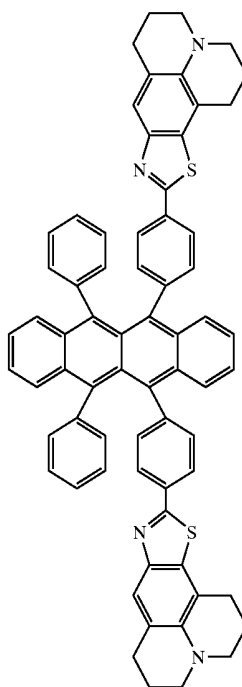
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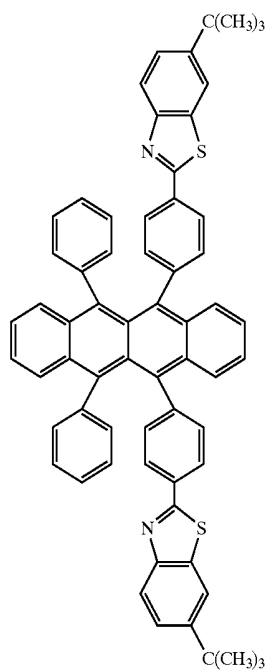
(C17)



(C19)

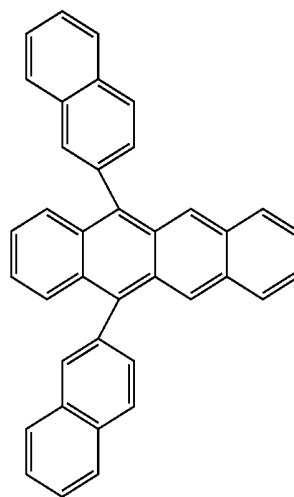


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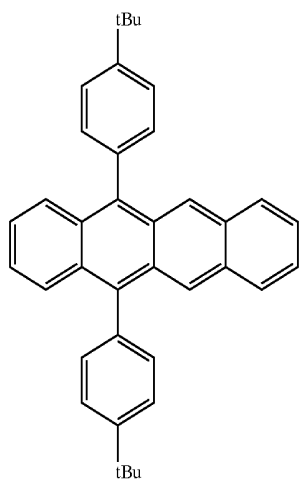


(C20)

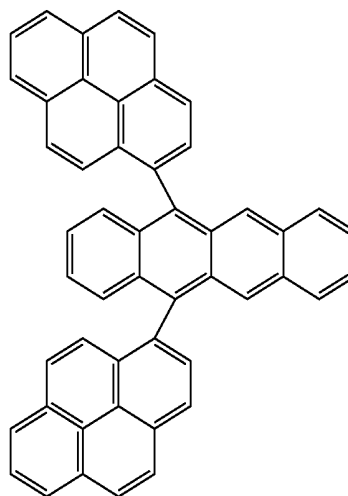
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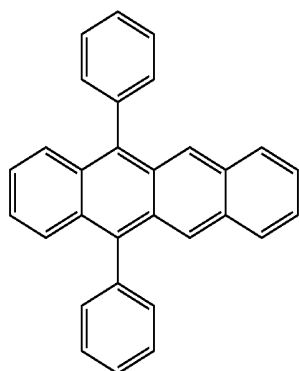
(A6)



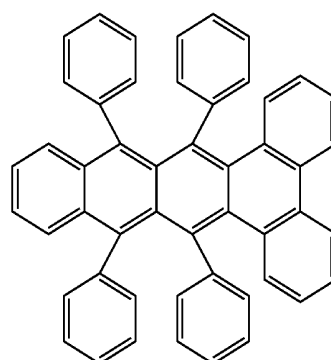
(A4)



(A7)



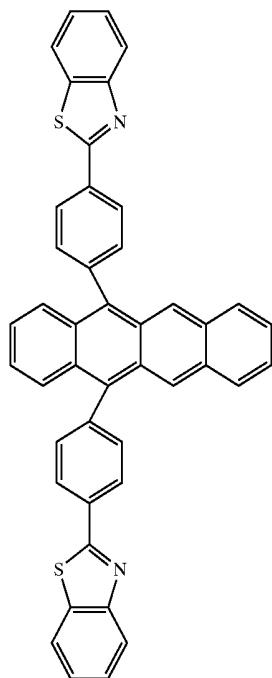
(A5)



(A10)

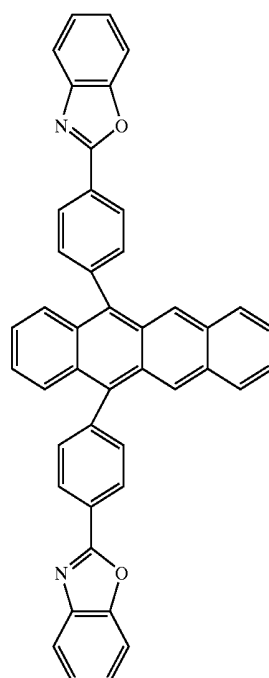
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(C21)

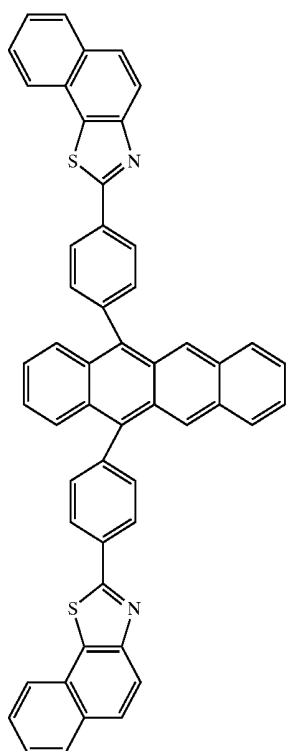


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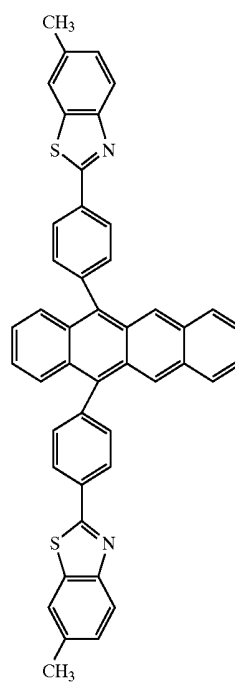
(C23)



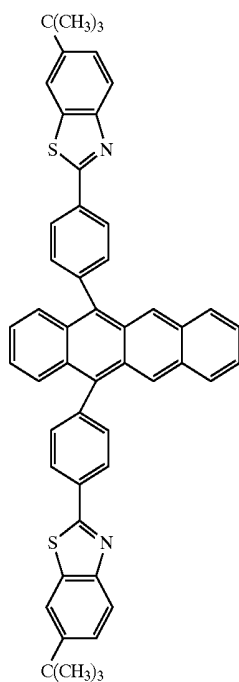
(C22)



(C24)

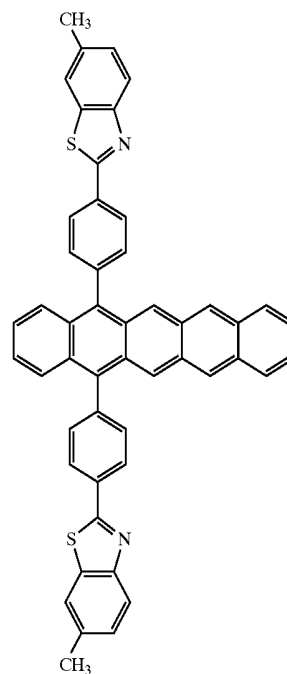


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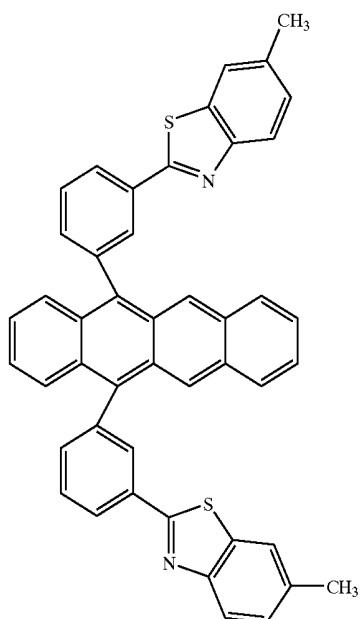
(C27)



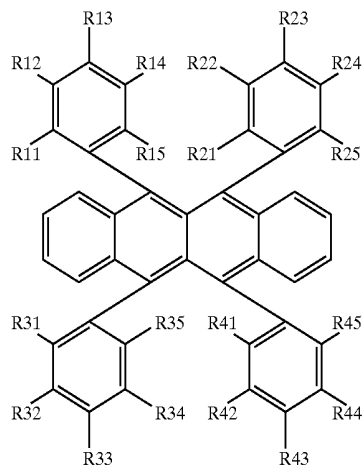
[0075] The compounds having the molecular structures represented by Formulas (C1)-(C20) are capable of emitting orange light and the luminescent materials having the molecular structures represented by Formulas (A4)-(A7), (A10) and (C21)-(C27) are capable of emitting green light. Thus, when the first light emitting layer contains an orange-emitting luminescent material and a green-emitting luminescent material and the second light emitting layer contains a blue-emitting luminescent material, it is possible to obtain high luminous efficiency and white light emission with high color purity.

(C26)

[0076] According to still another aspect of the invention, a luminescent material has a molecular structure represented by Formula (1):

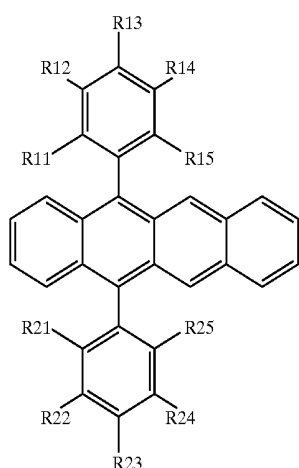


(1)



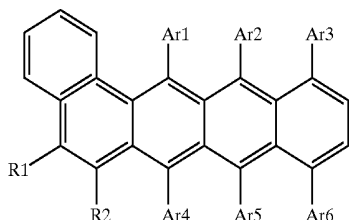
[0077] wherein R11-R15, R21-R25, R31-R35 and R41-R45 are the same or different and each represent a hydrogen atom or a substituent, where the structure in which all are hydrogen atoms is excluded. Adjacent two of R11-R15, adjacent two of R21-R25, adjacent two of R31-R35, and adjacent two of R41-R45 may be bonded together to form rings. Adjacent three of R11-R15, adjacent three of R21-R25, adjacent three of R31-R35, and adjacent three of R41-R45 may be bonded together to form rings.

[0078] According to a further aspect of the invention, a luminescent material has a molecular structure represented by Formula (2):



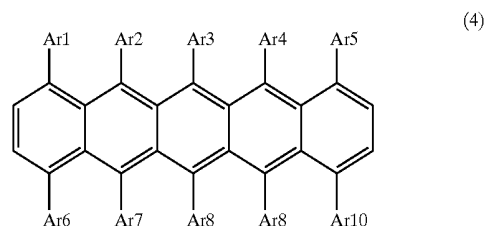
[0079] wherein R11-R15 and R21-R25 are the same or different and each represent a hydrogen atom or a substituent. Adjacent two of R11-R15 and adjacent two of R21-R25 may be bonded together to form rings. Adjacent three of R11-R15 and adjacent three of R21-R25 may be bonded together to form rings.

[0080] According to a further aspect of the invention, a luminescent material has a molecular structure represented by Formula (3):



[0081] wherein Ar1-Ar6 are the same or different and each represent a hydrogen atom or a substituent. R1 and R2 are the same or different and each represent a hydrogen atom or a substituent. Adjacent R1 and R2 may be bonded together to form a ring.

[0082] According to a further aspect of the invention, a luminescent material has a molecular structure represented by Formula (4):



[0083] wherein Ar1-Ar10 are the same or different and each represent a hydrogen atom or a substituent.

BRIEF DESCRIPTION OF THE DRAWINGS

[0084] FIG. 1 is a schematic diagram showing the structure of an organic EL device according to an embodiment of the invention; and

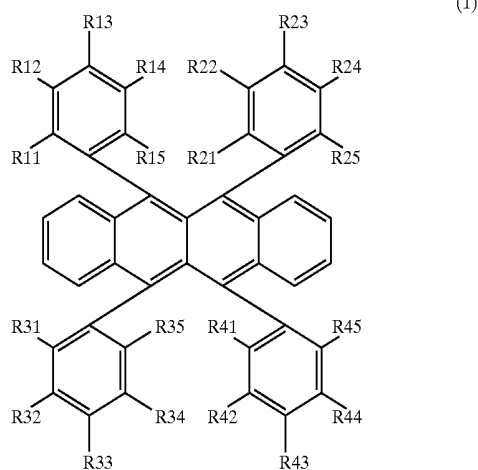
[0085] FIG. 2 is a schematic diagram showing the structure of an organic EL device according to another embodiment of the invention.

BEST MODE FOR CARRYING OUT THE INVENTION

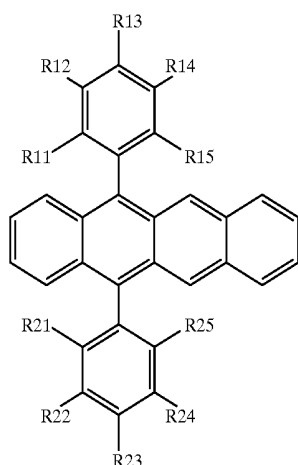
[0086] FIG. 1 is a schematic diagram showing the structure of an organic electroluminescent device (hereinafter referred to as an organic EL device) according to an embodiment of the invention.

[0087] As shown in FIG. 1, in the organic EL device 100, a hole injecting electrode (anode) 2, made of a transparent electrode film, resides on a glass substrate 1. On the hole injecting electrode 2, a hole injecting layer 3 made of an organic material, a hole transporting layer 4 of an organic material, and a light emitting layer 5 of an organic material are formed in sequence. An electron injecting electrode (cathode) 6 lies on the light emitting layer 5. In place of the hole transporting layer 4, an electron transporting layer may be provided between the light emitting layer 5 and the electron injecting electrode 6.

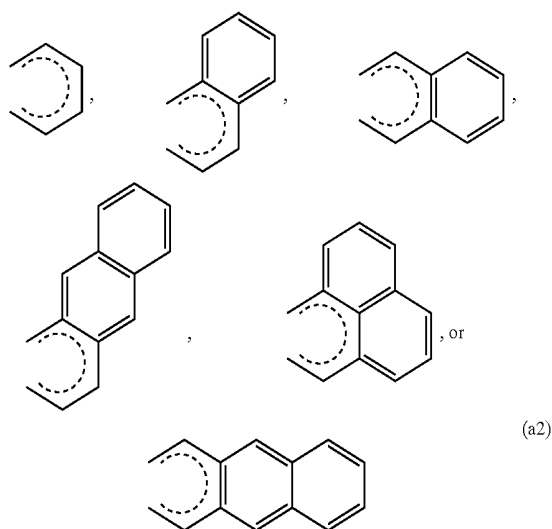
[0088] It is preferred that the light emitting layer 5 contain a rubrene derivative having a molecular structure represented by Formula (1) below, or a rubrene derivative having a molecular structure represented by Formula (2) below.



-continued



(2)

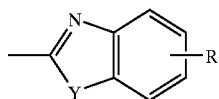


(a2)

[0089] In Formulas (1) and (2), R11-R15, R21-R25, R31-R35 and R41-R45 are the same or different and each represent a hydrogen atom or a substituent, excepting for structures in which all are hydrogen atoms. Adjacent two of R11-R15, adjacent two of R21-R25, adjacent two of R31-R35, and adjacent two of R41-R45 may be bonded together to form rings. Adjacent three of R11-R15, adjacent three of R21-R25, adjacent three of R31-R35, and adjacent three of R41-R45 may be bonded together to form rings.

[0090] In Formula (2), R11-R15 and R21-R25 are the same or different and each represent a hydrogen atom or a substituent. Adjacent two of R11-R15 and adjacent two of R21-R25 may be bonded together to form rings. Adjacent three of R11-R15 and adjacent three of R21-R25 may be bonded together to form rings.

[0091] For example, in Formulas (1) and (2), R11-R15, R21-R25, R31-R35 and R41-R45 are —H, —C_nH_{2n+1} (n=1-10), —OC_nH_{2n+1} (n=1-10), —N(C_nH_{2n+1})₂ (n=1-10), —X (X=F, Cl, Br, or I), —CN, or substituents represented by Formula (a1) below.

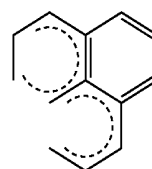


(a1)

[0092] Note that the structure in which R11-R15, R21-R25, R31-R35, R41-R45 in Formula (1) are all —H is excluded. In Formula (a1), Y is O or S, for example, and R' is —H, —C_nH_{2n+1} (n=1-10), —OC_nH_{2n+1} (n=1-10), —N(C_nH_{2n+1})₂ (n=1-10), —X (X=F, Cl, Br, or I), —CN, or a phenyl group, for example.

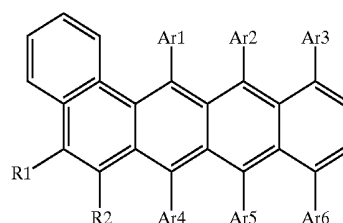
[0093] In Formulas (1) and (2), adjacent two of R11-R15, adjacent two of R21-R25, adjacent two of R31-R35, and adjacent two of R41-R45 may be bonded together to form any of the ring structures represented by Formula (a2) below.

[0094] In Formulas (1) and (2), adjacent three of R11-R15, adjacent three of R21-R25, adjacent three of R31-R35, and adjacent three of R41-R45 may be bonded together to form the ring structure represented by Formula (a3) below.

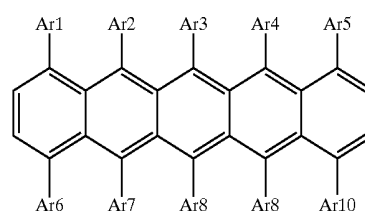


(a3)

[0095] Alternatively, the light emitting layer 5 preferably contains a rubrene derivative having a molecular structure represented by Formula (3) below, or a rubrene derivative having a molecular structure represented by Formula (4) below.



(3)

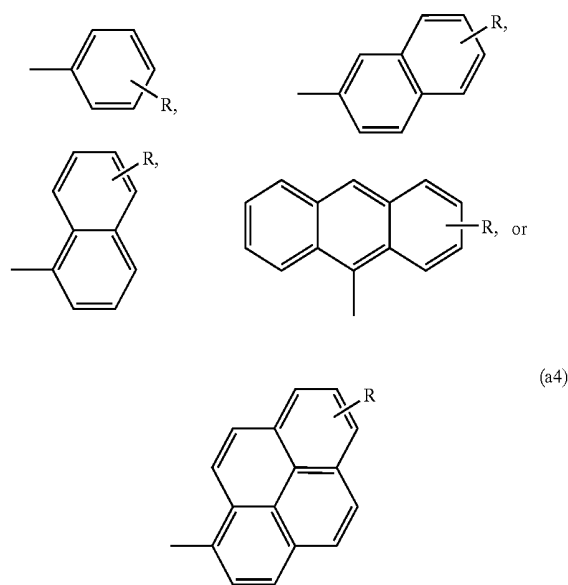


(4)

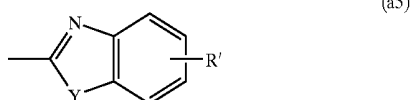
[0096] In Formulas (3) and (4), Ar1-Ar10 are the same or different and each represent a hydrogen atom or a substituent.

ent. In Formula (3), R1 and R2 are the same or different and each represent a hydrogen atom or a substituent. In Formula (3), adjacent R1 and R2 may be bonded together to form a ring.

[0097] For example, in Formula (3), Ar1-Ar6 are —H, —C_nH_{2n+1} (n=1-10), —OC_nH_{2n+1} (n=1-10), —N(C_nH_{2n+1})₂ (n=1-10), —X (X=F, Cl, Br, or I), —CN, or any of substituents represented by Formula (a4).

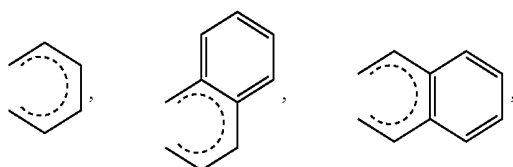


[0098] In Formula (a4), R is, for example, $-H$, $-C_nH_{2n+1}$ ($n=1-10$), $-OC_nH_{2n+1}$ ($n=1-10$), $-N(C_nH_{2n+1})_2$ ($n=1-10$), $-X$ ($X=F, Cl, Br, or I$), $-CN$, a phenyl group, or a substituent represented by Formula (a5).

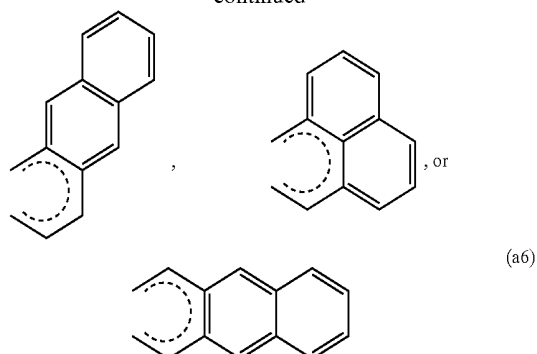


[0099] In Formula (a5), Y is O or S, for example, and R' is —H, —C_nH_{2n+1} (n=1-10), —OC_nH_{2n+1} (n=1-10), —N(C_nH_{2n+1})₂ (n=1-10), —X (X=F, Cl, Br, or I), —CN, or a phenyl group, for example.

[0100] In Formula (3), adjacent R1 and R2 may be bonded together to form any of the ring structures represented by Formula (a6) below.



-continued



[0101] In a first example, the light emitting layer **5** contains a host material, a light emitting dopant, and a first light-emission assisting dopant, where the first light-emission assisting dopant is composed of any of the rubrene derivatives shown above. The first light-emission assisting dopant serves to transfer excitation energy to the light emitting dopant. Using the rubrene derivatives shown above as the first light-emission assisting dopant enhances the luminance and luminous efficiency.

[0102] In a second example, the light emitting layer 5 contains a host material, a light emitting dopant, a first light-emission assisting dopant, and a second light-emission assisting dopant, where the first light-emission assisting dopant is composed of any of the rubrene derivatives shown above. The second light-emission assisting dopant serves to adjust the balance of carriers that flow in the light emitting layer. Further adding the second light-emission assisting dopant enhances the luminance and luminous efficiency.

[0103] The first and second light-emission assisting dopants do not emit light themselves.

[0104] In a third example, the light emitting layer 5 contains a host material and a light emitting dopant, where the light emitting dopant is composed of any of the rubrene derivatives shown above. Using the rubrene derivatives shown above as the light emitting dopant enhances the luminance and luminous efficiency.

[0105] In the cases above, the content of the light emitting dopant is from 0.1 to 50 percent by weight, preferably from 1 to 10 percent by weight, with respect to the host material.

[0106] In the organic EL device **100**, a voltage is applied between the hole injecting electrode **2** and the electron injecting electrode **6** to cause the light emitting layer **5** in the organic EL device **100** to emit light, which is emitted from the back of the glass substrate **1**.

[0107] Compounds represented by Formulas (1) to (4) can be prepared by conventional methods. For example, they can be obtained by coupling reactions, in the presence of transition metal compounds (e.g. palladium compounds), between condensed polycyclic hydrocarbons (e.g. naphthalene, pentacene, benz[a]naphthalene, dibenz[a,c]naphthalene, etc.) that have leaving groups (e.g. halogen atoms) at certain positions and that have adjacent benzene rings ortho-condensed, and compounds corresponding to substituents of the condensed polycyclic hydrocarbons (benzene

compounds having R11-R45, compounds corresponding to Ar1-Ar10). Further, the reactions may be caused in a presence of bases (e.g. sodium hydroxide). The reactions can usually be carried out using an inert solvent in an inert gas atmosphere at about 30 to 120° C.

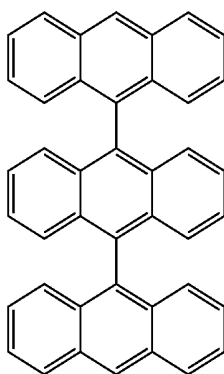
[0108] FIG. 2 is a schematic diagram showing the structure of an organic EL device according to another embodiment of the invention.

[0109] As shown in FIG. 2, in the organic EL device 100a, a hole injecting electrode (anode) 2, made of a transparent electrode film, resides on a glass substrate 1. On the hole injecting electrode 2, a hole injecting layer 3 made of an organic material, a hole transporting layer 4 of an organic material, a first light emitting layer 5a of an organic material, a second light emitting layer 5b, and an electron transporting layer 7 are formed in sequence. An electron injecting electrode (cathode) 6 lies on the electron transporting layer 7.

[0110] The first light emitting layer 5a contains a rubrene derivative that emits orange or yellow light, among rubrene derivatives having molecular structures represented by Formula (1) shown above, rubrene derivatives having molecular structures represented by Formula (2) above, rubrene derivatives having molecular structures represented by Formula (3) above, or among rubrene derivatives having molecular structures represented by Formula (4) above.

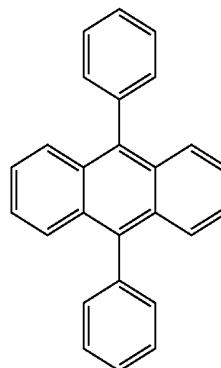
[0111] The second light emitting layer 5b contains a luminescent material that emits blue light. For example, the second light emitting layer 5b contains an anthracene derivative as a host material and contains a perylene derivative as a light emitting dopant.

[0112] For example, dianthranthracene having the molecular structure of Formula (B1) can be used as an anthracene derivative.



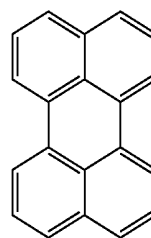
(B1)

[0113] Also, as an anthracene derivative, diphenylanthracene having the molecular structure of Formula (B2) may be used.



(B2)

[0114] As for a perylene derivative, perylene having the molecular structure of Formula (B3) can be used. (B 3)



(B3)

[0115] In the organic EL device 100a of this embodiment, the first light emitting layer 5a emits orange or yellow light and the second light emitting layer 5b emits blue light. Thus, the organic EL device 100a can emit white light, because of complementary relation between orange or yellow and blue.

[0116] The first light emitting layer 5a may be doped with light emitting dopants of two kinds: an orange-emitting rubrene derivative (for example, any of the rubrene derivatives represented by Formulas (C1) to (C20) shown later) and a green-emitting rubrene derivative (for example, any of the rubrene derivatives represented by Formulas (A4) to (A7), (A10) and (C21) to (C27) shown later). This enhances luminous efficiency of white, and also enhances color purity of white since the half bandwidth of the spectrum increases.

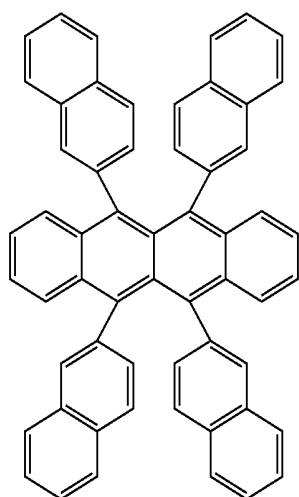
EXAMPLES

[0117] (1) First, organic EL devices of Examples 1 to 33 and Examples for Comparison, 1 to 5, were constructed and luminescence characteristics of these devices were measured.

[0118] Organic EL devices of Examples 1-10 and Comparative Example 1 have Device Structure A, organic EL devices of Examples 11-22 and Comparative Example 2 have Device Structure B, organic EL devices of Examples 23-28 and Comparative Examples 3-5 have Device Structure C, and organic EL devices of Examples 29-33 have Device Structure D.

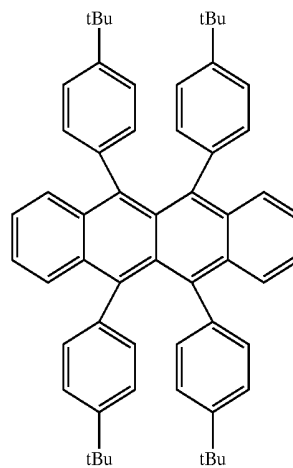
[0119] In particular, rubrene derivatives having the molecular structures of Formulas (A1)-(A10) below were used as materials of the light emitting layer.

[0120] 5,6,11,12-tetrakis(naphth-2-yl)-naphthacene (hereinafter referred to as TNN):



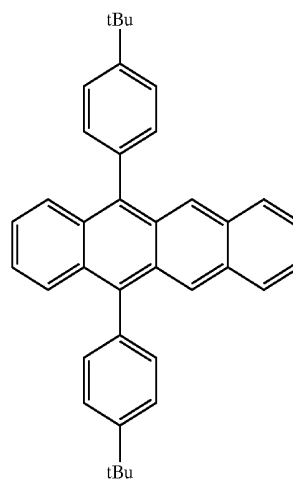
TNN

[0122] 5,6,11,12-tetrakis(4-tert-butylphenyl)-naphthacene (hereinafter referred to as TtBuPN):



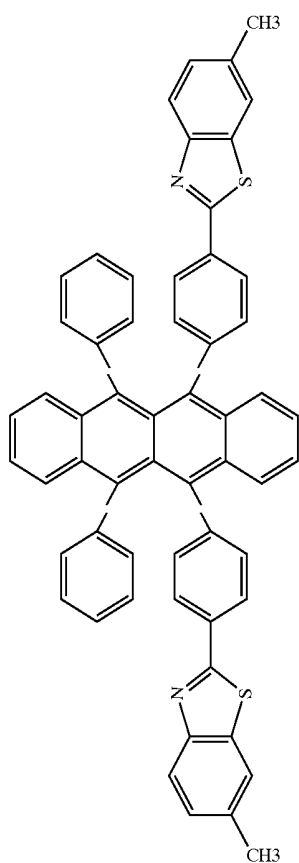
TtBuPN

[0123] 5,12-bis(4-tert-butylphenyl)-naphthacene (hereinafter referred to as DtBuPN):



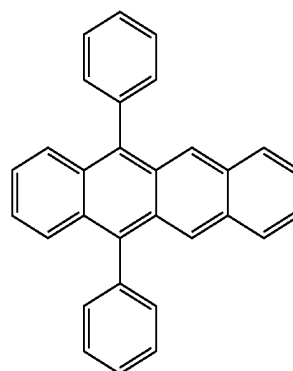
DtBuPN

[0121] 5,12-bis(4-(6-methylbenzothiazole-2-yl)phenyl)-6,11-diphenylnaphthacene (hereinafter referred to as DBZR):



DBZR

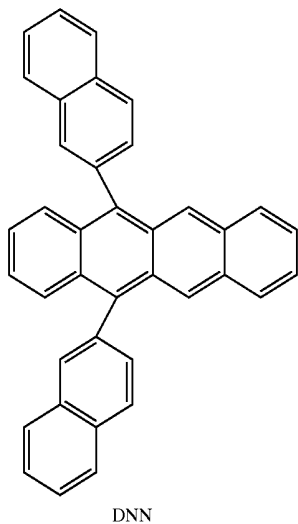
[0124] 5,12-diphenylnaphthacene (hereinafter referred to as DPN):



DPN

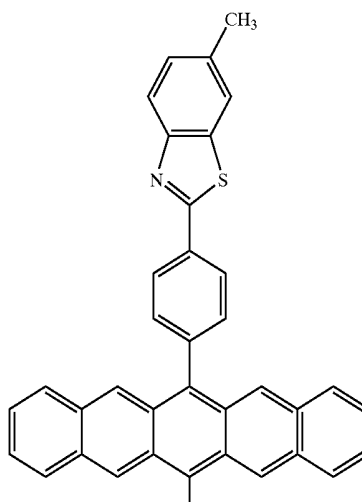
[0125] 5,12-bis(naphth-2-yl)-naphthacene(hereinafter referred to as DNN):

(A6)



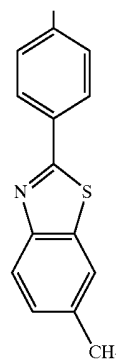
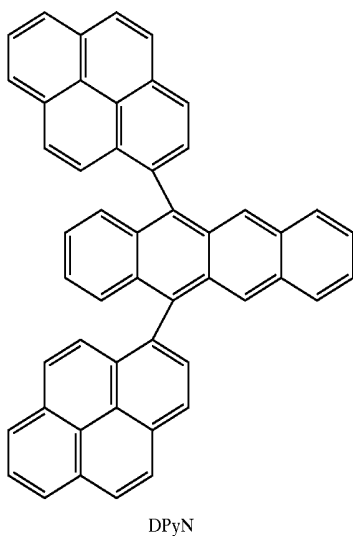
[0128] 6,13-bis(4-(6-methylbenzothiazole-2-yl)phenyl)-pentacene (hereinafter referred to as DBZP):

(A9)



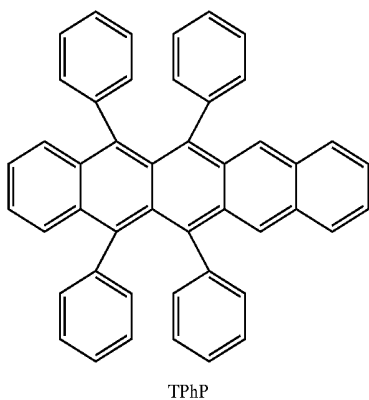
[0126] 5,12-bis(pyrene-1-yl)-naphthacene(hereinafter referred to as DPyN):

(A7)



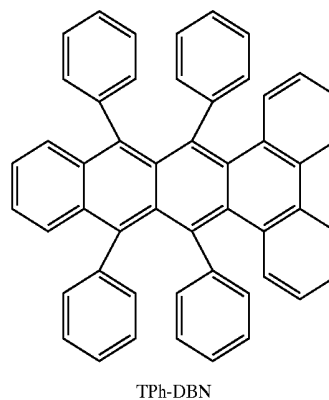
[0127] 5,6,13,14-tetrakisphenyl-pentacene (hereinafter referred to as TPhP):

(A8)



[0129] 5,6,11,12-tetrakisphenyl-1,2-benzo-(3,4-benzo-)naphthacene (hereinafter referred to as TPh-DBN):

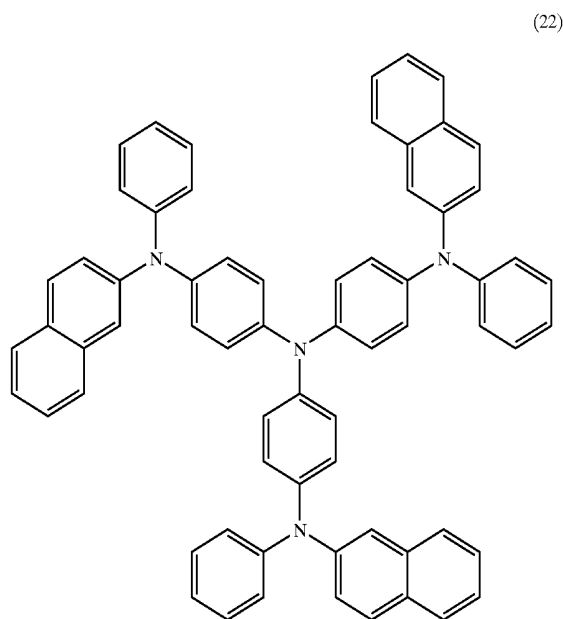
(A10)



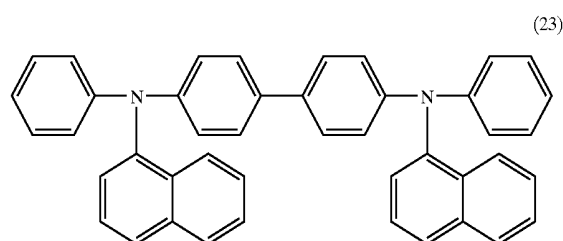
[0130] (A) Device Structure A

[0131] In Device Structure A, a hole injecting electrode (anode), a hole injecting layer, a hole transporting layer, a light emitting layer, and an electron injecting electrode (cathode) are sequentially stacked on a glass substrate.

[0132] In this case, the hole injecting electrode of the organic EL device has a thickness of 1000 Å and is formed of indium-tin oxide (ITO). The hole injecting layer has a thickness of 500 Å and is formed of 4,4',4''-Tris(N-(2-naphthyl)-N-phenyl-amino)-triphenylamine (hereinafter referred to as 2TNATA) having the molecular structure represented by Formula (22) below.

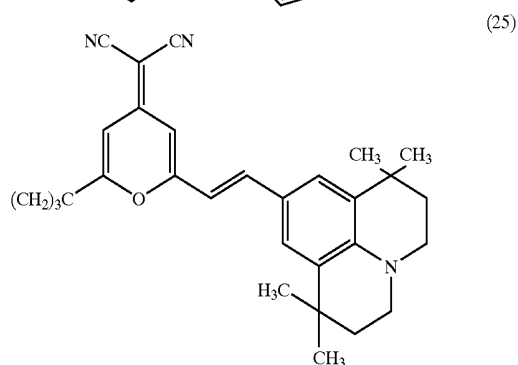
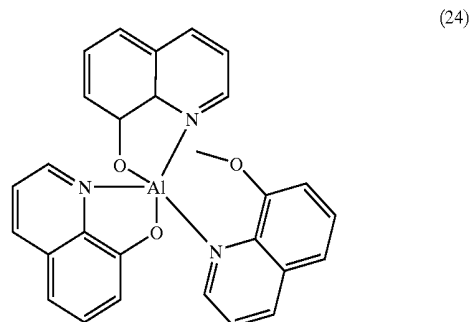


[0133] The hole transporting layer has a thickness of 150 Å and is formed of N,N'-Di(naphthalen-1-yl)-N,N'-diphenyl-benzidine (hereinafter referred to as NPB) having the molecular structure of Formula (23).



[0134] The light emitting layer has a thickness of 500 Å, and contains, as a host material, Tris(8-hydroxyquinolino)-aluminum (hereinafter referred to as Alq) having the molecular structure of Formula (24) below, and contains, as a red light emitting dopant, 2% of 2-(1,1-Dimethylethyl)-6-(2-(2,3,6,7-tetrahydro-1,1,7,7-tetramethyl-1H,5H-benzo[ij]quinolizin-9-yl)ethenyl)-4H-pyran-4-ylidene)propanedinitrile (hereinafter referred to as DCJTb) having the molecular structure of Formula (25), and also contains, as a first

light-emission assisting dopant, 5% of a rubrene derivative, or one of those shown above.



[0135] The electron injecting electrode is formed of a MgIn alloy (a ratio of 10:1) with a thickness of 2000 Å.

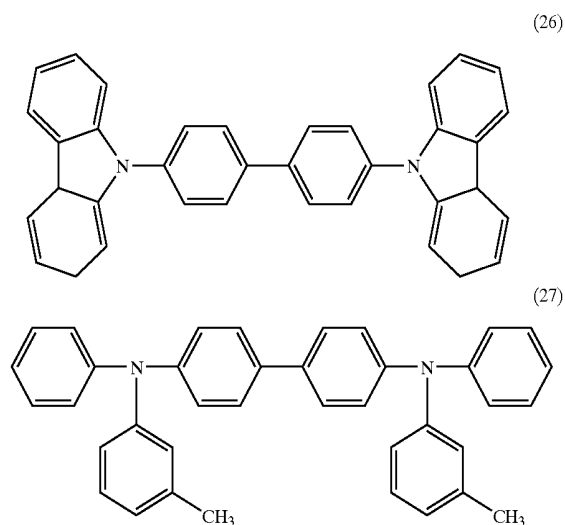
[0136] Examples 1-10 used, as first light-emission assisting dopants, DtBuPN, DPN, DNN, TNN, DBzR, DPyN, TiBuPN, DBZP, TPhP, and TPh-DBN, respectively. Comparative Example 1 used rubrene as a first light-emission assisting dopant.

[0137] (B) Device Structure B

[0138] In Device Structure B, a hole injecting electrode (anode), a hole injecting layer, a hole transporting layer, a light emitting layer, and an electron injecting electrode (cathode) are sequentially stacked on a glass substrate.

[0139] In this case, the hole injecting electrode of the organic EL device has a thickness of 1000 Å and is formed of indium-tin oxide (ITO). The hole injecting layer has a thickness of 500 Å and is formed of 2TNATA. The hole transporting layer has a thickness of 150 Å and is formed of NPB.

[0140] The light emitting layer has a thickness of 500 Å, and contains Alq as a host material, 2% of DCJTb as a red-emitting dopant, 5% of a rubrene derivative, one of the rubrene derivatives shown above, as a first light-emission assisting dopant, and also contains, as a second light-emission assisting dopant, 6% of 4,4-Bis(carbazol-9-yl)-biphenyl (hereinafter referred to as CBP) having the molecular structure of Formula (26), or N,N'-Bis-(3-methylphenyl)-N,N'-bis-(phenyl)-benzidine (hereinafter referred to as TPD) having the molecular structure of Formula (27) below, or NPB.



[0141] The electron injecting electrode has a thickness of 2000 Å and is formed of a MgIn alloy (with a ratio of 10:1).

[0142] Examples 11-20 used, as first light-emission assisting dopants, DtBuPN, DPN, DNN, TNN, DBzR, DPyN, TtBuPN, DBzP, TPhP, and TPh-DBN, respectively. Comparative Example used rubrene as the first light-emission assisting dopant.

[0143] Example 21 used DtBuPN as the first light-emission assisting dopant and TPD as the second light-emission assisting dopant. Example 22 used DPN as the first light-emission assisting dopant and NPB as the second light-emission assisting dopant.

[0144] (C) Device Structure C

[0145] In Device Structure C, a hole injecting electrode (anode), a hole injecting layer, a hole transporting layer, a light emitting layer, and an electron injecting electrode (cathode) are sequentially stacked on a glass substrate.

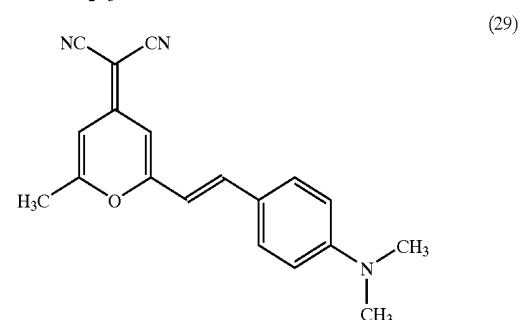
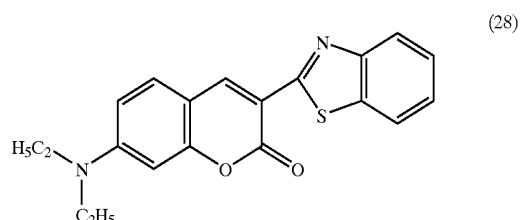
[0146] In this case, the hole injecting electrode of the organic EL device has a thickness of 1000 Å and is formed of indium-tin oxide (ITO). The hole injecting layer has a thickness of 500 Å and is formed of 2TNATA. The hole transporting layer has a thickness of 150 Å and is formed of NPB.

[0147] The light emitting layer has a thickness of 500 Å, and contains Alq as a host material, and 5% of a rubrene derivative, one of those shown above, as a light emitting dopant.

[0148] The electron injecting electrode is formed of a MgIn alloy (a ratio of 10:1) with a thickness of 2000 Å.

[0149] Examples 23-28 used, as the light emitting dopants, DtBuPN, DPN, DNN, TNN, DBzR, and DPyN, respectively. Comparative Examples 3-5 respectively used, as light emitting dopants, Coumarin6 (or 3-(2-Benzothiazolyl)-7-(diethylamino)coumarin) having the molecular

structure of Formula (28), rubrene, and 4-(Dicyanomethylene)-2-methyl-6-(4-dimethylaminostyryl)-4H-pyran (hereinafter referred to as DCM) having the molecular structure of Formula (29).



[0150] (D) Device Structure D

[0151] In Device Structure D, a hole injecting electrode (anode), a hole injecting layer, a hole transporting layer, a light emitting layer, an electron transporting layer, and an electron injecting electrode (cathode) are sequentially stacked on a glass substrate.

[0152] In this case, the hole injecting electrode of the organic EL device is formed of indium-tin oxide (ITO) with a thickness of 1000 Å. The hole injecting layer has a thickness of 500 Å and is formed of 2TNATA.

[0153] The light emitting layer has a thickness of 150 Å, and contains NPB as a host material, and 5% of a rubrene derivative, one of those shown above, as a light emitting dopant.

[0154] The electron transporting layer has a thickness of 500 Å and is formed of Alq. The electron injecting electrode is formed of MgIn alloy (a ratio of 10:1) with a thickness of 2000 Å.

[0155] Examples 29-33 used, as the light emitting dopants, DtBuPN, DPN, DNN, TNN, and DBzR, respectively.

[0156] A positive bias voltage was applied to the hole injecting electrode of each organic EL device and a negative bias voltage was applied to the electron injecting electrode, and luminescence characteristics of the devices were measured.

[0157] Table 1 shows measurements of luminescence characteristics of the organic EL devices of Examples 1-10 and Comparative Example 1.

TABLE 1

	DEVICE STRUC- TURE	HOST	LIGHT EMITTING DOPANT	1st LIGHT- EMISSION ASSISTING DOPANT	2nd LIGHT- EMISSION ASSISTING DOPANT	EMITTED COLOR (CIEx, y)	LUMINOUS EFFI- CIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMINANCE (cd/m ²)
EX. 1	A	Alq	DCJTb	DtBuPN	—	Red x = 0.65, y = 0.35	1.1	633	8,050
EX. 2	A	Alq	DCJTb	DPN	—	Red x = 0.65, y = 0.35	1.6	632	10,100
EX. 3	A	Alq	DCJTb	DNN	—	Red x = 0.65, y = 0.35	1.1	633	7,960
EX. 4	A	Alq	DCJTb	TNN	—	Red x = 0.65, y = 0.35	1.4	633	9,030
EX. 5	A	Alq	DCJTb	DBzR	—	Red x = 0.65, y = 0.35	1.5	634	9,500
EX. 6	A	Alq	DCJTb	DPyN	—	Red x = 0.65, y = 0.35	1.1	635	7,900
EX. 7	A	Alq	DCJTb	TtBuPN	—	Red x = 0.65, y = 0.35	1.5	634	9,600
EX. 8	A	Alq	DCJTb	DBzP	—	Red x = 0.65, y = 0.35	1.1	637	7,600
EX. 9	A	Alq	DCJTb	TPhP	—	Red x = 0.65, y = 0.35	1.1	635	7,400
EX. 10	A	Alq	DCJTb	TPh-DBN	—	Red x = 0.65, y = 0.35	1.1	635	7,700
Comparison 1	A	Alq	DCJTb	Rubrene	—	Red x = 0.65, y = 0.35	1.0	635	7,300

[0158] As shown in Table 1, the organic EL devices of Examples 1-10 and Comparative Example 1 all provided red light emission with high color purity. The organic EL devices of Examples 1-10 provided higher luminous efficiency and higher maximum luminance than the organic EL device of Comparative Example 1. This shows that the use

of the rubrene derivatives as the first light-emission assisting dopants is effective in enhancing the luminous efficiency and maximum luminance.

[0159] Table 2 shows measurements of luminescence characteristics of the organic EL devices of Examples 11-20 and Comparative Example 2.

TABLE 2

	DEVICE STRUC- TURE	HOST	LIGHT EMITTING DOPANT	1st LIGHT- EMISSION ASSISTING DOPANT	2nd LIGHT- EMISSION ASSISTING DOPANT	EMITTED COLOR (CIEx, y)	LUMINOUS EFFI- CIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMINANCE (cd/m ²)
EX. 11	B	Alq	DCJTb	DtBuPN	CBP	Red x = 0.65, y = 0.35	2.1	634	14,450
EX. 12	B	Alq	DCJTb	DPN	CBP	Red x = 0.65, y = 0.35	2.7	632	18,100
EX. 13	B	Alq	DCJTb	DNN	CBP	Red x = 0.65, y = 0.35	2.1	634	13,660
EX. 14	B	Alq	DCJTb	TNN	CBP	Red x = 0.65, y = 0.35	2.5	634	15,080

TABLE 2-continued

	DEVICE STRUC- TURE		LIGHT EMITTING DOPANT	1st	2nd	EMITTED COLOR (CIEx, y)	LUMINOUS EFFI- CIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMINANCE (cd/m ²)
				LIGHT- EMISSION ASSISTING DOPANT	LIGHT- EMISSION ASSISTING DOPANT				
EX. 15	B	Alq	DCJTB	DBzR	CBP	Red x = 0.65, y = 0.35	2.5	635	16,100
EX. 16	B	Alq	DCJTB	DPyN	CBP	Red x = 0.65, y = 0.35	2.1	635	7,900
EX. 17	B	Alq	DCJTB	TtBuPN	CBP	Red x = 0.65, y = 0.35	2.5	634	15,000
EX. 18	B	Alq	DCJTB	DBzP	CBP	Red x = 0.65, y = 0.35	2.1	637	8,100
EX. 19	B	Alq	DCJTB	TPhP	CBP	Red x = 0.65, y = 0.35	2.1	635	8,200
EX. 20	B	Alq	DCJTB	TPh-DBN	CBP	Red x = 0.65, y = 0.35	2.1	635	8,100
Comparison 2	B	Alq	DCJTB	Rubrene	CBP	Red x = 0.65, y = 0.35	2.0	634	12,820

[0160] As shown in Table 2, the organic EL devices of Examples 11-20 and Comparative Example 2 all provided red light emission with high color purity. With the organic EL devices of Examples 11-20, the addition of the second light-emission assisting dopant enabled higher luminous efficiency and higher maximum luminance than those of the organic EL devices of Examples 1-11. This shows that the addition of the second light-emission assisting dopant is effective in enhancing the luminous efficiency and maximum luminance. The organic EL devices of Examples 11-20 provided higher luminous efficiency than the organic EL device of Example 2. This shows that using the rubrene derivatives as the first light-emission assisting dopants is effective in enhancing the luminous efficiency and maximum luminance.

[0161] Table 3 shows measurements of luminescence characteristics of the organic EL devices of Examples 21 and 22.

[0162] As shown in Table 3, the organic EL devices of Examples 21 and 22 both provided red light emission with high color purity. With the organic EL devices of Examples 21 and 22, too, the addition of the second light-emission assisting dopant enhanced the luminous efficiency and maximum luminance, as compared with those of the organic EL devices of Examples 1-11. This shows that adding a second light-emission assisting dopant is effective in enhancing the luminous efficiency and maximum luminance. The organic EL devices of Examples 21 and 22, too, provided higher luminous efficiency than the organic EL device of Comparative Example 2. This shows that using rubrene derivatives as the first light-emission assisting dopants is effective in enhancing the luminous efficiency and maximum luminance also when TPD or NPB is used as a second light-emission assisting dopant.

[0163] Table 4 shows measurements of luminescence characteristics of the organic EL devices of Examples 23-28 and Comparative Examples 3-5.

TABLE 3

	DEVICE STRUCTURE		LIGHT EMITTING DOPANT	1st	2nd	EMITTED COLOR (CIEx, y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMINANCE (cd/m ²)
				LIGHT- EMISSION ASSISTING DOPANT	LIGHT- EMISSION ASSISTING DOPANT				
EX. 21	B	Alq	DCJTB	DtBuPN	TPD	Red x = 0.65, y = 0.35	2.1	634	14,000
EX. 22	B	Alq	DCJTB	DPN	NPB	Red x = 0.65, y = 0.35	2.6	632	19,100

TABLE 4

	DEVICE STRUC- TURE	HOST	LIGHT EMITTING DOPANT	1st LIGHT- EMISSION ASSISTING DOPANT	2nd LIGHT- EMISSION ASSISTING DOPANT	EMITTED COLOR (CIEx, y)	LUMINOUS EFFI- CIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMINANCE (cd/m ²)
EX. 23	C	Alq	DtBuPN	—	—	Green x = 0.30, y = 0.68	9.0	538	41,800
EX. 24	C	Alq	DPN	—	—	Green x = 0.29, y = 0.62	4.2	534	18,800
EX. 25	C	Alq	DNN	—	—	Green x = 0.31, y = 0.65	5.8	540	23,000
EX. 26	C	Alq	TNN	—	—	Orange x = 0.50, y = 0.49	6.8	578	45,400
EX. 27	C	Alq	DBzR	—	—	Orange x = 0.50, y = 0.49	4.6	585	26,000
EX. 28	C	Alq	DPyN	—	—	Green x = 0.29, y = 0.68	4.1	541	25,700
Comparison 3	C	Alq	Coumarin 6	—	—	Green x = 0.31, y = 0.66	3.5	538	18,000
Comparison 4	C	Alq	Rubrene	—	—	Yellow x = 0.49, y = 0.50	6.5	560	40,100
Comparison 5	C	Alq	DCM	—	—	Orange x = 0.53, y = 0.47	2.0	575	10,200

[0164] As shown in Table 4, the organic EL devices of Examples 23-28 provided luminous efficiencies of 4.1 to 9.0 cd/A, which are higher than those of the organic EL devices of Comparison Examples 3-5. This shows that using the rubrene derivatives as light emitting dopants, too, is effective in enhancing the luminous efficiency and maximum luminance.

[0165] Table 5 shows measurements of luminescence characteristics of the organic EL devices of Examples 29-33.

[0166] As shown in Table 5, the organic EL devices of Examples 29-33 provided high luminous efficiencies of 3.6 to 12.5 cd/A. This shows that using the rubrene derivatives as light emitting dopants with an electron transporting layer replacing the hole transporting layer is also effective in enhancing the luminous efficiency and maximum luminance.

[0167] Thus, it is seen from Examples 1-33 and Comparative Examples 1-5 that using the rubrene derivatives shown

TABLE 5

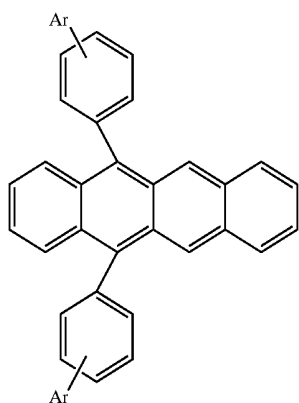
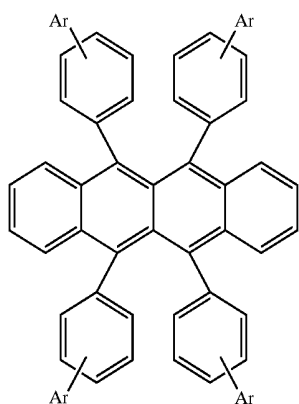
	DEVICE STRUCTURE	HOST	LIGHT EMITTING DOPANT	1st LIGHT- EMISSION ASSISTING DOPANT	2nd LIGHT- EMISSION ASSISTING DOPANT	EMITTED COLOR (CIEx, y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMINANCE (cd/m ²)
EX. 29	D	NPB	DtBuPN	—	—	Green x = 0.29, y = 0.67	7.8	535	36,100
EX. 30	D	NPB	DPN	—	—	Green x = 0.30, y = 0.62	3.6	532	27,700
EX. 31	D	NPB	DNN	—	—	Green x = 0.30, y = 0.68	6.2	540	33,900
EX. 32	D	NPB	TNN	—	—	Yellow x = 0.46, y = 0.53	9.0	570	40,500
EX. 33	D	NPB	DBzR	—	—	Yellow x = 0.49, y = 0.51	12.5	559	46,600

above as a light emitting dopant or first light-emission assisting dopant in a light emitting layer improves luminous efficiency and luminance.

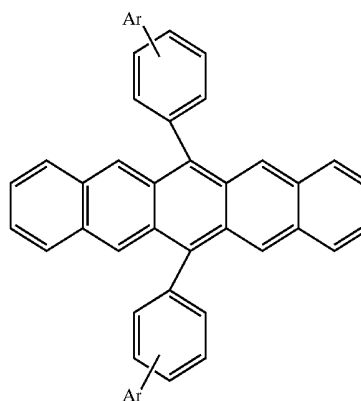
[0168] (2) Next, organic EL devices of Examples 34-108 were constructed and luminescence characteristics of these devices were measured.

[0169] Organic EL devices of Examples 34-40 have Device Structure E, organic EL devices of Examples 41-67 have Device Structure F, organic EL devices of Examples 68-94 have Device Structure G, and organic EL devices of Examples 95-108 have Device Structure H.

[0170] Examples 34-40 used rubrene derivatives having molecular structures of Formula (1a) below, among rubrene derivatives represented by Formula (1) shown earlier, rubrene derivatives having molecular structures of Formula (2a) among rubrene derivatives represented by Formula (2), and rubrene derivatives having molecular structures of Formula (4a) among rubrene derivatives represented by Formula (4).



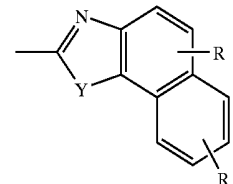
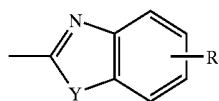
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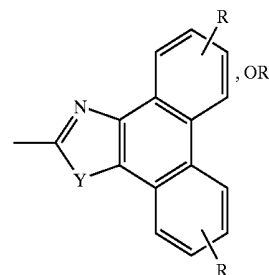
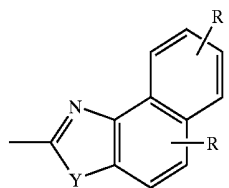
(4a)

[0171] In Formulas (1a), (2a) and (4a), Ar represents a substituent having any of the structures represented by Formula (7a).

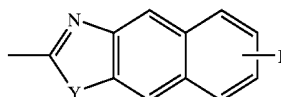
(1a)



(7a)



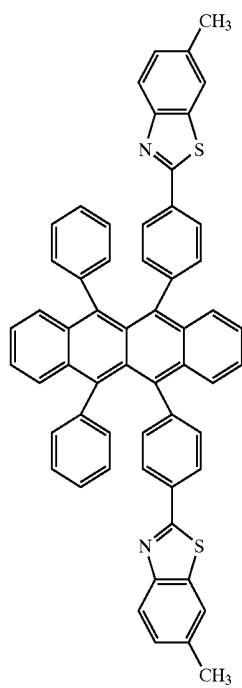
(2a)



[0172] In Formula (7a), Y is O or S, R is a hydrogen atom, a halogen atom, or a substituent, such as $-H$, $-C_nH_{2n+1}$ ($n=1-10$), $-OC_nH_{2n+1}$ ($n=1-10$), $-N(C_nH_{2n+1})_2$ ($n=1-10$), $-X$ ($X=F, -Cl, -Br, \text{ or } -I$), $-CN$, a phenyl group, or a naphthyl group.

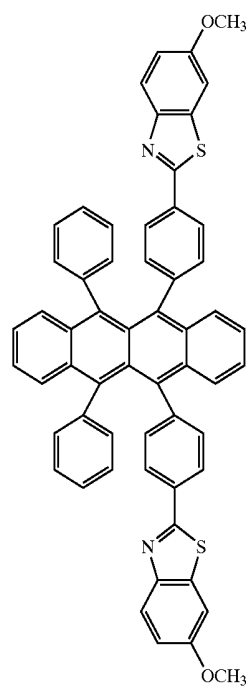
[0173] In particular, Compounds 1-27 having molecular structures of Formulas (C1)-(C27) below were used as materials of the light emitting layer.

COMPOUND 1:



(C1)

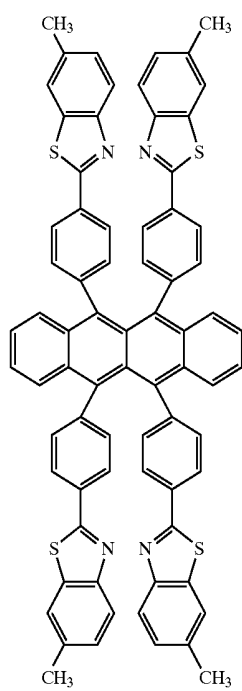
COMPOUND 3:



(C3)

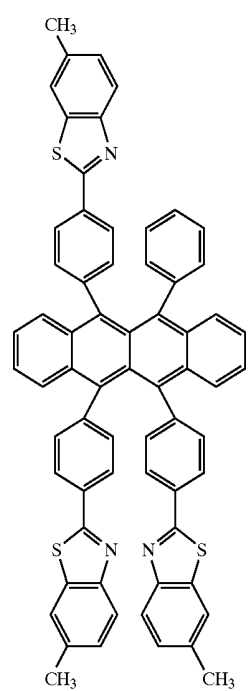
-continued

COMPOUND 2:



(C2)

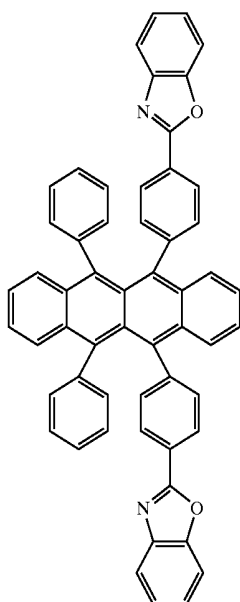
COMPOUND 4:



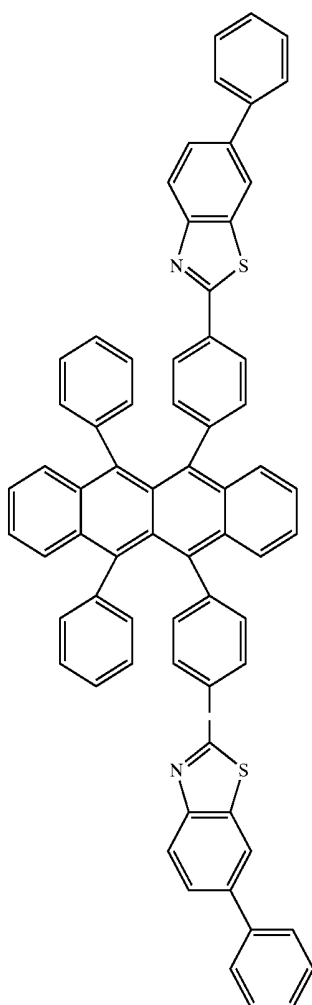
(C4)

-continued

COMPOUND 5:



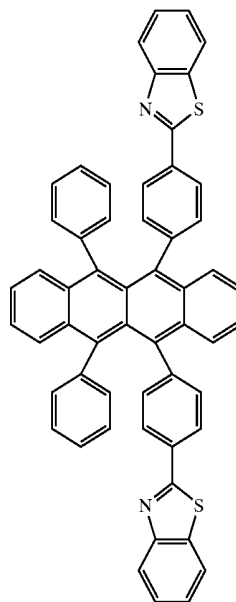
COMPOUND 6:



COMPOUND 7:

-continued

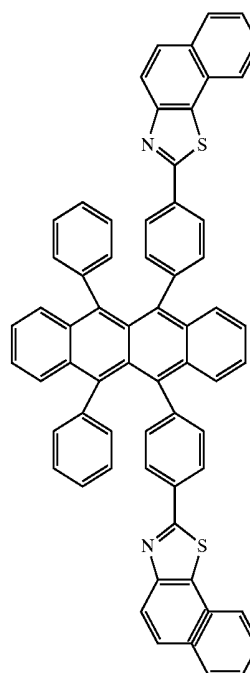
(C5)



(C7)

(C6)

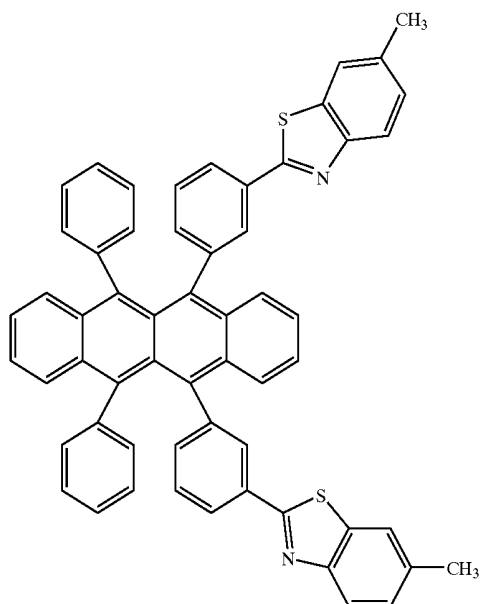
COMPOUND 8:



(C8)

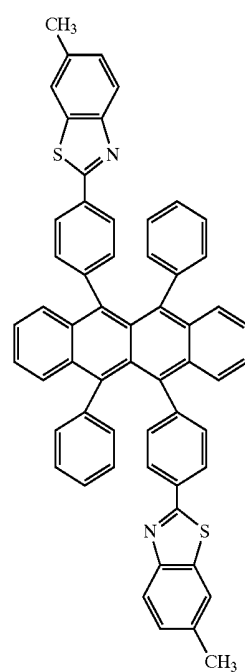
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COMPOUND 9:

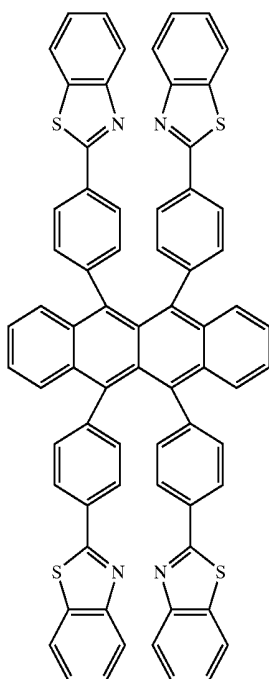


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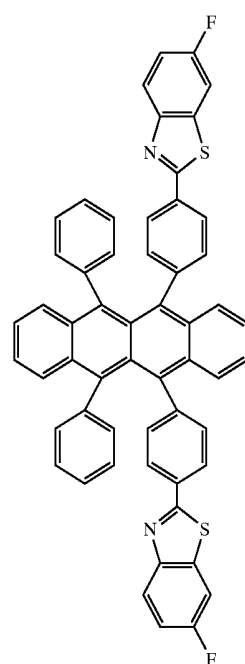
COMPOUND 11:



COMPOUND 10:

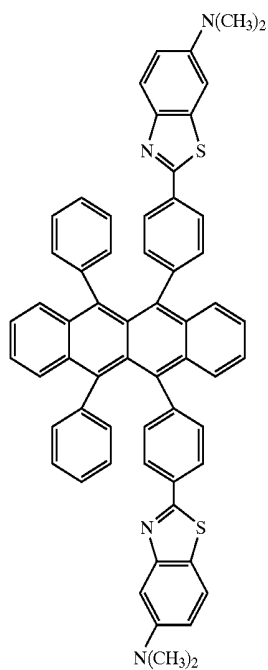


COMPOUND 12:



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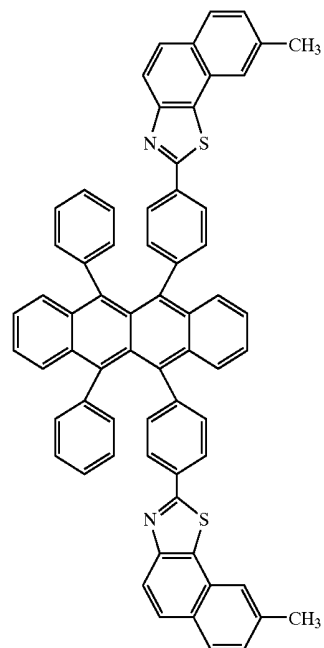
COMPOUND 13:



COMPOUND 15:

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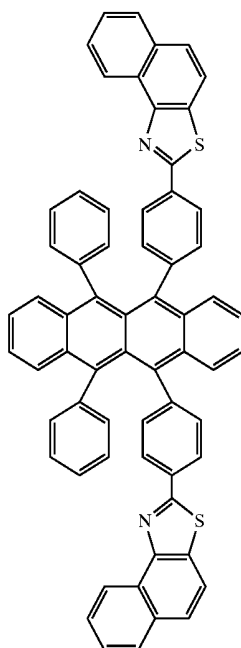
(C13)



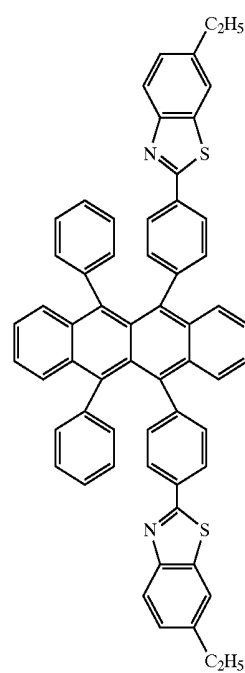
(C15)

COMPOUND 16:

COMPOUND 14:



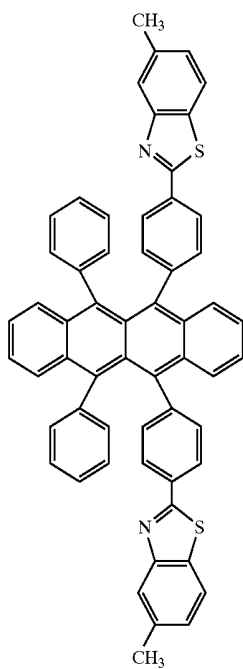
(C14)



(C16)

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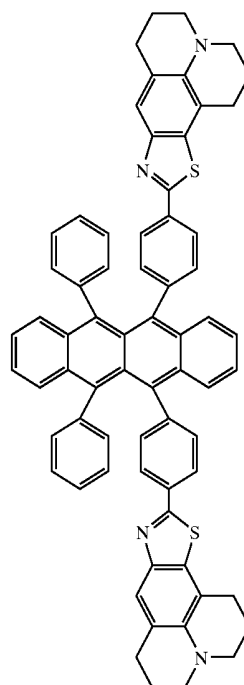
COMPOUND 17:



(C17)

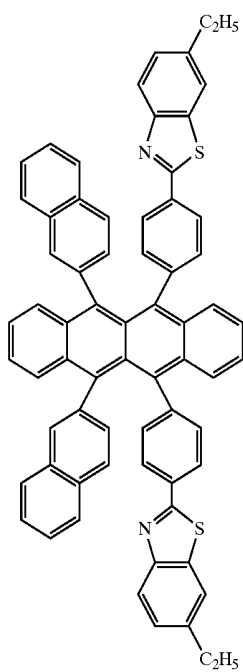
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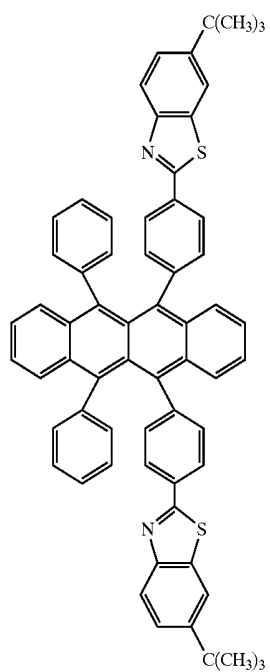
(C19)

COMPOUND 18:



(C18)

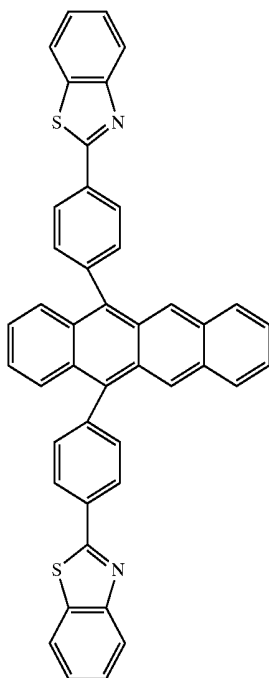
COMPOUND 20:



(C20)

-continued

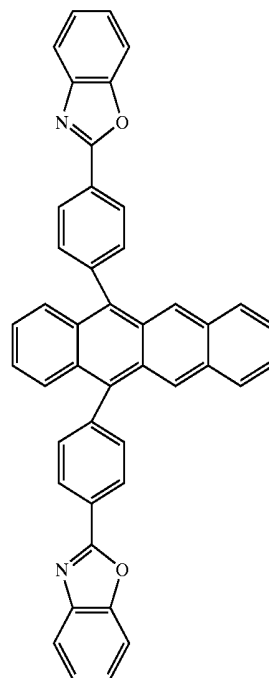
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(C21)

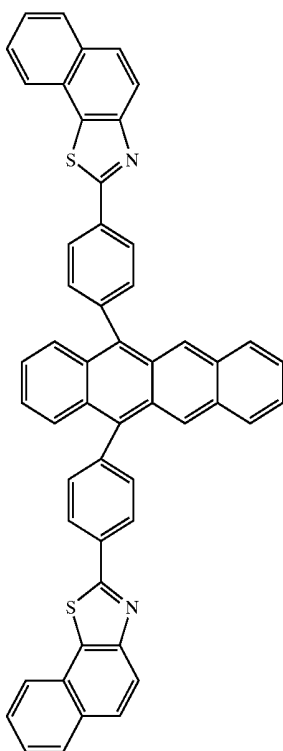
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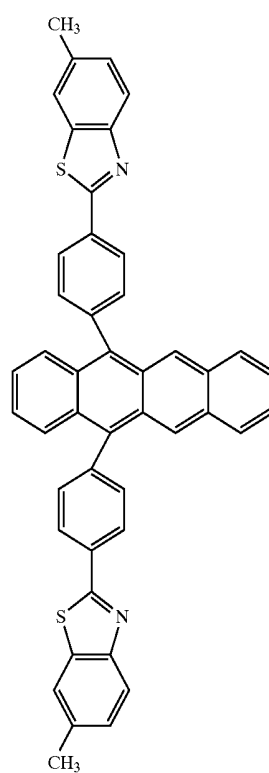
(C23)

COMPOUND 22:



(C22)

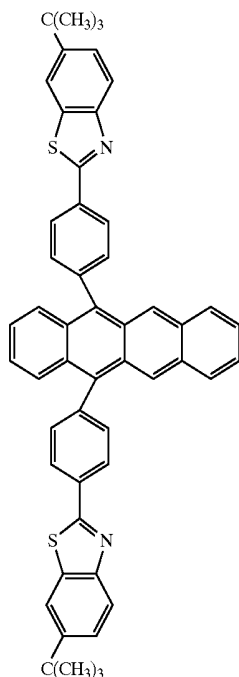
COMPOUND 24:



(C24)

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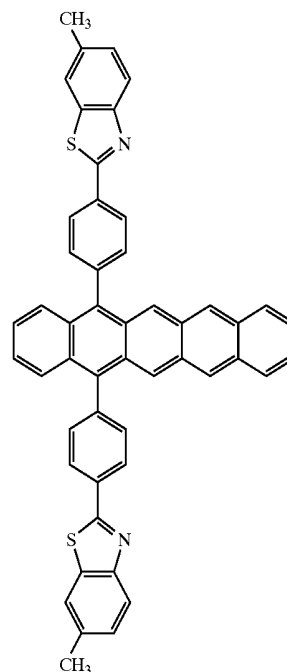
COMPOUND 25:



(C25)

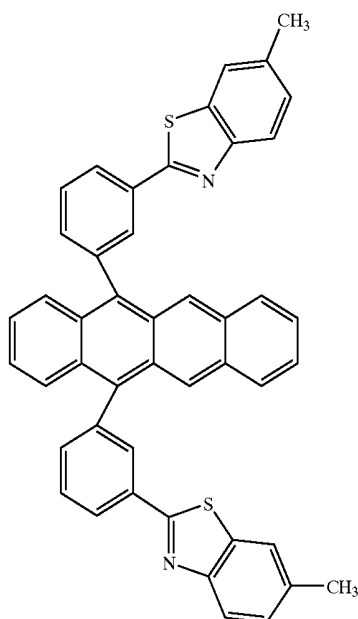
-continued

COMPOUND 27:



(C27)

COMPOUND 26:



(C26)

[0174] (E) Device Structure E

[0175] In Device Structure E, a hole injecting electrode (anode), a hole injecting layer, a hole transporting layer, a light emitting layer, an electron transporting layer, and an electron injecting electrode (cathode) are sequentially stacked on a glass substrate.

[0176] In this case, the hole injecting electrode of the organic EL device has a thickness of 1000 Å and is formed of indium-tin oxide (ITO). The hole injecting layer has a thickness of 100 Å and is formed of copper phthalocyanine (hereinafter referred to as CuPc).

[0177] The hole transporting layer has a thickness of 500 Å and is formed of NPB having the molecular structure of Formula (23) shown before.

[0178] The light emitting layer has a thickness of 400 Å, and contains, as a host material, Alq having the molecular structure of Formula (24) above, and contains, as a red light emitting dopant, 2% of DCJTB having the molecular structure of Formula (25) above, and also contains, as a light-emission assisting dopant, 5% of a rubrene derivative, one of those shown above.

[0179] Examples 34-40 respectively used, as the light-emission assisting dopants, Compounds 1, 3, 7, 8, 16, 17 and 18 represented by Formulas (C1), (C3), (C7), (C8), (C16), (C17) and (C18).

[0180] The electron transporting layer is formed of Alq with a thickness of 100 Å. The electron injecting electrode is formed of LiF/Al with a thickness of 2000 Å.

[0181] (F) Device Structure F

[0182] in Device Structure F, a hole injecting electrode (anode), a hole injecting layer, a hole transporting layer, a

light emitting layer, an electron transporting layer, and an electron injecting electrode (cathode) are sequentially stacked on a glass substrate.

[0183] In this case, the hole injecting electrode of the organic EL device has a thickness of 1000 Å and is formed of indium-tin oxide (ITO). The hole injecting layer has a thickness of 100 Å and is formed of CuPc.

[0184] The hole transporting layer has a thickness of 500 Å and is formed of NPB having the molecular structure of Formula (23).

[0185] The light emitting layer has a thickness of 400 Å, and contains Alq having the molecular structure of Formula (24) as a host material, and 5% of a rubrene derivative, one of the rubrene derivatives shown above, as a light emitting dopant.

[0186] Examples 41-67 respectively used Compounds 1-27 of Formulas (C1)-(C27) as the light emitting dopants.

[0187] The electron transporting layer is formed of Alq with a thickness of 100 Å. The electron injecting electrode is formed of LiF/Al with a thickness of 2000 Å.

[0188] (G) Device Structure G

[0189] In Device Structure G, a hole injecting electrode (anode), a hole injecting layer, a hole transporting layer, a light emitting layer, an electron transporting layer, and an electron injecting electrode (cathode) are sequentially stacked on a glass substrate.

[0190] In this case, the hole injecting electrode of the organic EL device has a thickness of 1000 Å and is formed of indium-tin oxide (ITO). The hole injecting layer has a thickness of 100 Å and is formed of CuPc.

[0191] The hole transporting layer has a thickness of 500 Å and is formed of NPB having the molecular structure of Formula (23) shown above.

[0192] The light emitting layer has a thickness of 400 Å, and contains NPB having the molecular structure of Formula (23) as a host material, and 5% of a rubrene derivative, one of those shown above, as a light emitting dopant.

[0193] Examples 68-94 used Compounds 1-27 of Formulas (C1)-(C27) as light emitting dopants.

[0194] The electron transporting layer is formed of Alq with a thickness of 100 Å. The electron injecting electrode is formed of LiF/Al with a thickness of 2000 Å.

[0195] (H) Device Structure H

[0196] In Device Structure H, a hole injecting electrode (anode), a hole injecting layer, a hole transporting layer, a first light emitting layer, a second light emitting layer, an

electron transporting layer, and an electron injecting electrode (cathode) are sequentially stacked on a glass substrate.

[0197] In this case, the hole injecting electrode of the organic EL device has a thickness of 1000 Å and is formed of indium-tin oxide (ITO). The hole injecting layer has a thickness of 100 Å and is formed of CuPc.

[0198] The hole transporting layer has a thickness of 400 Å and is formed of NPB having the molecular structure of Formula (23) shown above.

[0199] The first light emitting layer has a thickness of 100 Å, and contains, as a host material, NPB having the molecular structure of Formula (23), and contains, as a light emitting dopant(s), 2% (Examples 95-104) or 8% (Examples 105-108) of one or ones of rubrene derivatives shown above.

[0200] Examples 95-104 respectively used, as light emitting dopants in the first light emitting layer, Compounds 1, 1, 3, 7, 8, 16, 17, 18, 19 and 20 of Formulas (C1), (C1), (C3), (C7), (C8), (C16), (C17), (C18), (C19) and (C20).

[0201] The second light emitting layer has a thickness of 300 Å, and contains, as a host material, diphenylanthracene having the molecular structure of Formula (B2) and contains, as a light emitting dopant, 2% of perylene of Formula (B3) shown earlier.

[0202] In Examples 105-108, in order to enhance the luminous efficiency of white and to increase the half bandwidth of the spectrum to enhance color purity of white, the first light emitting layer was doped with two kinds of light emitting dopants: an orange-emitting rubrene derivative and a green-emitting rubrene derivative.

[0203] Example 105 used Compound 1 of Formula (C1) and DtBuPN of Formula (A4) as light emitting dopants in the first light emitting layer. Example 106 used Compound 1 of Formula (C1) and Compound 24 of Formula (C24) as light emitting dopants in the first light emitting layer. Example 107 used Compound 7 of Formula (C7) and Compound 25 of Formula (C25) as light emitting dopants in the first light emitting layer. Example 108 used Compound 9 of Formula (C9) and Compound 26 of Formula (26) as light emitting dopants in the first light emitting layer.

[0204] The electron transporting layer is formed of Alq with a thickness of 100 Å. The electron injecting electrode is formed of LiF/Al with a thickness of 2000 Å.

[0205] A positive bias voltage was applied to the hole injecting electrode of each organic EL device and a negative bias voltage was applied to the electron injecting electrode, and luminescence characteristics of the devices were measured.

[0206] Table 6 shows measurements of luminescence characteristics of the organic EL devices of Examples 34-40.

TABLE 6

EX.	HOLE INJECTING LAYER	HOLE TRANSPORTING LAYER	LIGHT- EMITTING LAYER	ELECTRON TRANSPORTING LAYER	EMITTED COLOR (CIEx, y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMINANCE (cd/m ²)
34	CuPc	NPB	Alq + 2% DCJTb + 5% Compound1	Alq	Red x = 0.65, y = 0.35	3.9	638	24,000
35	CuPc	NPB	Alq + 2% DCJTb + 5% Compound3	Alq	Red x = 0.65, y = 0.35	3.7	639	21,000

TABLE 6-continued

EX.	HOLE INJECTING LAYER	HOLE TRANSPORTING LAYER	LIGHT- EMITTING LAYER	ELECTRON TRANSPORTING LAYER	EMITTED COLOR (CIE _x , y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMINANCE (cd/m ²)
36	CuPc	NPB	Alq + 2% DCJTB + 5% Compound7	Alq	Red x = 0.65, y = 0.35	3.8	638	23,000
37	CuPc	NPB	Alq + 2% DCJTB + 5% Compound8	Alq	Red x = 0.65, y = 0.35	3.2	638	19,000
38	CuPc	NPB	Alq + 2% DCJTB + 5% Compound16	Alq	Red x = 0.65, y = 0.35	3.8	638	23,000
39	CuPc	NPB	Alq + 2% DCJTB + 5% Compound17	Alq	Red x = 0.65, y = 0.35	3.5	638	22,000
40	CuPc	NPB	Alq + 2% DCJTB + 5% Compound18	Alq	Red x = 0.65, y = 0.35	3.6	638	22,000

[0207] As shown in Table 6, the organic EL devices of Examples 34-40 all provided red light emission with high color purity. The organic EL devices of Examples 39-40 provided high luminous efficiency and high maximum luminance. This shows that the use of the rubrene derivatives as

light-emission assisting dopants is effective in enhancing the luminous efficiency and maximum luminance.

[0208] Tables 7 and 8 show measurements of luminescence characteristics of the organic EL devices of Examples 41-67.

TABLE 7

EX.	HOLE INJECTING LAYER	HOLE TRANSPORTING LAYER	LIGHT- EMITTING LAYER	ELECTRON TRANSPORTING LAYER	EMITTED COLOR (CIE _x , y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMI- NANCE (cd/m ²)
41	CuPc	NPB	Alq + 5% Compound1	Alq	Orange-Yellow x = 0.51, y = 0.48	8.5	583	39,900
42	CuPc	NPB	Alq + 5% Compound2	Alq	Orange-Yellow x = 0.52, y = 0.47	7.5	589	37,600
43	CuPc	NPB	Alq + 5% Compound3	Alq	Orange-Yellow x = 0.51, y = 0.48	8.5	583	39,700
44	CuPc	NPB	Alq + 5% Compound4	Alq	Orange-Yellow x = 0.51, y = 0.48	6.8	587	35,400
45	CuPc	NPB	Alq + 5% Compound5	Alq	Orange-Yellow x = 0.50, y = 0.50	5.5	579	32,100
46	CuPc	NPB	Alq + 5% Compound6	Alq	Orange-Yellow x = 0.51, y = 0.48	8.0	583	39,000
47	CuPc	NPB	Alq + 5% Compound7	Alq	Orange-Yellow x = 0.51, y = 0.48	8.6	583	40,000
48	CuPc	NPB	Alq + 5% Compound8	Alq	Orange-Yellow x = 0.51, y = 0.48	7.9	584	39,000
49	CuPc	NPB	Alq + 5% Compound9	Alq	Orange-Yellow x = 0.50, y = 0.50	6.9	570	33,300
50	CuPc	NPB	Alq + 5% Compound10	Alq	Orange-Yellow x = 0.52, y = 0.47	7.5	589	37,600
51	CuPc	NPB	Alq + 5% Compound11	Alq	Orange-Yellow x = 0.51, y = 0.48	6.5	579	34,000
52	CuPc	NPB	Alq + 5% Compound12	Alq	Orange-Yellow x = 0.51, y = 0.48	8.5	583	39,700

TABLE 7-continued

EX.	HOLE INJECTING LAYER	HOLE TRANSPORTING LAYER	LIGHT- EMITTING LAYER	ELECTRON TRANSPORTING LAYER	EMITTED COLOR (CIE _x , y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMI- NANCE (cd/m ²)
53	CuPc	NPB	Alq + 5% Compound13	Alq	Orange-Yellow x = 0.51, y = 0.48	8.0	580	39,000
54	CuPc	NPB	Alq + 5% Compound14	Alq	Orange-Yellow x = 0.51, y = 0.48	7.9	584	38,900

[0209]

TABLE 8

EX.	HOLE INJECTING LAYER	HOLE TRANSPORTING LAYER	LIGHT- EMITTING LAYER	ELECTRON TRANSPORTING LAYER	EMITTED- COLOR (CIE _x , y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMI- NANCE (cd/m ²)
55	CuPc	NPB	Alq + 5% Compound15	Alq	Orange-Yellow x = 0.51, y = 0.48	7.9	584	39,000
56	CuPc	NPB	Alq + 5% Compound16	Alq	Orange-Yellow x = 0.51, y = 0.48	8.5	583	39,900
57	CuPc	NPB	Alq + 5% Compound17	Alq	Orange-Yellow x = 0.51, y = 0.48	8.2	584	39,700
58	CuPc	NPB	Alq + 5% Compound18	Alq	Orange-Yellow x = 0.51, y = 0.48	7.9	585	39,100
59	CuPc	NPB	Alq + 5% Compound19	Alq	Orange-Yellow x = 0.51, y = 0.48	8.0	581	39,000
60	CuPc	NPB	Alq + 5% Compound20	Alq	Orange-Yellow x = 0.51, y = 0.48	8.0	585	39,500
61	CuPc	NPB	Alq + 5% Compound21	Alq	Green x = 0.30, y = 0.64	11.0	537	45,000
62	CuPc	NPB	Alq + 5% Compound22	Alq	Green x = 0.30, y = 0.64	9.8	536	41,000
63	CuPc	NPB	Alq + 5% Compound23	Alq	Green x = 0.30, y = 0.64	8.9	535	39,900
64	CuPc	NPB	Alq + 5% Compound24	Alq	Green x = 0.30, y = 0.64	11.0	537	45,000
65	CuPc	NPB	Alq + 5% Compound25	Alq	Green x = 0.30, y = 0.64	11.1	537	45,100
66	CuPc	NPB	Alq + 5% Compound26	Alq	Green x = 0.29, y = 0.65	8.1	529	40,500
67	CuPc	NPB	Alq + 5% Compound27	Alq	Red x = 0.65, y = 0.35	2.0	648	11,000

[0210] As shown in Tables 7 and 8, the organic EL devices of Examples 41-60 provided orange-yellow light emission. The organic EL devices of Examples 61-66 provided green light emission. The organic EL device of Example 67 provided red light emission. The organic EL devices of Examples 41-67 provided high luminous efficiency and high

maximum luminance. This shows that using the rubrene derivatives as light emitting dopants when Alq is used as the host material is effective in enhancing the luminous efficiency and maximum luminance.

[0211] Tables 9 and 10 show measurements of luminescence characteristics of the organic EL devices of Examples 68-94.

TABLE 9

EX.	HOLE INJECTING LAYER	HOLE TRANSPORTING LAYER	LIGHT- EMITTING LAYER	ELECTRON TRANSPORTING LAYER	EMITTED COLOR (CIEx, y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMI- NANCE (cd/m ²)
68	CuPc	NPB	NPB + 5% Compound1	Alq	Orange-Yellow x = 0.49, y = 0.51	12.5	559	46,600
69	CuPc	NPB	NPB + 5% Compound2	Alq	Orange-Yellow x = 0.51, y = 0.48	9.6	572	38,800
70	CuPc	NPB	NPB + 5% Compound3	Alq	Orange-Yellow x = 0.49, y = 0.51	10.1	561	39,100
71	CuPc	NPB	NPB + 5% Compound4	Alq	Orange-Yellow x = 0.51, y = 0.48	9.0	570	37,200
72	CuPc	NPB	NPB + 5% Compound5	Alq	Orange-Yellow x = 0.48, y = 0.52	6.8	558	31,000
73	CuPc	NPB	NPB + 5% Compound6	Alq	Orange-Yellow x = 0.49, y = 0.51	10.1	560	40,100
74	CuPc	NPB	NPB + 5% Compound7	Alq	Orange-Yellow x = 0.49, y = 0.51	12.3	559	45,700
75	CuPc	NPB	NPB + 5% Compound8	Alq	Orange-Yellow x = 0.50, y = 0.50	9.3	561	37,800
76	CuPc	NPB	NPB + 5% Compound9	Alq	Yellow x = 0.47, y = 0.53	7.8	555	33,000
77	CuPc	NPB	NPB + 5% Compound10	Alq	Orange-Yellow x = 0.51, y = 0.48	9.6	572	38,800
78	CuPc	NPB	NPB + 5% Compound11	Alq	Orange-Yellow x = 0.49, y = 0.51	7.8	562	33,100
79	CuPc	NPB	NPB + 5% Compound12	Alq	Orange-Yellow x = 0.49, y = 0.51	11.1	563	42,000
80	CuPc	NPB	NPB + 5% Compound13	Alq	Orange-Yellow x = 0.49, y = 0.51	10.0	564	39,900
81	CuPc	NPB	NPB + 5% Compound14	Alq	Orange-Yellow x = 0.50, y = 0.50	9.3	561	37,600

[0212]

TABLE 10

EX.	HOLE INJECTING LAYER	HOLE TRANSPORTING LAYER	LIGHT- EMITTING LAYER	ELECTRON TRANSPORTING LAYER	EMITTED COLOR (CIEx, y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMI- NANCE (cd/m ²)
82	CuPc	NPB	NPB + 5% Compound15	Alq	Orange-Yellow x = 0.50, y = 0.50	9.4	562	38,000
83	CuPc	NPB	NPB + 5% Compound16	Alq	Orange-Yellow x = 0.49, y = 0.51	12.5	559	46,500
84	CuPc	NPB	NPB + 5% Compound17	Alq	Orange-Yellow x = 0.49, y = 0.51	12.0	561	46,000

TABLE 10-continued

EX.	HOLE INJECTING LAYER	HOLE TRANSPORTING LAYER	LIGHT- EMITTING LAYER	ELECTRON TRANSPORTING LAYER	EMITTED COLOR (CIE _x , y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMI- NANCE (cd/m ²)
85	CuPc	NPB	NPB + 5% Compound18	Alq	Orange-Yellow x = 0.49, y = 0.51	11.5	560	43,400
86	CuPc	NPB	NPB + 5% Compound19	Alq	Orange-Yellow x = 0.49, y = 0.51	10.0	563	39,900
87	CuPc	NPB	NPB + 5% Compound20	Alq	Orange-Yellow x = 0.49, y = 0.51	12.0	561	46,100
88	CuPc	NPB	NPB + 5% Compound21	Alq	Green x = 0.29, y = 0.67	13.0	535	52,000
89	CuPc	NPB	NPB + 5% Compound22	Alq	Green x = 0.29, y = 0.67	10.0	536	42,000
90	CuPc	NPB	NPB + 5% Compound23	Alq	Green x = 0.29, y = 0.67	9.1	534	38,200
91	CuPc	NPB	NPB + 5% Compound24	Alq	Green x = 0.29, y = 0.67	12.5	535	50,100
92	CuPc	NPB	NPB + 5% Compound25	Alq	Green x = 0.29, y = 0.67	12.0	535	47,000
93	CuPc	NPB	NPB + 5% Compound26	Alq	Green x = 0.30, y = 0.65	9.8	539	38,500
94	CuPc	NPB	NPB + 5% Compound27	Alq	Red x = 0.65, y = 0.35	2.1	645	16,100

[0213] As shown in Tables 9 and 10, the organic EL devices of Examples 68-87 provided orange-yellow light emission. The organic EL devices of Examples 88-93 provided green light emission. The organic EL device of Example 94 provided red light emission. The organic EL devices of Examples 68-94 provided high luminous efficiency and high maximum luminance. This shows that using

the rubrene derivatives as light emitting dopants when NPB is used as a host material is effective in enhancing the luminous efficiency and maximum luminance.

[0214] Table 11 shows measurements of luminescence characteristics of the organic EL devices of Examples 95-108.

TABLE 11

EX.	HOLE IN- JECT- ING LAYER	HOLE TRANS- PORT- ING LAYER	1st LIGHT- EMITTING LAYER	2nd LIGHT- EMITTING LAYER	ELECTRON TRANS- PORT- ING LAYER	EMITTED COLOR (CIE _x , y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE- LENGTH (nm)	MAX LUMINANCE (cd/m ²)
95	CuPc	NPB	NPB + 2% Compound1	Diphenylanthracene + 2% Perylene	Alq	White x = 0.35, y = 0.34	15.0	489,560	66,000
96	CuPc	NPB	NPB + 2% Compound1	Dianthrylanthracene + 2% Perylene	Alq	White x = 0.35, y = 0.34	15.0	489,560	66,000
97	CuPc	NPB	NPB + 2% Compound3	Dianthrylanthracene + 2% Perylene	Alq	White x = 0.35, y = 0.34	14.1	490,560	61,000
98	CuPc	NPB	NPB + 2% Compound7	Dianthrylanthracene + 2% Perylene	Alq	White x = 0.35, y = 0.34	15.3	489,560	67,000
99	CuPc	NPB	NPB + 2% Compound8	Diphenylanthracene + 2% Perylene	Alq	White x = 0.35, y = 0.34	12.0	489,563	49,800
100	CuPc	NPB	NPB + 2% Compound16	Dianthrylanthracene + 2% Perylene	Alq	White x = 0.35, y = 0.34	15.6	489,560	68,000

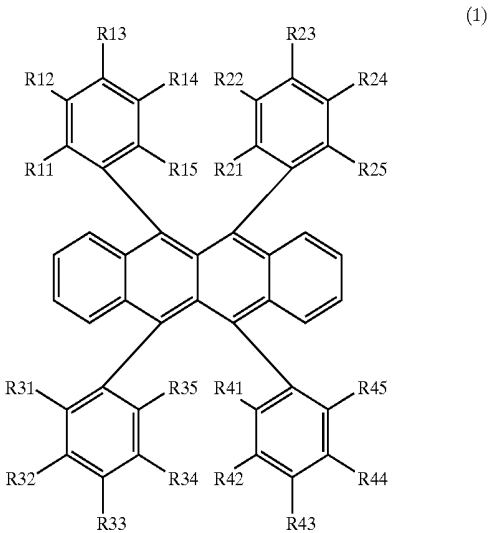
TABLE 11-continued

EX.	HOLE IN-JECT-ING LAYER	HOLE TRANS-PORT-ING LAYER	1st LIGHT-EMITTING LAYER	2nd LIGHT-EMITTING LAYER	ELECTRON TRANS-PORT-ING LAYER	EMITTED COLOR (CIEx, y)	LUMINOUS EFFICIENCY (cd/A) At100 cd/m ²	WAVE-LENGTH (nm)	MAX LUMINANCE (cd/m ²)
101	CuPc	NPB	NPB + 2% Compound17	Dianthranylthracene + 2% Perylene	Alq	White x = 0.35, y = 0.35	14.5	489,561	62,000
102	CuPc	NPB	NPB + 2% Compound18	Dianthranylthracene + 2% Perylene	Alq	White x = 0.34, y = 0.36	12.2	489,566	50,000
103	CuPc	NPB	NPB + 2% Compound19	Dianthranylthracene + 2% Perylene	Alq	White x = 0.35, y = 0.36	14.7	489,568	62,000
104	CuPc	NPB	NPB + 2% Compound20	Dianthranylthracene + 2% Perylene	Alq	White x = 0.35, y = 0.34	14.5	489,560	61,700
105	CuPc	NPB	NPB + 5% Compound1 + 3% Compound94	Dianthranylthracene + 2% Perylene	Alq	White x = 0.33, y = 0.33	16.1	490,560	73,000
106	CuPc	NPB	NPB + 5% Compound1 + 3% Compound136	Dianthranylthracene + 2% Perylene	Alq	White x = 0.33, y = 0.33	16.5	490,560	75,000
107	CuPc	NPB	NPB + 5% Compound1 + 3% Compound137	Dianthranylthracene + 2% Perylene	Alq	White x = 0.34, y = 0.33	16.2	490,560	73,000
108	CuPc	NPB	NPB + 5% Compound1 + 3% Compound138	Dianthranylthracene + 2% Perylene	Alq	White x = 0.34, y = 0.34	16.0	490,560	72,000

[0215] As shown in Table 11, the organic EL devices of Examples 95-108 provided white light emission. The organic EL devices of Examples 95-108 provided high luminous efficiency and high maximum luminance. This shows that using the rubrene derivatives as light emitting dopants in the first light emitting layer is effective in enhancing the luminous efficiency and maximum luminance.

[0216] In particular, Examples 105-108 used two kinds of light emitting dopants in the first light emitting layer: an orange-emitting rubrene derivative and a green-emitting rubrene derivative, whereby the luminous efficiency of white and the color purity of white were enhanced.

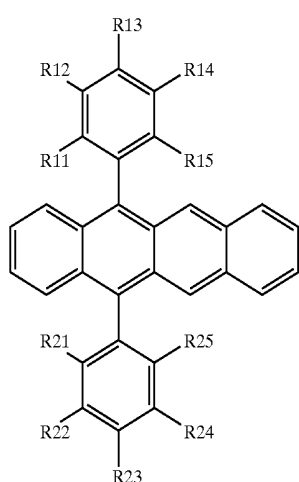
[0217] Thus, it was seen from Examples 34-108 that using the rubrene derivatives shown above as a light emitting dopant or light-emission assisting dopant in a light emitting layer improves luminous efficiency and luminance.



1. An organic electroluminescent device comprising:
- a hole injecting electrode;
- an electron injecting electrode; and
- a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer containing a rubrene derivative having a molecular structure represented by Formula (1):

wherein R11-R15, R21-R25, R31-R35 and R41-R45 are the same or different and each represent a hydrogen atom or a substituent, where the structure in which all are hydrogen atoms is excluded, and adjacent two of R11-R15, adjacent two of R21-R25, adjacent two of R31-R35, and adjacent two of R41-R45 may be bonded together to form rings, and adjacent three of R11-R15, adjacent three of R21-R25, adjacent three of R31-R35, and adjacent three of R41-R45 may be bonded together to form rings.

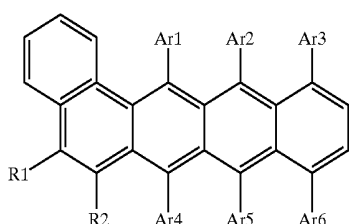
2. An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer containing a rubrene derivative having a molecular structure represented by Formula (2):



(2)

wherein R 11-R15 and R21-R25 are the same or different and each represent a hydrogen atom or a substituent, adjacent two of R 11-R15 and adjacent two of R21-R25 may be bonded together to form rings, and adjacent three of R11-R15 and adjacent three of R21-R25 may be bonded together to form rings.

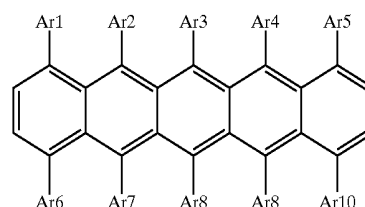
3. An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer containing a rubrene derivative having a molecular structure represented by Formula (3):



(3)

wherein Ar1-Ar6 are the same or different and each represent a hydrogen atom or a substituent, R1 and R2 are the same or different and each represent a hydrogen atom or a substituent, and adjacent R1 and R2 may be bonded together to form a ring.

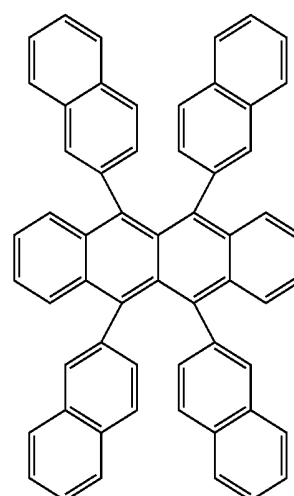
4. An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer containing a rubrene derivative having a molecular structure represented by Formula (4):



(4)

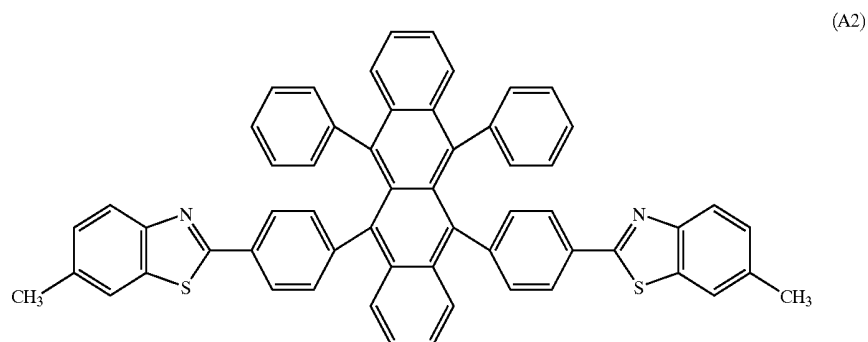
wherein Ar1-Ar10 are the same or different and each represent a hydrogen atom or a substituent.

5. The organic electroluminescent device according to claim 1, wherein said rubrene derivative is 5,6,11,12-tetrakis(naphth-2-yl)naphthacene having a molecular structure represented by Formula (A1).

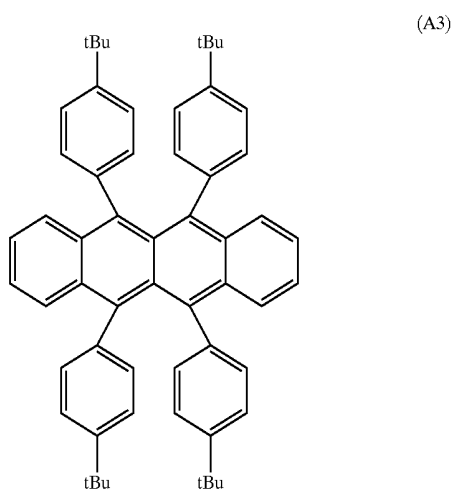


(A1)

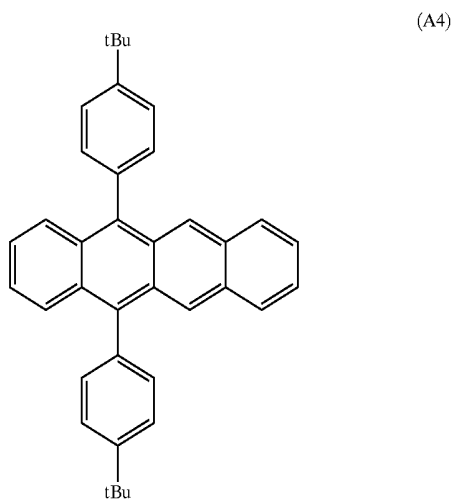
6. The organic electroluminescent device according to claim 1, wherein said rubrene derivative is 5,12-bis(4-(6-methylbenzothiazole-2-yl)phenyl)-6,11-diphenylnaphthacene represented by Formula (A2).



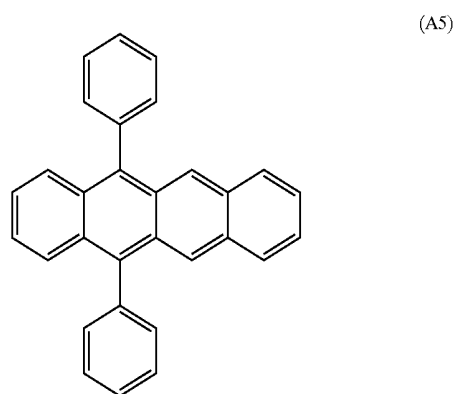
7. The organic electroluminescent device according to claim 1, wherein said rubrene derivative is 5,6,11,12-tetrakis(4-tert-butylphenyl)-naphthacene represented by



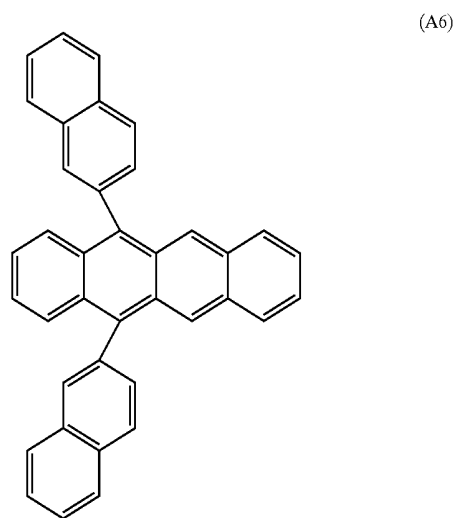
8. The organic electroluminescent device according to claim 2, wherein said rubrene derivative is 5,12-bis(4-tert-butylphenyl)-naphthacene represented by Formula (A4).



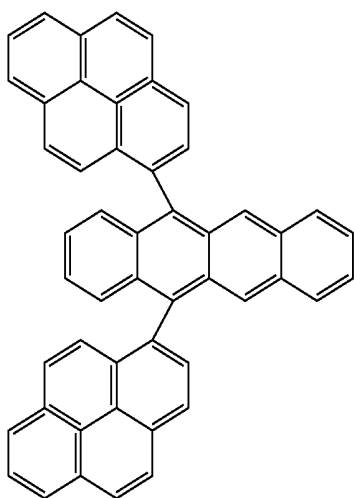
9. The organic electroluminescent device according to claim 2, wherein said rubrene derivative is 5,12-diphenyl-naphthacene represented by Formula (A5).



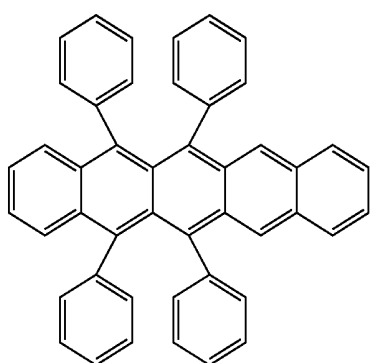
10. The organic electroluminescent device according to claim 2, wherein said rubrene derivative is 5,12-bis(naphth-2-yl)-naphthacene represented by Formula (A6).



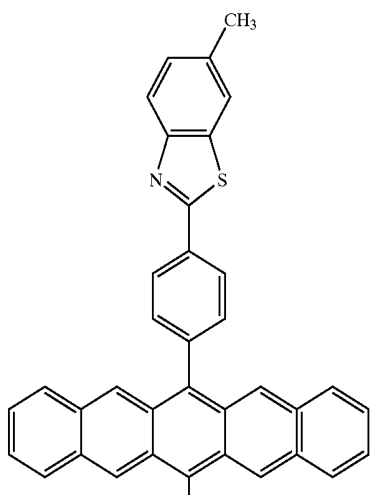
11. The organic electroluminescent device according to claim 2, wherein said rubrene derivative is 5,12-bis(pyrene-1-yl)-naphthacene represented by Formula (A7).



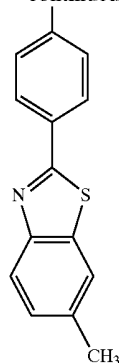
12. The organic electroluminescent device according to claim 3, wherein said rubrene derivative is 5,6,13,14-6-tetrakisphenyl-pentacene represented by Formula (A8).



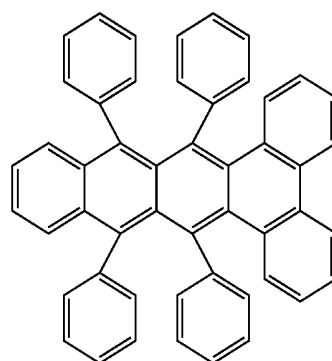
13. The organic electroluminescent device according to claim 3, wherein said rubrene derivative is 6,13-bis(4-(6-methylbenzothiazole-2-yl)phenyl)-pentacene represented by Formula (A9).



-continued



14. The organic electroluminescent device according to claim 4, wherein said rubrene derivative is 5,6,11,12-tetrakisphenyl-1,2-benzo-(3,4-benzo-)naphthacene represented by Formula (A10).



15. The organic electroluminescent device according to claim 1, wherein said light emitting layer contains a host material, a light emitting dopant, and a first light-emission assisting dopant, and said first light-emission assisting dopant is composed of said rubrene derivative.

16. The organic electroluminescent device according to claim 15, wherein said light emitting layer further contains a second light-emission assisting dopant.

17. The organic electroluminescent device according to claim 1, wherein said light emitting layer contains a host material and a light emitting dopant, and said light emitting dopant is composed of said rubrene derivative.

18. The organic electroluminescent device according to claim 15, wherein the content of said light emitting dopant is not less than 0.1 percent by weight nor more than 50 percent by weight, with respect to said host material.

19. An organic electroluminescent device comprising:

a hole injecting electrode;

an electron injecting electrode; and

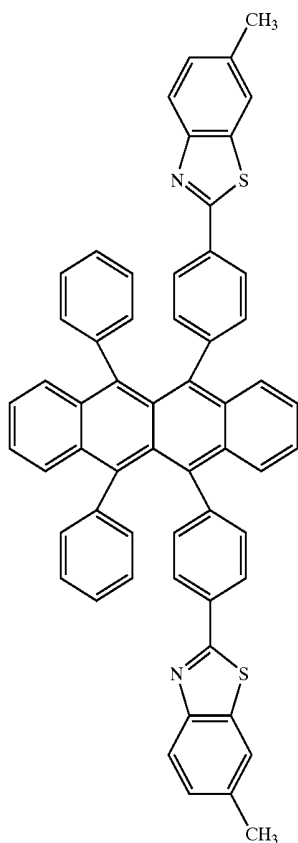
a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,

said light emitting layer comprising,

a first light emitting layer that contains a compound having a molecular structure represented by Formula (C1), and

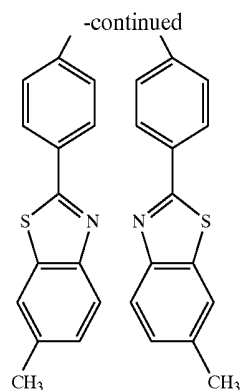
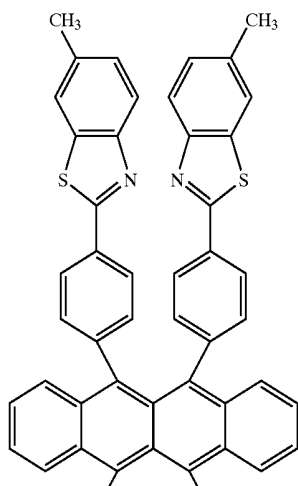
a second light emitting layer that contains a luminescent material that emits blue light.

(C1)



20. An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer comprising,
 a first light emitting layer that contains a compound having a molecular structure represented by Formula (C2), and
 a second light emitting layer that contains a luminescent material that emits blue light.

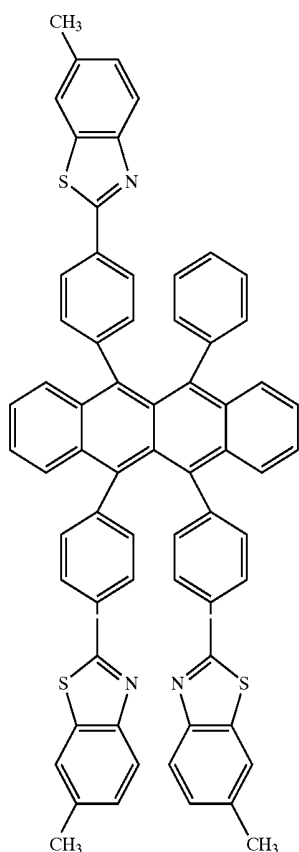
(C2)



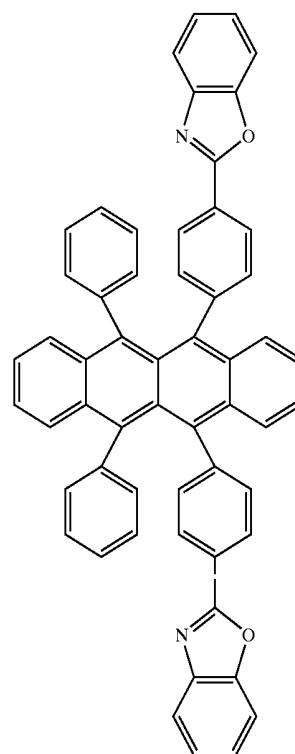
(C3)

21. An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer comprising,
 a first light emitting layer that contains a compound having a molecular structure represented by Formula (C3), and
 a second light emitting layer that contains a luminescent material that emits blue light.

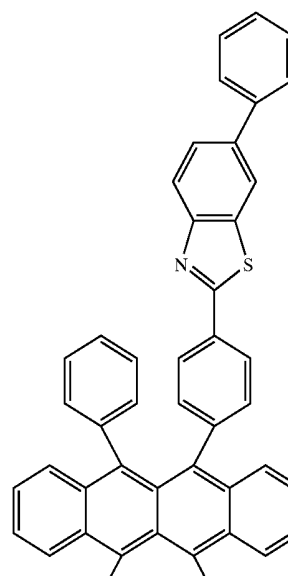
- 22.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising,
- a first light emitting layer that contains a compound having a molecular structure represented by Formula (C4), and
 - a second light emitting layer that contains a luminescent material that emits blue light.

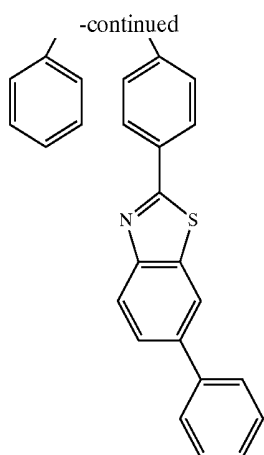


- 23.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising,
- a first light emitting layer that contains a compound having a molecular structure represented by Formula (C5), and
 - a second light emitting layer that contains a luminescent material that emits blue light.

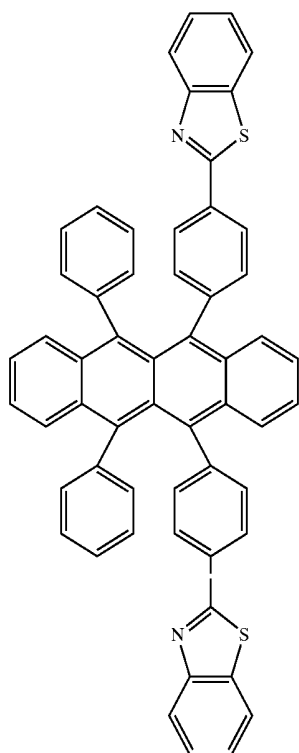


- 24.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising,
- a first light emitting layer that contains a compound having a molecular structure represented by Formula (C6), and
 - a second light emitting layer that contains a luminescent material that emits blue light.





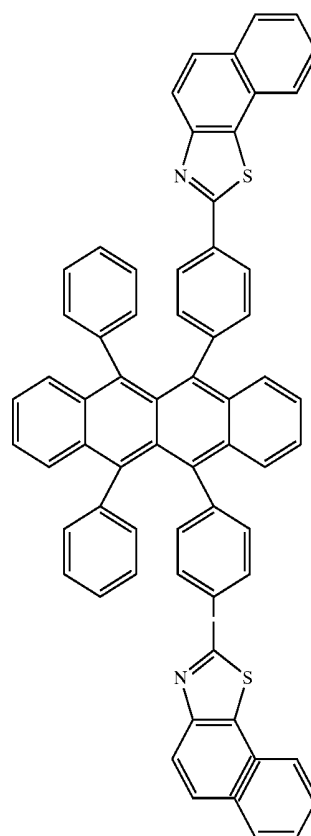
- 25.** An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer comprising,
 a first light emitting layer that contains a compound having a molecular structure represented by Formula (C7), and
 a second light emitting layer that contains a luminescent material that emits blue light.



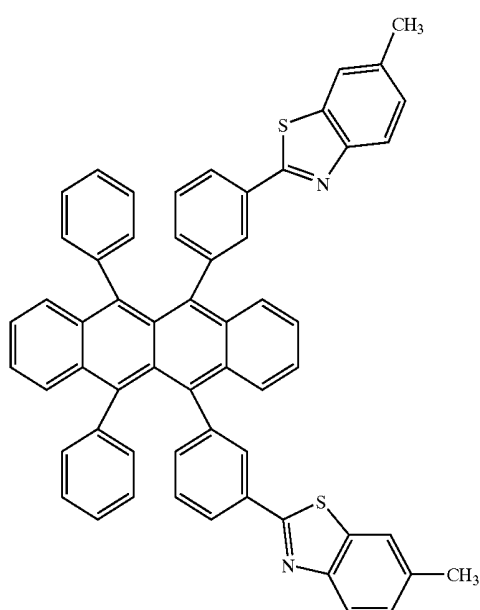
(C7)

- 26.** An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer comprising,
 a first light emitting layer that contains a compound having a molecular structure represented by Formula (C8), and
 a second light emitting layer that contains a luminescent material that emits blue light.

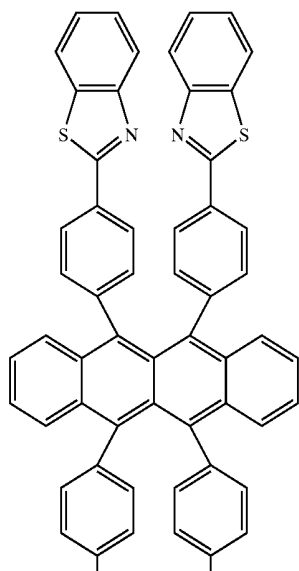
(C8)



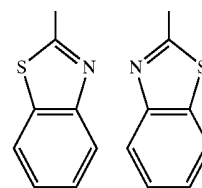
- 27.** An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer comprising,
 a first light emitting layer that contains a compound having a molecular structure represented by Formula (C9), and
 a second light emitting layer that contains a luminescent material that emits blue light.



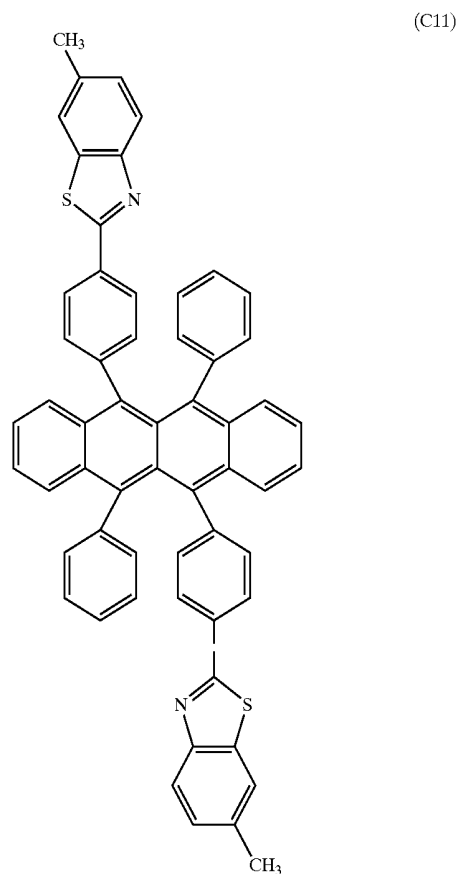
- 28.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising,
- a first light emitting layer that contains a compound having a molecular structure represented by Formula (C10), and
 - a second light emitting layer that contains a luminescent material that emits blue light.



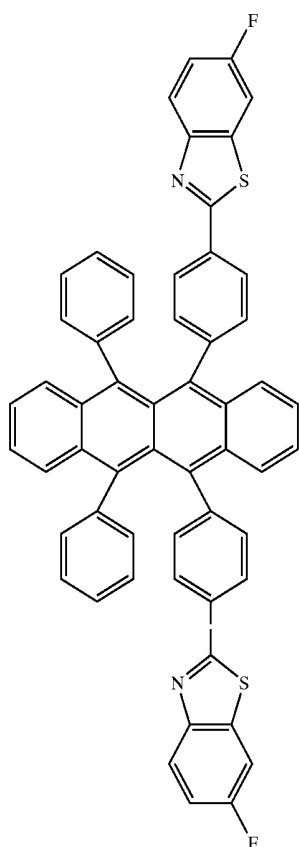
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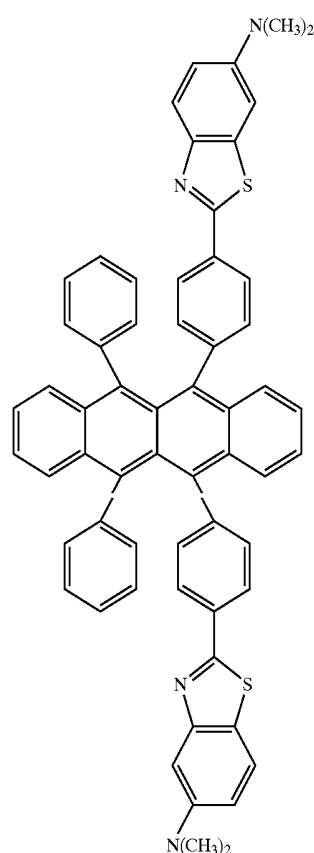
- 29.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising,
- a first light emitting layer that contains a compound having a molecular structure represented by Formula (C11), and
 - a second light emitting layer that contains a luminescent material that emits blue light.



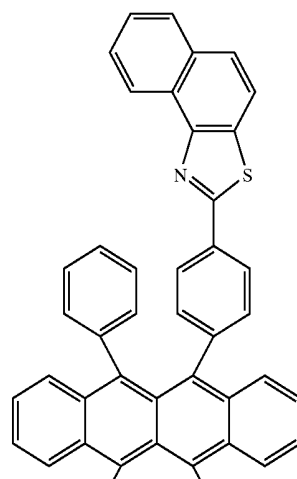
- 30.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising,
- a first light emitting layer that contains a compound having a molecular structure represented by Formula (C12), and
 - a second light emitting layer that contains a luminescent material that emits blue light.

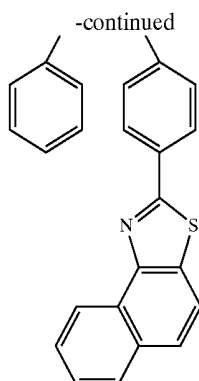


- 31.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising,
- a first light emitting layer that contains a compound having a molecular structure represented by Formula (C13), and
 - a second light emitting layer that contains a luminescent material that emits blue light.



- 32.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising,
- a first light emitting layer that contains a compound having a molecular structure represented by Formula (C14), and
 - a second light emitting layer that contains a luminescent material that emits blue light.
- 33.** An organic electroluminescent device comprising:





a hole injecting electrode;

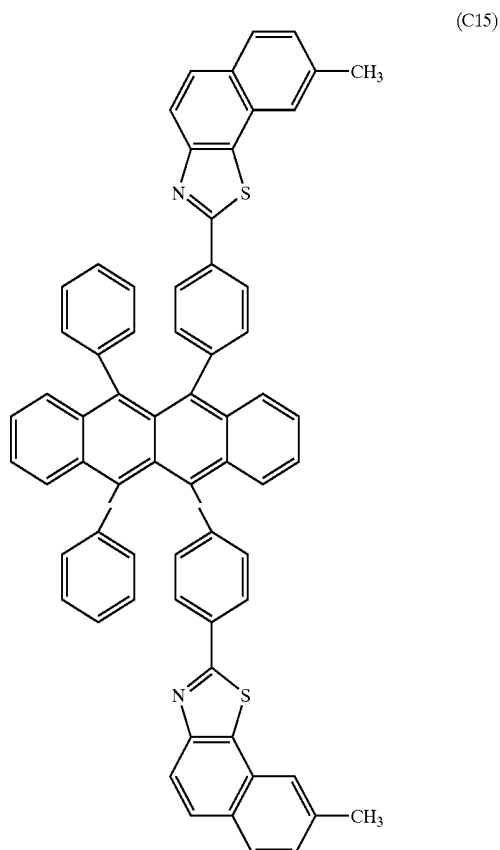
an electron injecting electrode; and

a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,

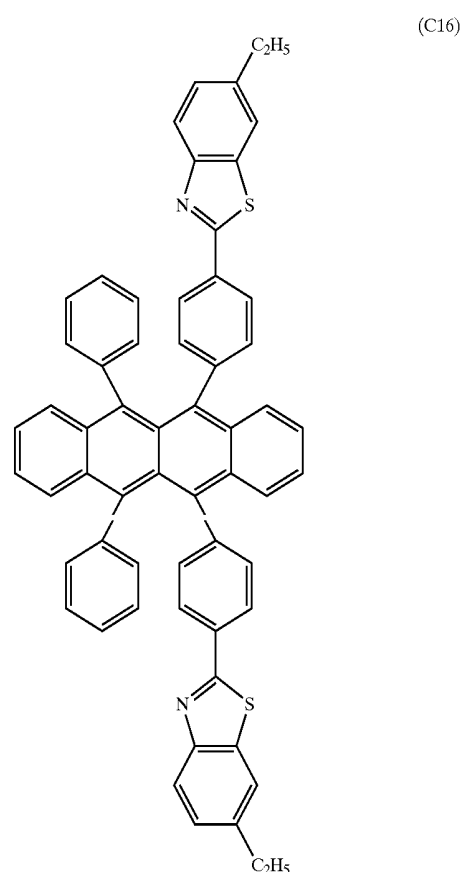
said light emitting layer comprising,

a first light emitting layer that contains a compound having a molecular structure represented by Formula (C15), and

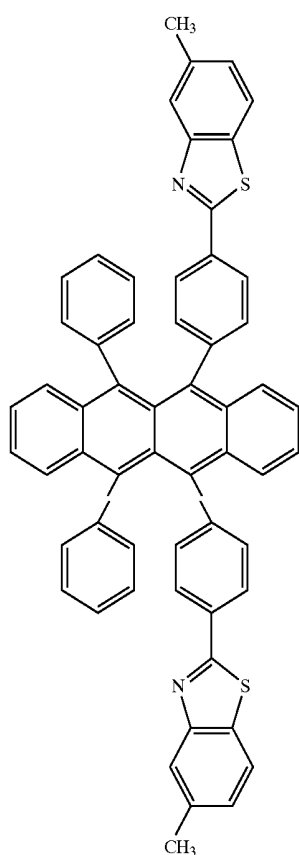
a second light emitting layer that contains a luminescent material that emits blue light.



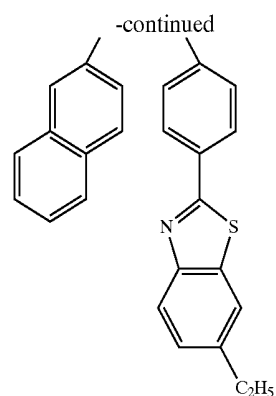
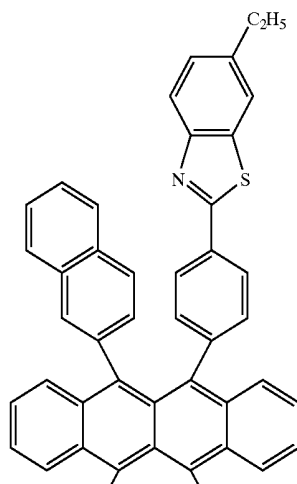
34. An organic electroluminescent device comprising:
a hole injecting electrode;
an electron injecting electrode; and
a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
said light emitting layer comprising,
a first light emitting layer that contains a compound having a molecular structure represented by Formula (C16), and
a second light emitting layer that contains a luminescent material that emits blue light.



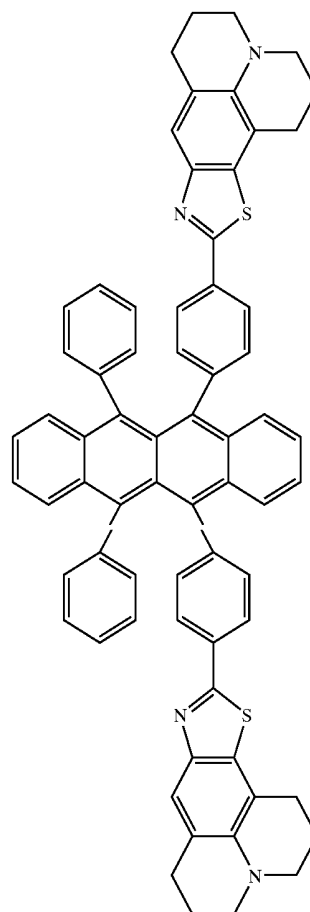
35. An organic electroluminescent device comprising:
a hole injecting electrode;
an electron injecting electrode; and
a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
said light emitting layer comprising,
a first light emitting layer that contains a compound having a molecular structure represented by Formula (C17), and
a second light emitting layer that contains a luminescent material that emits blue light.



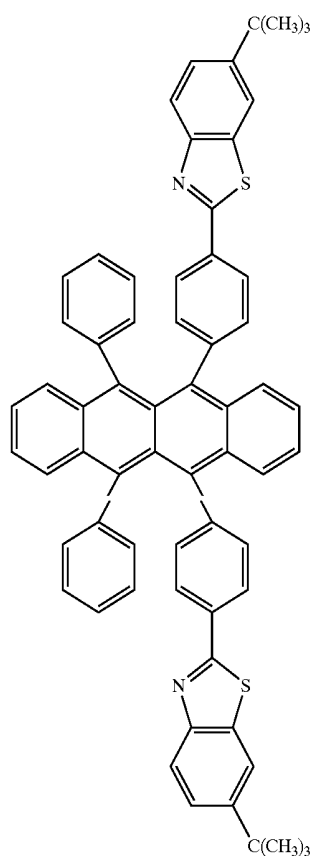
- 36.** An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer comprising,
 a first light emitting layer that contains a compound having a molecular structure represented by Formula (C18), and
 a second light emitting layer that contains a luminescent material that emits blue light.



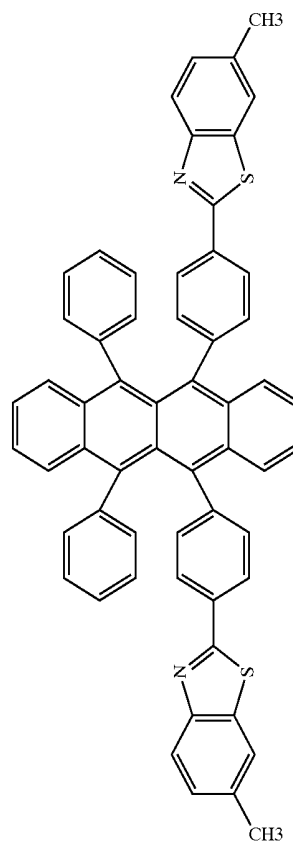
- 37.** An organic electroluminescent device comprising:
 a hole injecting electrode;
 an electron injecting electrode; and
 a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
 said light emitting layer comprising,
 a first light emitting layer that contains a compound having a molecular structure represented by Formula (C19), and
 a second light emitting layer that contains a luminescent material that emits blue light.



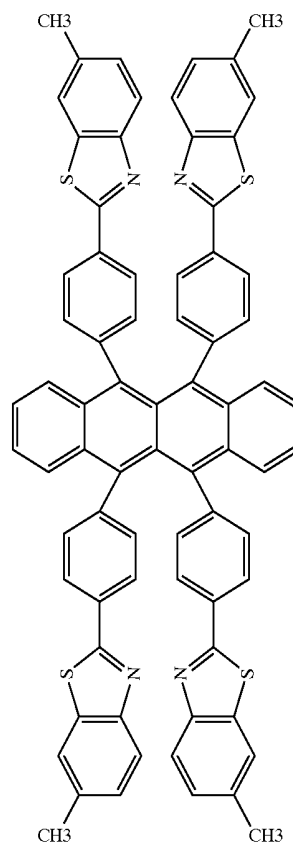
- 38.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising,
- a first light emitting layer that contains a compound having a molecular structure represented by Formula (C20), and
 - a second light emitting layer that contains a luminescent material that emits blue light.



(C20)



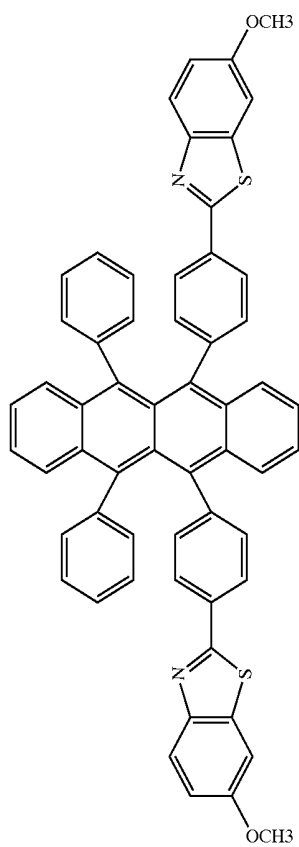
(C1)



(C2)

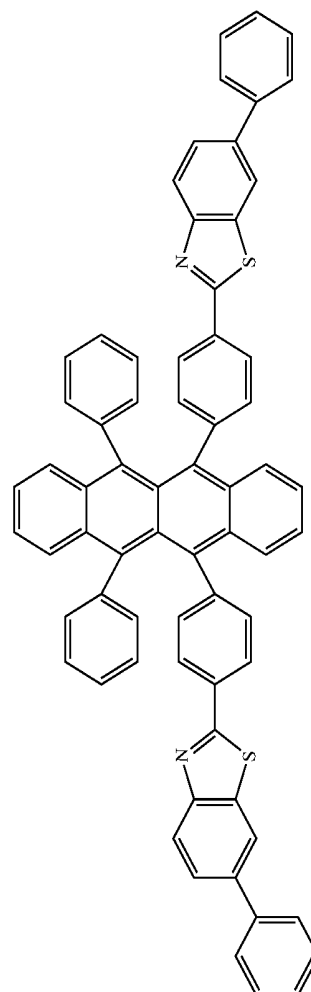
- 39.** An organic electroluminescent device comprising:
- a hole injecting electrode;
 - an electron injecting electrode; and
 - a light emitting layer provided between said hole injecting electrode and said electron injecting electrode,
- said light emitting layer comprising a first light emitting layer that contains at least one compound selected from the group consisting of compounds having molecular structures represented by Formulas (C1)-(C20) and at least one compound selected from the group consisting of compounds represented by Formulas (A4)-(A7), (A10), and (C21)-(C27), and a second light emitting layer that contains a luminescent material that emits blue light.

-continued



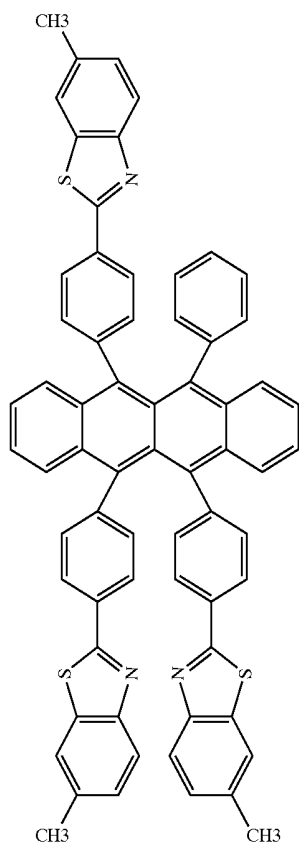
(C3)

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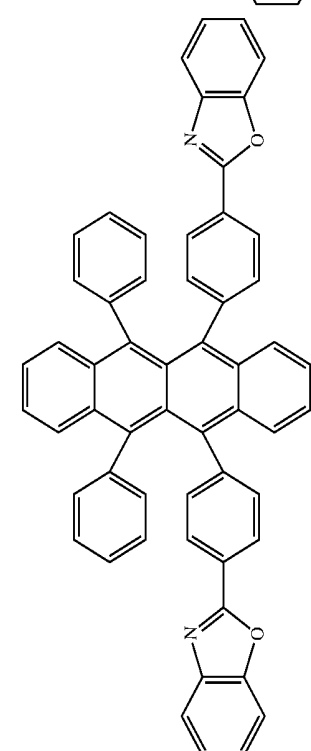


(C6)

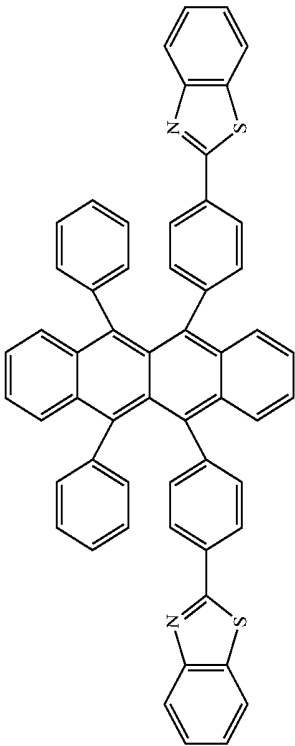
(C4)



(C5)

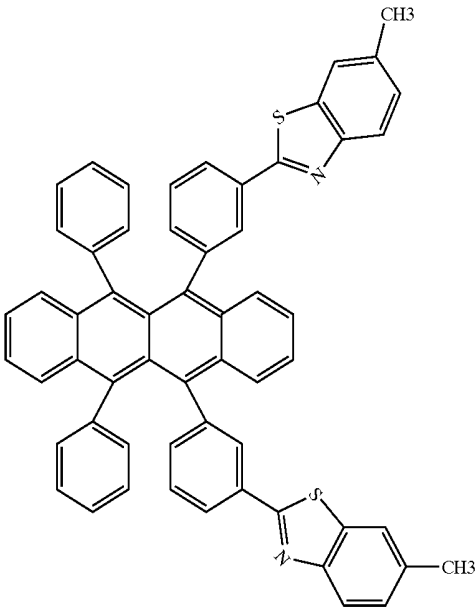


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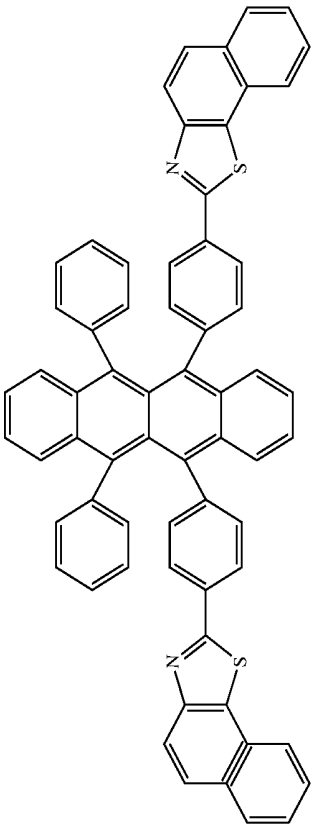
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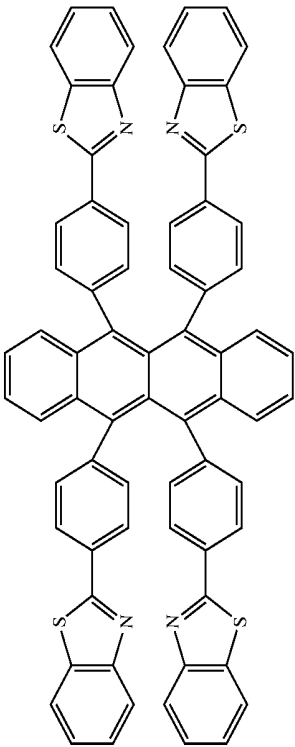


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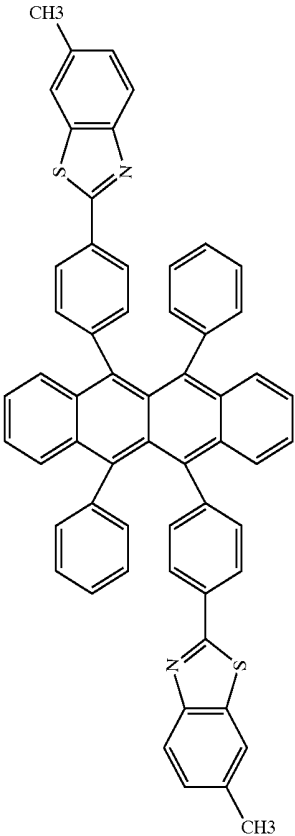
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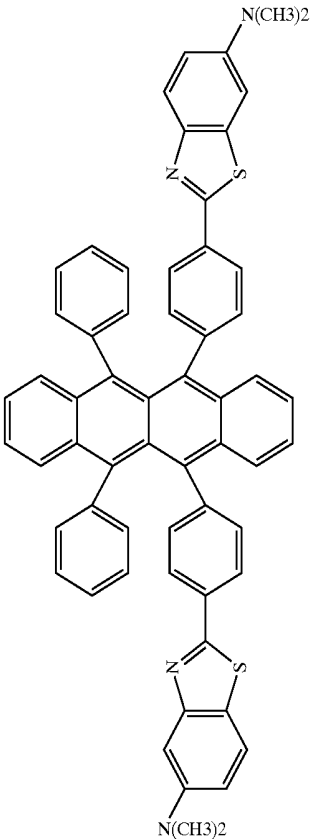
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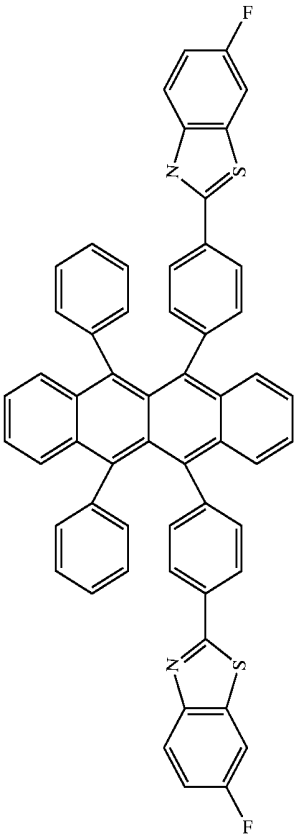
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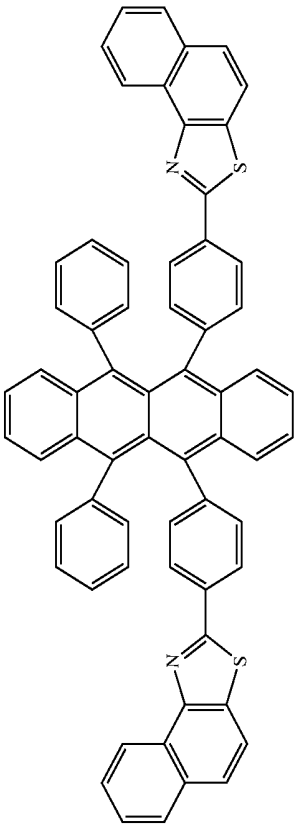
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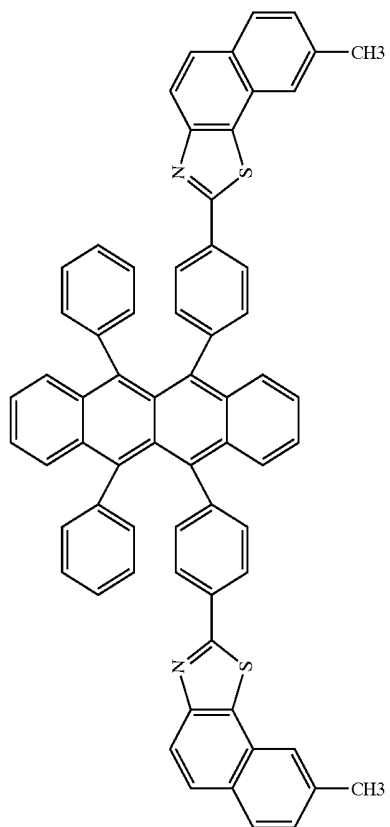
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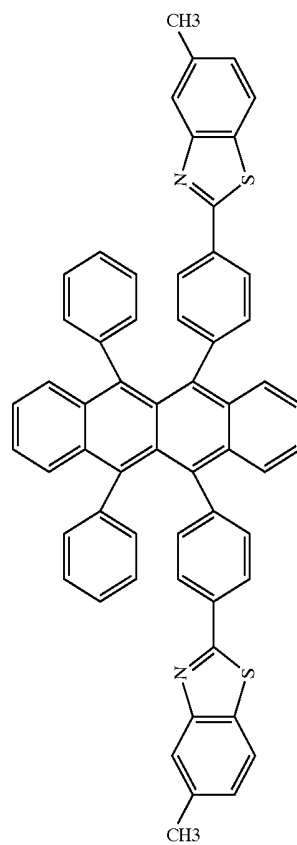
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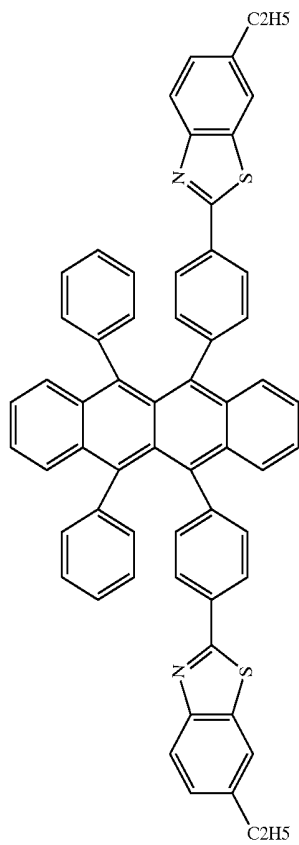
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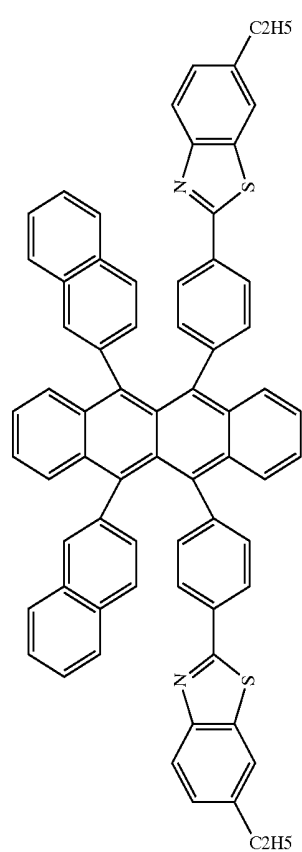
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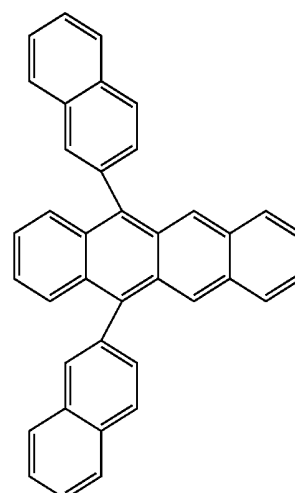
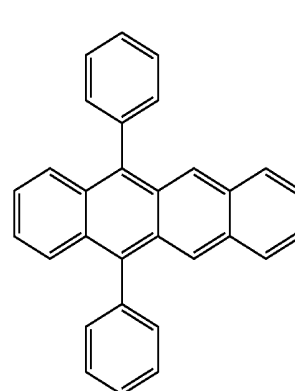
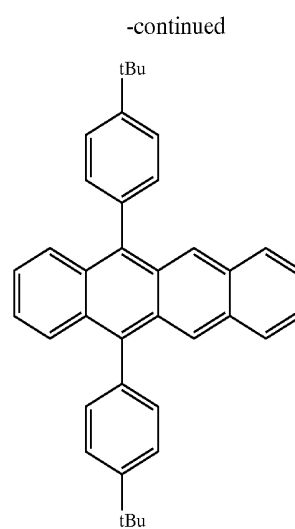
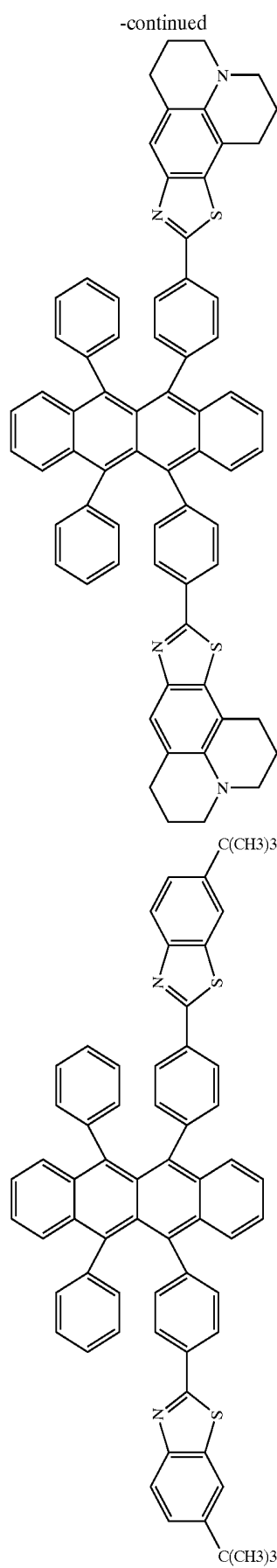


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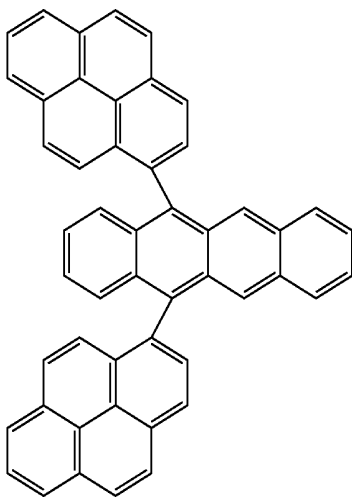


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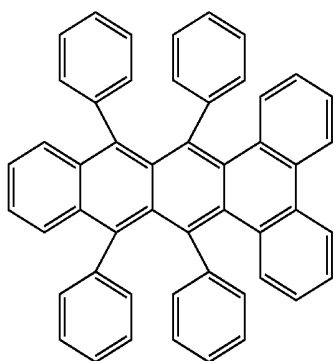




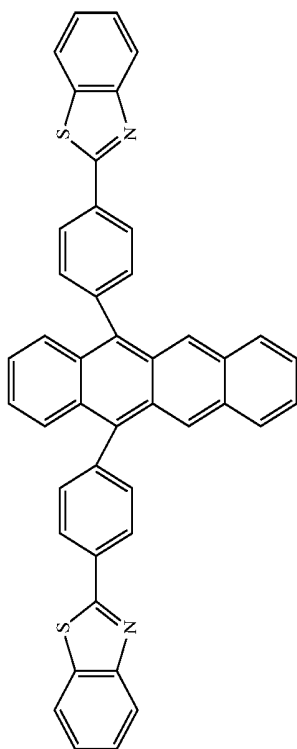
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(A7)

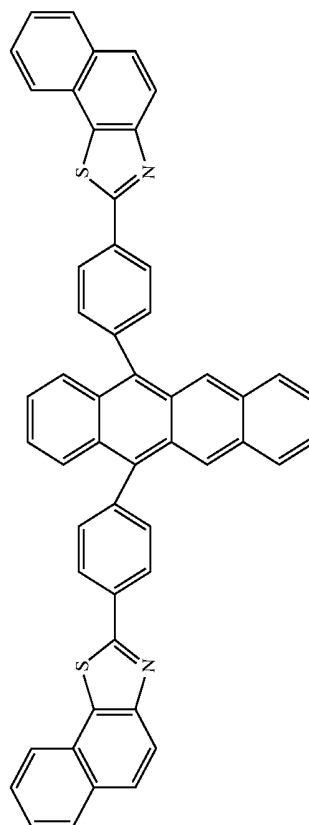


(A10)

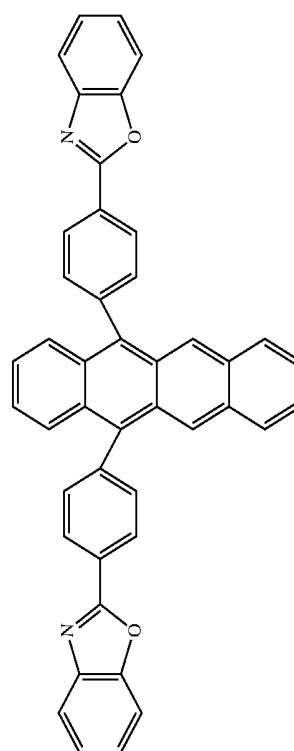


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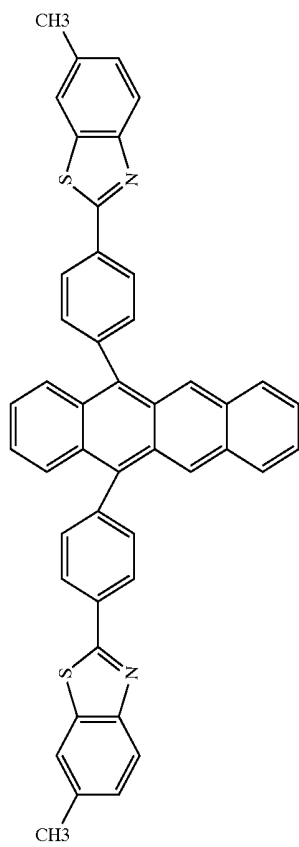


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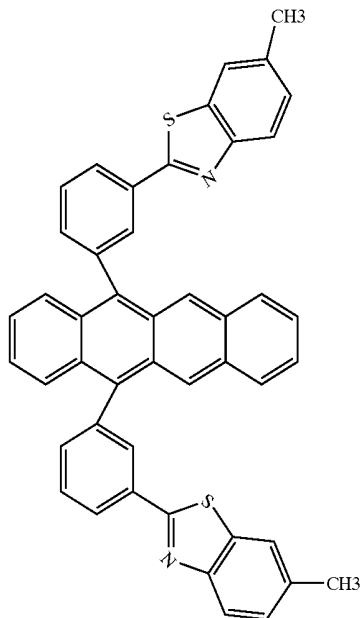
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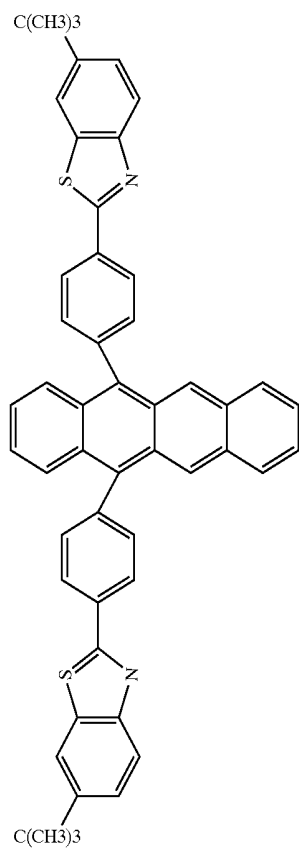


(C24)

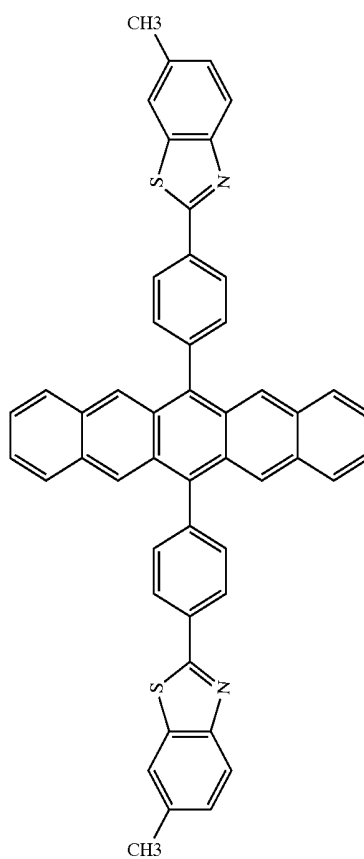
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(C26)

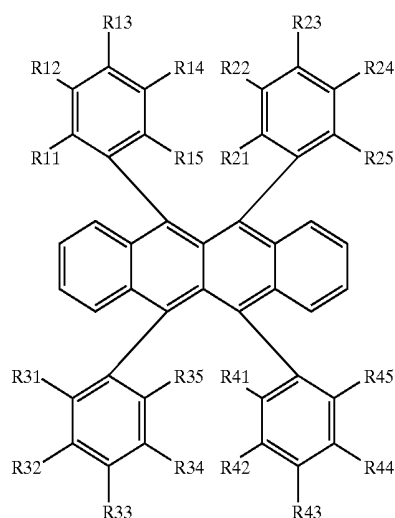


(C25)



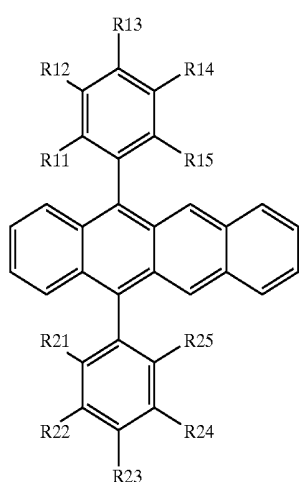
(C27)

40. A luminescent material having a molecular structure represented by Formula (1):



wherein R11-R15, R21-R25, R31-R35 and R41-R45 are the same or different and each represent a hydrogen atom or a substituent, where the structure in which all are hydrogen atoms is excluded, and adjacent two of R11-R15, adjacent two of R21-R25, adjacent two of R31-R35, and adjacent two of R41-R45 may be bonded together to form rings, and adjacent three of R11-R15, adjacent three of R21-R25, adjacent three of R31-R35, and adjacent three of R41-R45 may be bonded together to form rings.

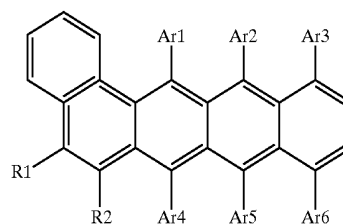
41. A luminescent material having a molecular structure represented by Formula (2):



(2)

wherein R11-R15 and R21-R25 are the same or different and each represent a hydrogen atom or a substituent, adjacent two of R11-R15 and adjacent two of R21-R25 may be bonded together to form rings, and adjacent three of R11-R15 and adjacent three of R21-R25 may be bonded together to form rings.

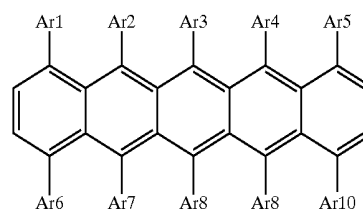
42. A luminescent material having a molecular structure represented by Formula (3):



(3)

wherein Ar1-Ar6 are the same or different and each represent a hydrogen atom or a substituent, and R1 and R2 are the same or different and each represent a hydrogen atom or a substituent, and adjacent R1 and R2 may be bonded together to form a ring.

43. A luminescent material having a molecular structure represented by Formula (4):



(4)

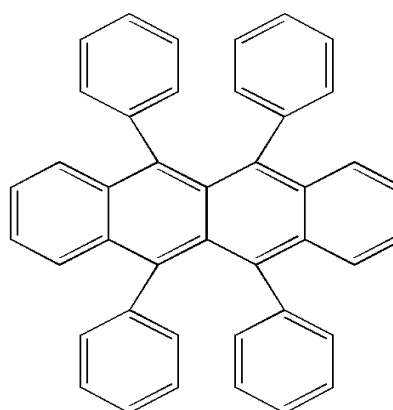
wherein Ar1-Ar10 are the same or different and each represent a hydrogen atom or a substituent.

* * * * *

专利名称(译)	有机电致发光器件和亮度材料		
公开(公告)号	US20050079381A1	公开(公告)日	2005-04-14
申请号	US10/479734	申请日	2002-06-04
[标]申请(专利权)人(译)	滨田YUJI TSUJIOKA TSUYOSHI		
申请(专利权)人(译)	滨田YUJI TSUJIOKA TSUYOSHI		
当前申请(专利权)人(译)	SANYO ELECTRIC CO. , LTD.		
[标]发明人	HAMADA YUJI TSUJIOKA TSUYOSHI		
发明人	HAMADA, YUJI TSUJIOKA, TSUYOSHI		
IPC分类号	H01L51/50 C07C15/38 C07D263/56 C07D277/66 C07D471/16 C09K11/06 H01L51/00 H01L51/30 H05B33/14		
CPC分类号	C09K11/06 C09K2211/1003 C09K2211/1011 C09K2211/1033 C09K2211/1037 H01L51/0054 Y10S428/917 H01L51/0058 H01L51/0059 H01L51/0069 H01L51/0071 H01L51/5012 H01L51/5036 H01L51/0055		
优先权	2001171664 2001-06-06 JP 2002161323 2002-06-03 JP		
其他公开文献	US7598666		
外部链接	Espacenet USPTO		

摘要(译)

提供一种有机EL器件，其能够提供高亮度和高发光效率。在有机EL器件中，空穴注入电极位于玻璃基板上，并且在其上依次形成空穴注入层，空穴传输层和发光层。电子注入电极位于发光层上。发光层包含主体材料，发光掺杂剂和第一发光辅助掺杂剂。第一种发光辅助掺杂剂由红荧烯衍生物组成。



RUBRENE