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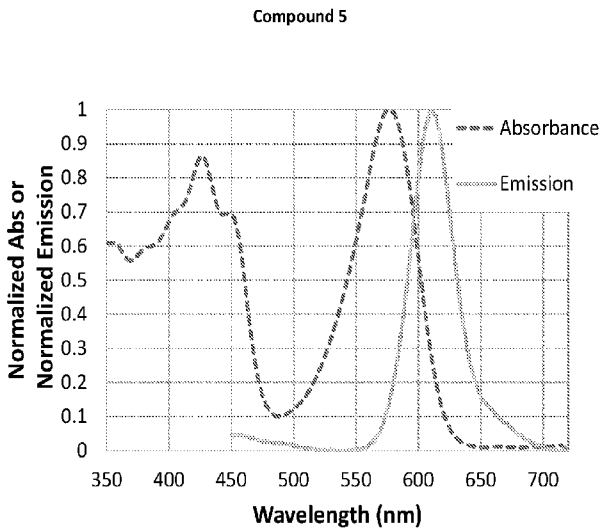


FIG. 1

(57) Abstract: The present disclosure relates to novel photoluminescent complex comprising a BODIPY moiety covalently bonded to a blue light absorbing xanthenoisoquinoline derivative, and a color conversion film and a back-light unit using the same

WO 2023/158977 A1

[Continued on next page]

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BORON-CONTAINING CYCLIC EMISSIVE COMPOUNDS AND COLOR CONVERSION FILM CONTAINING THE SAME

Inventors: Shijun Zheng, Jeffrey R. Hammaker, Xinliang Ding, Peng Wang, Tissa Sajoto, Jie Cai, Isamu Kitahara, and Hiep Luu

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Nos. 63/311,640, filed February 18, 2022, and 63/346,756 filed May 27, 2022, both of which are incorporated by reference in their entirety.

FIELD

The present disclosure is related to compounds for use in a color conversion film, and backlight unit and a display apparatus including the same.

BACKGROUND

Unless otherwise indicated in the present disclosure, the materials described in the present disclosure are not prior art to the claims in the present application and are not admitted to be prior art by inclusion in this section.

In color reproduction the gamut, or color gamut, is a certain complete subset of colors available on a device such as a television or monitor. For example, Adobe™ Red Green Blue (RGB), a wide-gamut color space achieved by using pure spectral primary colors, was developed to provide a broader color gamut and offer a more realistic representation of visible colors viewed through a display. It is believed that a device which could provide a wider gamut could enable the display to portray more vibrant colors.

As high-definition large screen displays become more common, the demand for higher performance, slimmer and highly functional displays has increased. Current light emitting diodes (LEDs) are obtained by a blue light source exciting a green phosphor, a red phosphor, or a yellow phosphor to obtain a white light source. However, the full width half maximum (FWHM) of the emission peak of the current green and red phosphors are quite large usually greater than 40 nm, resulting in the green and red color spectrums overlapping and rendering colors that are not fully distinguishable from one another. This overlap leads to poor color rendition and the deterioration of the color gamut.

To correct the deterioration in the color gamut, methods have been developed using films containing quantum dots in combination with LEDs. Quantum dots suffer from a variety of shortcomings including toxicity, low efficiency, expensive encapsulating processes and size uniformity.

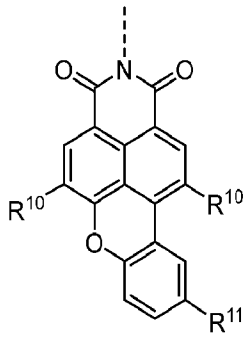
Therefore, there exists a need for improving performance in color conversion films, backlight units, and display devices.

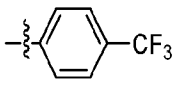
SUMMARY

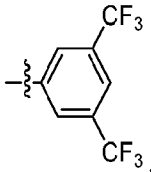
Photoluminescent complexes described herein may be used to improve the contrast between distinguishable colors in televisions, computer monitors, smart devices and any other device that utilizes color displays. The photoluminescent complexes of the present disclosure provides novel color converting dye complex with good blue light absorbance and narrow emissions bandwidths, with the full width half maximum [FWHM] of emission band of less than about 40 nm. In some embodiments, a photoluminescent complex absorbs light of a first wavelength and emits light of a second higher wavelength than the first wavelength. The photoluminescent complexes disclosed herein may be utilized with a color conversion film for use in a light emitting apparatus. The color conversion film of the present disclosure reduced color deterioration by reducing overlap within the color spectrum resulting in high quality color rendition.

In some embodiments, the photoluminescent complex described herein may include a blue light absorbing xanthenoisoquinoline derivative; a linker complex, wherein the linker complex is an unsubstituted ester or substituted ester; and a boron-dipyrromethene (BODIPY) moiety, wherein the linker complex covalently links the xanthenoisoquinoline derivative and the BODIPY moiety, wherein the xanthenoisoquinoline derivative absorbs light energy of a first excitation wavelength and transfers an energy to the BODIPY moiety, wherein the BODIPY moiety absorbs the energy from the xanthenoisoquinoline derivative and emits a light energy of a second higher wavelength, and wherein the photoluminescent complex has an emission quantum yield greater than 80%.

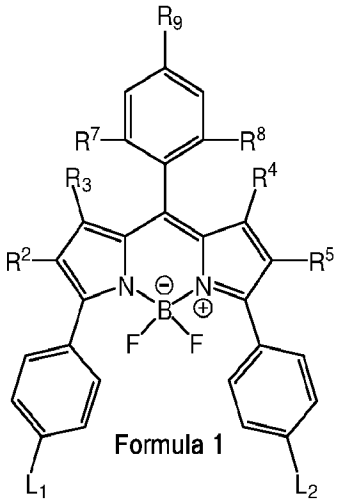
In some embodiments, the xanthenoisoquinoline derivative may be of the general formula:



, wherein R^{10} is a bond, an H, a C_1-C_4 alkyl group, or an optionally substituted aryl group. In some embodiments the optionally substituted aryl group may comprise 

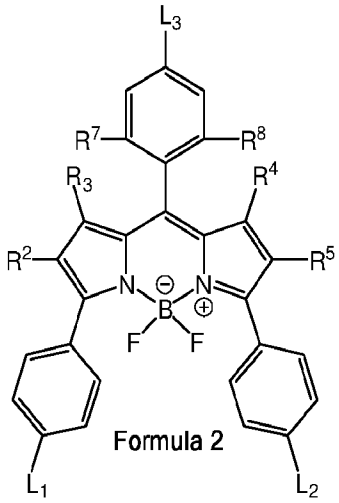
, and/or 

. In some embodiments, the BODIPY moiety may be of the general Formula 1 or Formula 2, as shown below:



Formula 1

or



Formula 2

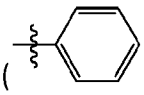
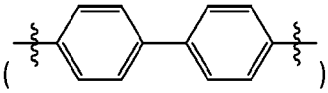
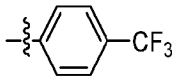
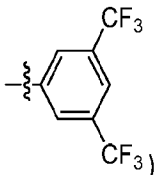
; wherein

R^1, R^2, R^3, R^4, R^5, R^6 are independently H, a C_1-C_3 alkyl, an optionally substituted aryl group, or an optionally substituted ether group;

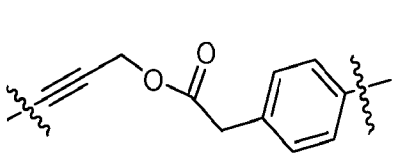
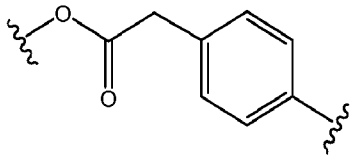
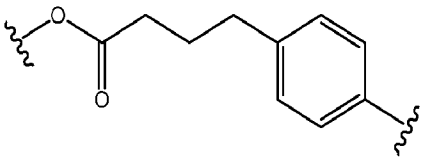
R^7, R^8, and R^9 are independently H or a methyl group ($-CH_3$); and

L_1, L_2, and L_3 are linker complexes, independently comprising an optionally substituted ester moiety.

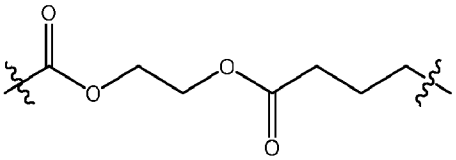
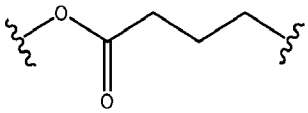
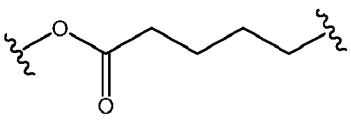
In some embodiments, R^3 and R^4 may each be an aryl group, e.g., a phenyl group. In some embodiments, the aryl group may be an optionally substituted aryl group. In some

embodiments, the optionally substituted aryl group can be a phenyl group (), or a diphenyl group (). In some embodiments the optionally substituted aryl group may comprise a 4-trifluoromethylphenyl group (), or a 3,5-bis(trifluoromethyl)phenyl group ().

In some embodiments, the linker complexes L_1, L_2, and L_3, may be independently

, , or .

In some embodiments, the linker complexes L_1, L_2, and L_3, may be independently

, , or .

In some embodiments, the color conversion film may comprise a transparent substrate layer, and a color conversion layer. In some embodiments, the color conversion layer includes a resin matrix, wherein the resin matrix comprises poly(butyl acrylate) or poly(methyl methacrylate), and a photoluminescent complex comprising the compounds described herein dispersed within the resin matrix. In some embodiments, the color conversion film may further comprise a singlet oxygen quencher. In some embodiments, the color conversion film may further comprise a radical scavenger. In some embodiments, the

color conversion film may have a thickness of between 10 μm and 200 μm. In some embodiments, the film may absorb light in a wavelength range of about 400 nm to about 590 nm and emit light in a wavelength range of about the 600 nm to about 620 nm.

In some embodiments, a method for preparing the color conversion film is described, the method may comprise dissolving the photoluminescent complex of the embodiments described above, and a binder resin within a solvent; and applying the mixture to one of the transparent substrates opposing surfaces.

In some embodiments, a backlight unit is described, the backlit unit may include the color conversion film described above.

In some embodiments, a display device is described, the display device may include the back-light unit described above.

The present application provides a photoluminescent complex's having excellent color gamut and luminescent properties, a method for manufacturing color conversion films using the photoluminescent complexes, and a backlight unit including the color conversion film. These and other embodiments are described in greater detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph depicting the absorption and emission spectra of one embodiment of a photoluminescent complex (Compound 5).

FIG. 2 is a graph depicting the absorption and emission spectra of one embodiment of a photoluminescent complex (Compound 6).

FIG. 3 is a graph depicting the absorption and emission spectra of one embodiment of a photoluminescent complex (Compound 7).

DETAILED DESCRIPTION

The current disclosure includes photoluminescent complexes and their uses in color conversion films, backlight units, and/or display devices. A photoluminescent complex may be used to improve and enhance the transmission of one or more desired emissive bandwidths within a color conversion film. In some embodiments, the photoluminescent complex may both enhance the transmission of a desired first emissive bandwidth and

decrease the transmission of a second emissive bandwidth. For example, a color conversion film may enhance the contrast or intensity between two or more colors, increasing the distinction from one another. The present disclosure describes a photoluminescent complex that may enhance the contrast or intensity between two colors, increasing their distinction from one another. The present disclosure also includes methods for preparing the color conversion films described herein.

As used herein, when a compound or chemical structure is referred to as being "substituted" it may include one or more substituents. A substituted group is derived from the unsubstituted parent structure wherein one or more hydrogen atoms on the parent structure have been independently replaced by one or more substituent groups. A substituent group may have one or more substituent groups on the parent group structure. In one or more forms, the substituent groups may be independently selected from an optionally substituted alkyl, alkenyl, or a C_3-C_7 heteroalkyl. The term "optionally substituted" includes parent structures that may or may not be substituted as defined above.

The term "alkyl" group as used herein refers to an aliphatic hydrocarbon group. The alkyl group may be a "saturated alkyl" group, which means that it does not contain any alkene or alkyne moieties. The alkyl moiety may also be an "unsaturated alkyl" moiety, which means that it contains at least one alkene or alkyne moiety. An "alkene moiety refers to a group that has at least one carbon-carbon double bond (-C=C-) and an "alkyne" moiety refers to a group that has at least one carbon-carbon triple bond (-C≡C-). The alkyl moiety, whether saturated or unsaturated, may be branched, straight chain, or cyclic.

The alkyl moiety may have 1 to 6 carbon atoms (whether it appears herein, a numerical range such as "1 to 6" refers to each integer in the given range: e.g., "1 to 6 carbon atoms" means that the alkyl group may have 1 carbon atom, 2 carbon atoms, 3 carbon atoms, etc., up to and including 6 carbon atoms, although the present definition also covers the occurrence of the term "alkyl" where no numerical range is designated). The alkyl group of the compounds designated herein may be designated as "C_1-C_6 alkyl" or similar designations. By way of example only, "C_1-C_6 alkyl" indicates that there are one to six carbon atoms in the alkyl chain, i.e., the alkyl chain is methyl, ethyl, propyl, iso-propyl, n-butyl, iso-butyl, sec-butyl, or t-butyl. Thus, C_1-C_6 alkyl includes C_1-C_2 alkyl, C_1-C_3 alkyl, C_1-C_4 alkyl, C_1-C_5 alkyl. Alkyl groups

may be substituted or unsubstituted. Typical alkyl groups include, but are in no way limited to, methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tertiary butyl, pentyl, hexyl, ethenyl, propenyl, butenyl, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, and the like.

The term "heteroalkyl" as used herein refers to an alkyl group, as defined herein, in which one or more of the constituent carbon atoms have been replaced by a nitrogen, oxygen, or sulphur. Examples include but are not limited to, $-CH_2-O-CH_3$, $-CH_2-CH_2-O-CH_3$, $-CH_2-NH-CH_3$, $-CH_2-N(CH_3)-CH_3$, $-CH_2-CH_2-NH-CH_3$, $-CH_2-CH_2-N(CH_3)-CH_3$, $-CH_2-S-CH_2-CH_3$, $-CH_2-CH_2-S(O)-CH_3$. In addition, up to two heteroatoms may be consecutive, such as, by way of example, $-CH_2-NH-O-CH_3$, etc.

The term "aromatic" refers to a planar ring having a delocalized π-electron system containing 4n+2 π electrons, where n is an integer. Aromatic rings may be formed from five, six, seven, eight, nine, or more than nine atoms. Aromatics may be optionally substituted. The term "aromatic" includes both carbocyclic aryl (e.g., phenyl) and heterocyclic aryl (or "heteroaryl" or heteroaromatic") group (e.g., pyridine). The term includes monocyclic or fused-ring polycyclic (i.e., rings which share adjacent pairs of carbon atoms) groups.

The term "aryl" as used herein means an aromatic ring wherein each of the atoms forming the ring is a carbon atom. Aryl rings may be formed by five, six, seven, eight, or more than eight carbon atoms. Aryl groups may be substituted or unsubstituted. Examples of aryl groups include, but are not limited to, phenyl, naphthalenyl, phenanthrenyl, etc.

The term "aralkyl" refers to an alkyl radical, as defined herein, substituted with an aryl, as defined herein. Non-limiting aralkyl groups include benzyl, phenethyl; and the like.

The term "halogen" as used herein means fluorine, chlorine, bromine, and iodine.

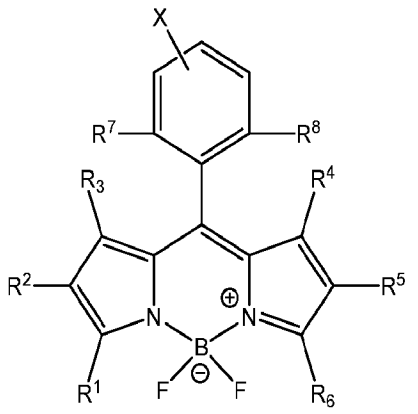
The term "bond", "bonded", "direct bond" or "single bond" as used herein means a chemical bond between two atoms or to two moieties when the atoms joined by the bond are considered to be part of a larger structure.

The term "moiety" as used herein refers to a specific segment or functional group of a molecule. Chemical moieties are often recognized chemical entities embedded in or appended to a molecule.

The term "ester" refers to a chemical moiety with the formula -COOR, where R is alkyl, cycloalkyl, aryl, heteroaryl (bonded through a ring carbon) or heterocyclic (bonded through a ring carbon). Any hydroxyl, or carboxyl side chain on the compounds described herein may be esterified. Any suitable procedure to prepare an ester may be used.

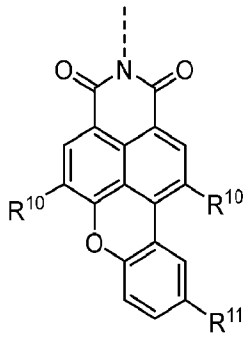
Use of the term "may" or "may be" should be construed as shorthand for "is" or "is not" or, alternatively, "does" or "does not" or "will" or "will not," etc. For example, the statement "the binder resin may comprise poly(methyl methacrylate)" should be interpreted as, for example, "In some embodiments, the binder resin comprises poly(methyl methacrylate)," or "In some embodiments, the binder resin does not comprise poly(methyl methacrylate)."

The term "BODIPY" as used herein, refers to a chemical moiety with the general formula:



, wherein the BODIPY compound is composed of a dipyrromethene moiety complexed with a di-substituted boron atom, typically a BF_2 unit. The IUPAC name for the BODIPY core is 4,4-difluoro-4-bora-3a,4a-diaza-s-indacene.

The term "xanthenoisoquinoline" or "xanthenoisoquinoline derivative" as used herein, refers to a chemical moiety with the general formula:



. The IUPAC name for the xanthenoisoquinoline core is 1H-xantheno[2,1,9-def]isoquinoline-1,3(2H)-dione.

The present disclosure is related to photoluminescent complexes that absorb light energy of a first wavelength and emit light energy in a second higher wavelength. The photoluminescent complex of the present disclosure comprises an absorbing luminescent moiety and an emitting luminescent moiety that are coupled through a linker such that their distance is optimized for the absorbing luminescent moiety to transfer its energy to the acceptor luminescent moiety, wherein the acceptor luminescent moiety then emits energy at a second wavelength that is larger than the absorbed first wavelength.

In some embodiments, the photoluminescent complexes described herein comprise: a blue light absorbing xanthenoisoquinoline derivative (XI derivative); a linker complex; and a boron-dipyrromethene (BODIPY) moiety. In some embodiments, the linker complex may covalently link the xanthenoisoquinoline derivative to the BODIPY moiety. In some embodiments, the xanthenoisoquinoline derivative absorbs light of a first excitation wavelength and transfers energy to the BODIPY moiety, the BODIPY moiety then emits a light energy of a second wavelength, wherein the light energy of the second wavelength is higher than the first wavelength. It is believed that energy transfer from the excited xanthenoisoquinoline derivative to the BODIPY moiety occurs through a Förster resonance energy transfer (FRET). This belief is due to the absorbance/emission spectra of the photoluminescent complexes where there are two major absorption bands, one at the blue light absorption band (xanthenoisoquinoline derivative) and one at the BODIPY absorption band, and only one emission band located at the BODIPY moiety's emission wavelength (see **FIGs 1-3**).

In an embodiment, the photoluminescent complex may have a high emission quantum yield. In some embodiments, the emission quantum yield may be greater than 50%, 60%,

70%, 80%, or 90%. In some embodiments, the emission quantum yield may be greater than 50%, or 55%, or 60%, or 65%, or 70%, or 75%, or 80%, or 85%, or 90%, or 95%. Emission quantum yield may be measured by dividing the number of photons emitted by the number of photons absorbed, which is equivalent to the emission efficiency of the luminescent moiety. In some embodiments, the absorbing luminescent moiety, may have an emission quantum yield greater than 80%. In some embodiments, the quantum yield may be greater than 0.8 (80%), 0.81 (81%), 0.82 (82%), 0.83 (83%), 0.84 (84%), 0.85 (85%), 0.86 (86%), 0.87 (87%), 0.88 (88%), 0.89 (89%), 0.9 (90%), 0.91 (91%), 0.92 (92%), 0.93 (93%), 0.94 (94%), 0.95 (95%), or up to 100%. Quantum yield measurements of photoluminescent complex films may be made by spectrophotometer, e.g., Quantaurus-QY spectrophotometer (Hamamatsu, Inc., Campbell, CA, USA).

In some embodiments, the photoluminescent complex has an emission band, wherein the emission band may have a full width half maximum (FWHM) of less than 40 nm. The FWHM is the width of the emission band in nanometers at the emission intensity that is half of the maximum emission intensity for the band. In some embodiments, the photoluminescent complex has an emission band FWHM value that is less than or equal to about 55 nm, less than or equal to about 50 nm, less than or equal to about 45 nm, less than or equal to about 40 nm, less than or equal to about 35 nm, less than or equal to about 30 nm, less than or equal about 25 nm, less than or equal to about 20 nm, or about 39 nm, about 40 nm, or about 41 nm.

In some embodiments, the photoluminescent complex may have a Stokes shift that is equal to or greater than 45 nm. As used herein the term "Stokes shift" means the distance between the excitation peak of the photoluminescent complex (or a moiety thereof) and the emission peak of the photoluminescent complex (or a moiety thereof). In some embodiments, the Stokes shift of the photoluminescent complex may be about 45-50 nm, about 50-55 nm, about 55-60 nm, about 60-65 nm, about 65-70 nm, about 70-75 nm, about 75-80 nm, about 80-85 nm, about 85-90 nm, about 90-95 nm, about 95-100 nm, or greater than about 100 nm, or any number in a range bounded by any of these values. In some embodiments, the Stokes shift of the photoluminescent complex may be greater than 100 nm, greater than 120 nm, greater than 130, greater than 140 nm, greater than 150 nm, or

greater than 170 nm. For example, the Stokes shift between the blue-light absorbing moiety and the emission peak of the BODIPY moiety may be any number or range disclosed herein.

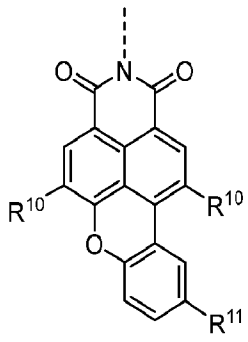
The photoluminescent complex of the current disclosure may have a tunable (or adjustable) emission wavelength. By incorporating different substituents to the BODIPY moiety, the emission wavelength may be adjusted to between about 600 nm to about 645 nm.

In some embodiments, the photoluminescent complex may absorb light energy at one or more wavelengths. In some embodiments, the xanthenoisoquinoline moiety of the photoluminescent complex may absorb light. In some embodiments, the BODIPY moiety of the photoluminescent complex may absorb light. In some embodiments, both the BODIPY moiety of the photoluminescent complex and the xanthenoisoquinoline moiety of the photoluminescent complex may absorb light. In some embodiments, the xanthenoisoquinoline moiety of the photoluminescent complex may have a peak absorption maximum wavelength between about 400 nm to about 470 nm, about 400-405 nm, about 405-410 nm, about 410-415 nm, about 415-420 nm, about 420-425 nm, about 425-430 nm, about 430-435 nm, about 435-440 nm, about 440-445 nm, about 445-450 nm, about 450-455 nm, about 455-460 nm, about 460-465 nm, about 465-470 nm. In some embodiments, the BODIPY moiety of the photoluminescent complex may have a peak absorption maximum wavelength between about 500 nm to about 600 nm, about 500-510 nm, about 510-520 nm, about 520-530 nm, about 530-540 nm, about 540-550 nm, about 550-555 nm, about 555-560 nm, about 560-565 nm, about 565-570 nm, about 570-575 nm, about 575-585 nm, about 585-590 nm, about 590-600 nm, about 570-585 nm, or any wavelength in a range bounded by any of these values. In some embodiments, the photoluminescent complex may have an absorption wavelength between about 400 nm to about 405 nm, about 405-410 nm, about 410-415 nm, about 415-420 nm, about 420-425 nm, about 425-430 nm, about 430-435 nm, about 435-440 nm, about 440-445 nm, about 445-450 nm, about 450-455 nm, about 455-460 nm, about 460-465 nm, about 465-470 nm, about 500-600 nm, about 500-510 nm, about 510-520 nm, about 520-530 nm, about 530-540 nm, about 540-550 nm, about 550-555 nm, about 555-560 nm, about 560-565 nm, about 565-570 nm, about 570-575 nm, about 575-585 nm, about 585-590 nm, about 590-600 nm, about 570-585 nm, or any wavelength in a range bounded by any of these values.

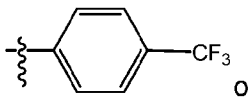
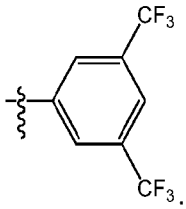
In another embodiment, the photoluminescent complex may have an emission peak wavelength between about 595 nm to about 645 nm, about 595-600 nm, about 600-605 nm, about 605-610 nm, about 610-615 nm, about 615-620 nm, about 620-625 nm, about 625-630 nm, about 630-635 nm, about 635-640 nm, about 640-645 nm, about 605-620 nm, or any wavelength in a range bounded by any these values.

Other embodiments include photoluminescent complexes wherein the blue light absorbing xanthenoisoquinoline derivative and the BODIPY moiety's spatial distance is adjusted through the linker complex, for improving the transfer of the blue light absorbing xanthenoisoquinoline derivative's energy to the BODIPY moiety. In some embodiments, the linker complex covalently links the blue light absorbing xanthenoisoquinoline derivative and the BODIPY moiety. In some embodiments, the xanthenoisoquinoline derivative absorbs light energy of a first excitation wavelength and transfers an energy to the BODIPY moiety, wherein the BODIPY moiety absorbs the energy from the xanthenoisoquinoline derivative and emits a light energy of a second higher wavelength, and wherein the photoluminescent complex has an emission quantum yield greater than 80%.

Some embodiments include a blue light absorbing xanthenoisoquinoline derivative of the following general formula:

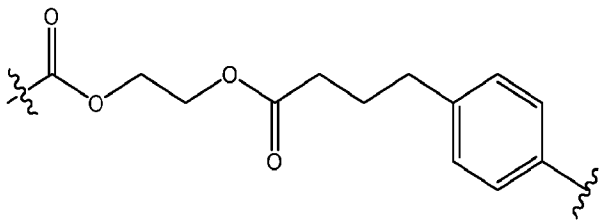
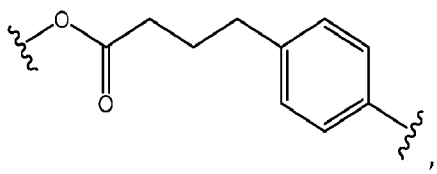
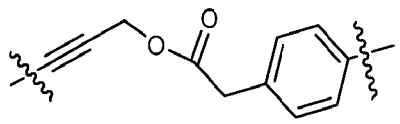
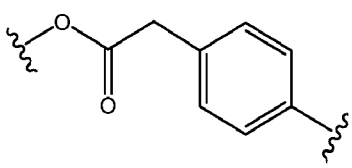


wherein R^{10} may be independently H, methyl ($-CH_3$), a, optionally substituted alkyl group, or an optionally substituted aryl group. In some embodiments, the optionally substituted alkyl group may be a trifluoromethyl group ($-CF_3$) or a trichloromethyl group ($-CCl_3$). In some embodiments, the optionally substituted aryl group may be phenyl. In some embodiments, the optionally substituted aryl group may be a substituted phenyl or benzyl group. In some embodiments, the optionally substituted aryl group may comprise trifluoromethyl group. In

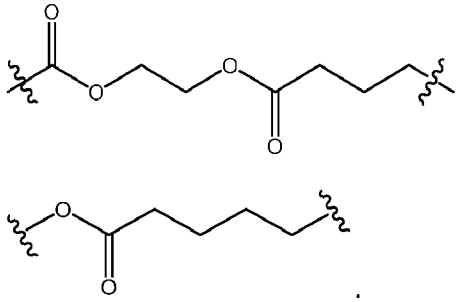
some embodiments, the optionally substituted aryl group may be  or .

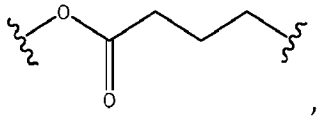
In some embodiments, the linker complex covalently links the blue absorbing xanthenoisoquinoline derivative with the BODIPY moiety. The linker complex may be tuned (or adjusted) to optimize the spatial distance between the blue light absorbing xanthenoisoquinoline derivative and the BODIPY moiety. By optimizing the spatial distance between the xanthenoisoquinoline derivative and the BODIPY moiety, the quantum yield may be improved. In some embodiments, the distance separating the blue light absorbing xanthenoisoquinoline derivative and the BODIPY moiety may be about 8 Å or greater. In some embodiments, the linker complex maintains a distance between the blue light absorbing xanthenoisoquinoline derivative and the BODIPY moiety.

In some embodiments, the photoluminescent complex comprises a linker complex, wherein the linker complex covalently links the blue light absorbing xanthenoisoquinoline derivative to the BODIPY moiety. In some embodiments, the linker complex may comprise a single bond between the xanthenoisoquinoline derivative and the BODIPY moiety.

In some embodiments, the linker complex (e.g., L_1, L_2 and/or L_3) may comprise an optionally substituted C_2-C_7 ester group. When the linker complex comprises a substituted ester group, the linker complex may be one of the following structures: , , , and or .

In some, embodiments, the linker complex may comprise an unsubstituted ester group, wherein the linker complex may be one of the following structures:



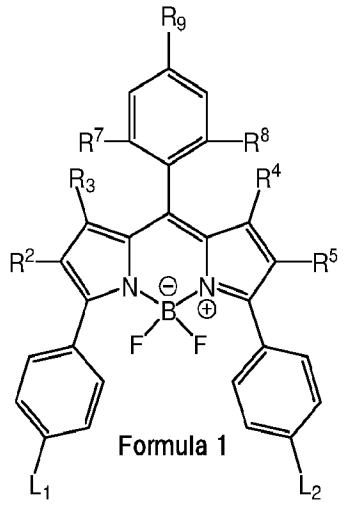


, or

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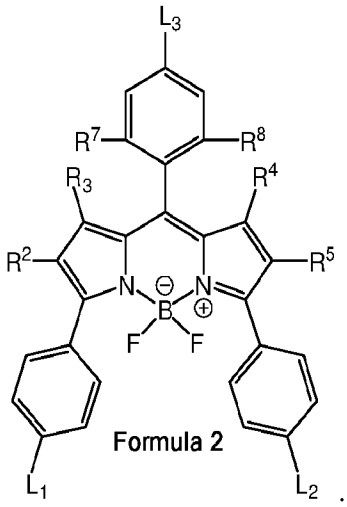
It is to be understood that the linker complexes L_1, L_2, and L_3 may be the same or different. In some embodiments, L_1, L_2, and L_3 may all be identical. In some embodiments, L_1, L_2, and L_3 may all be different. In some embodiments, L_1, and L_2 may be identical and L_3 is different. All possible permutations for the linker complexes are contemplated.

The photoluminescent complex of the current disclosure may comprise a BODIPY moiety. The BODIPY moiety may have the following general formulae;



Formula 1

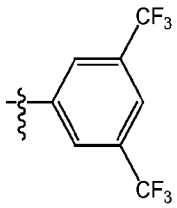
or



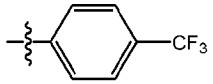
Formula 2

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In some embodiments, R^1, R^2, R^3, R^4, R^5, and R^6 are independently selected from a bond, H, a C_1-C_3 alkyl, an aryl, or an ether. In some embodiments, the aryl group may be

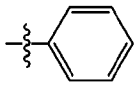
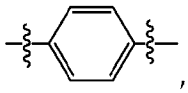
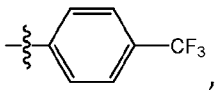
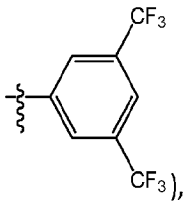
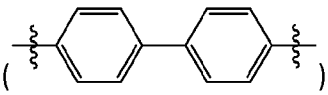
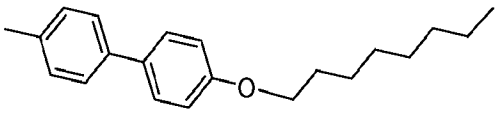


substituted. In some embodiments, the substituted aryl group may be . In some embodiments, the substituted aryl group may be

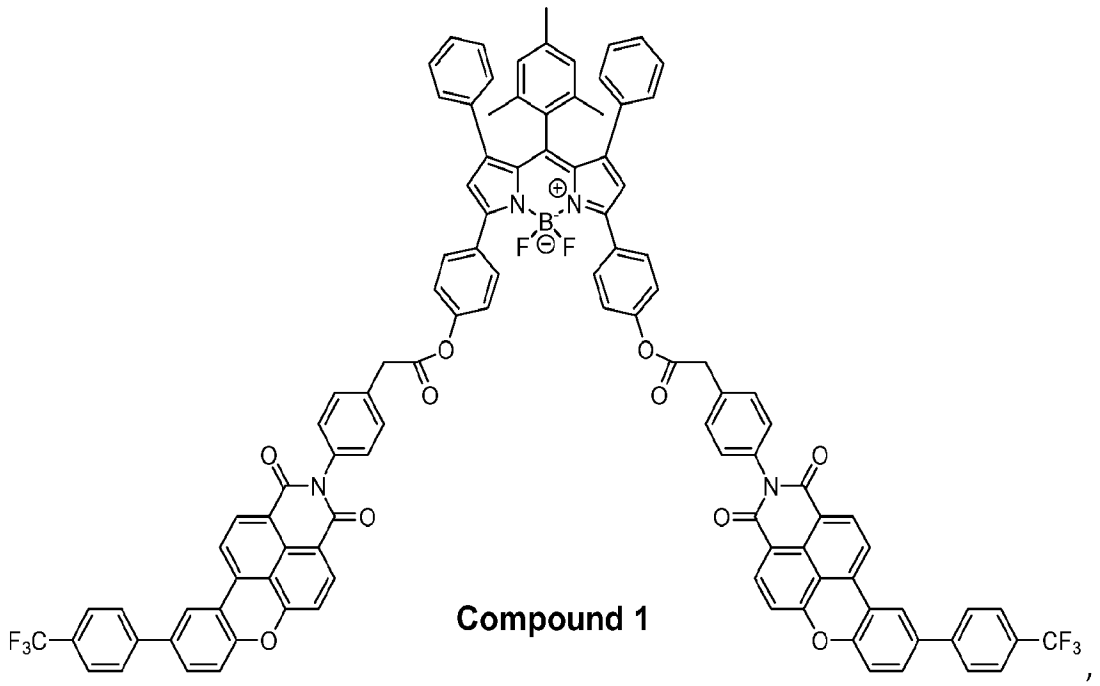


In some

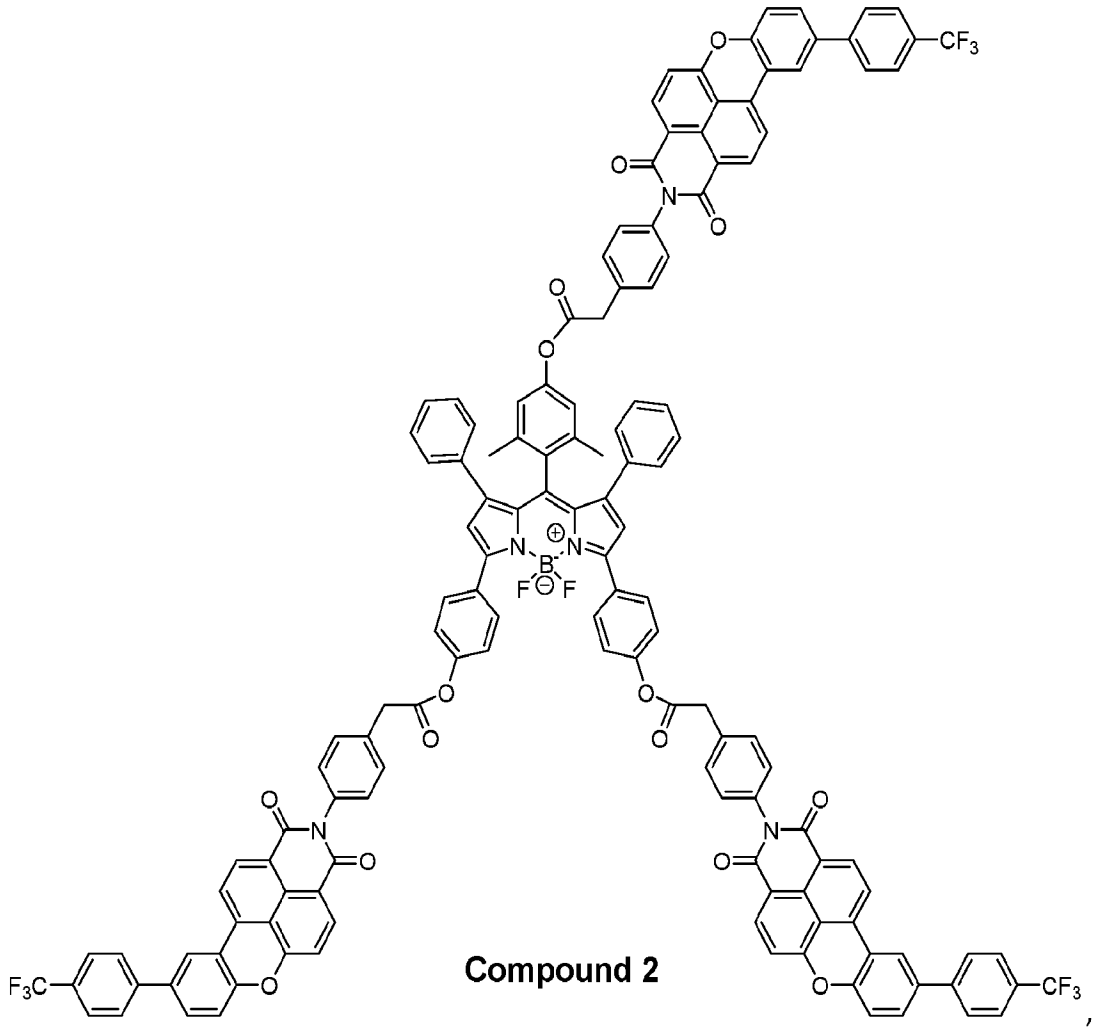
embodiments, R^7, R^8, and R^9 may be independently selected from a bond, H, or a methyl group ($-CH_3$).

The BODIPY moiety of the present disclosure may be a BODIPY moiety wherein R^3 and R^4 may each be an aryl group, e.g., a phenyl group; R^1, R^2 , R^5 and /or R^6 may be a bond or an H, a substituted aryl group, e.g., a phenyl group (,  ,  ,  , ), a diphenyl group () and/or a C_2-C_{10} alkyl ether group ().

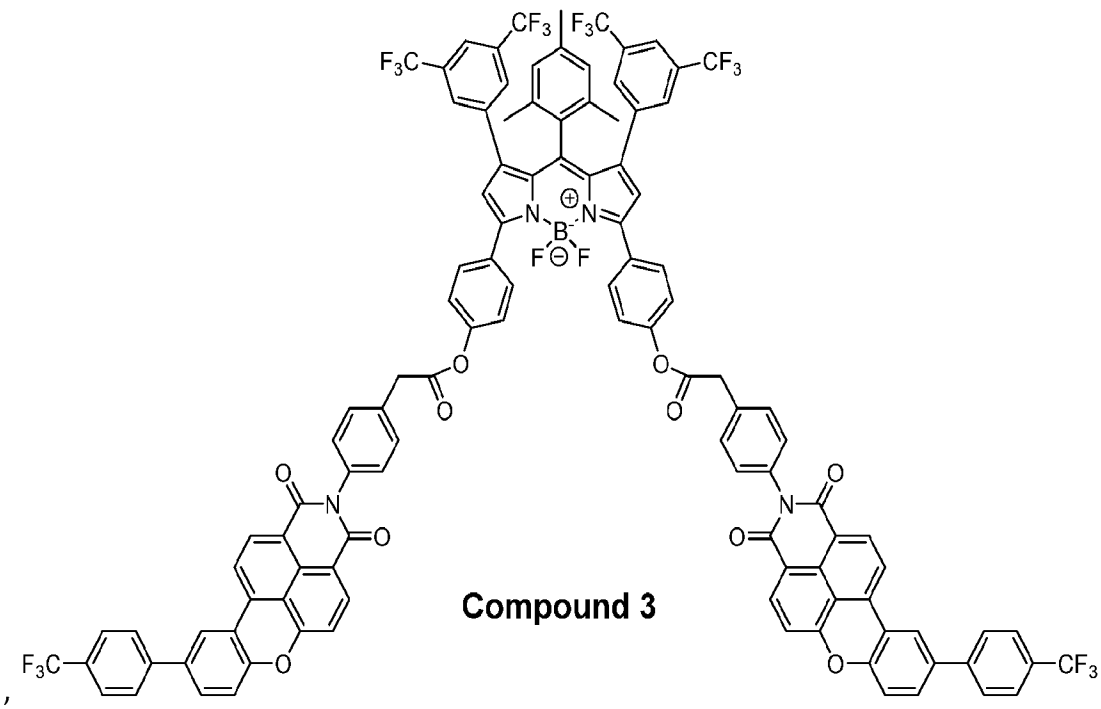
The photoluminescent complexes of the present disclosure may be represented by the following structure which are provided for purpose of illustration and are in no way to be construed as limiting:



Compound 1

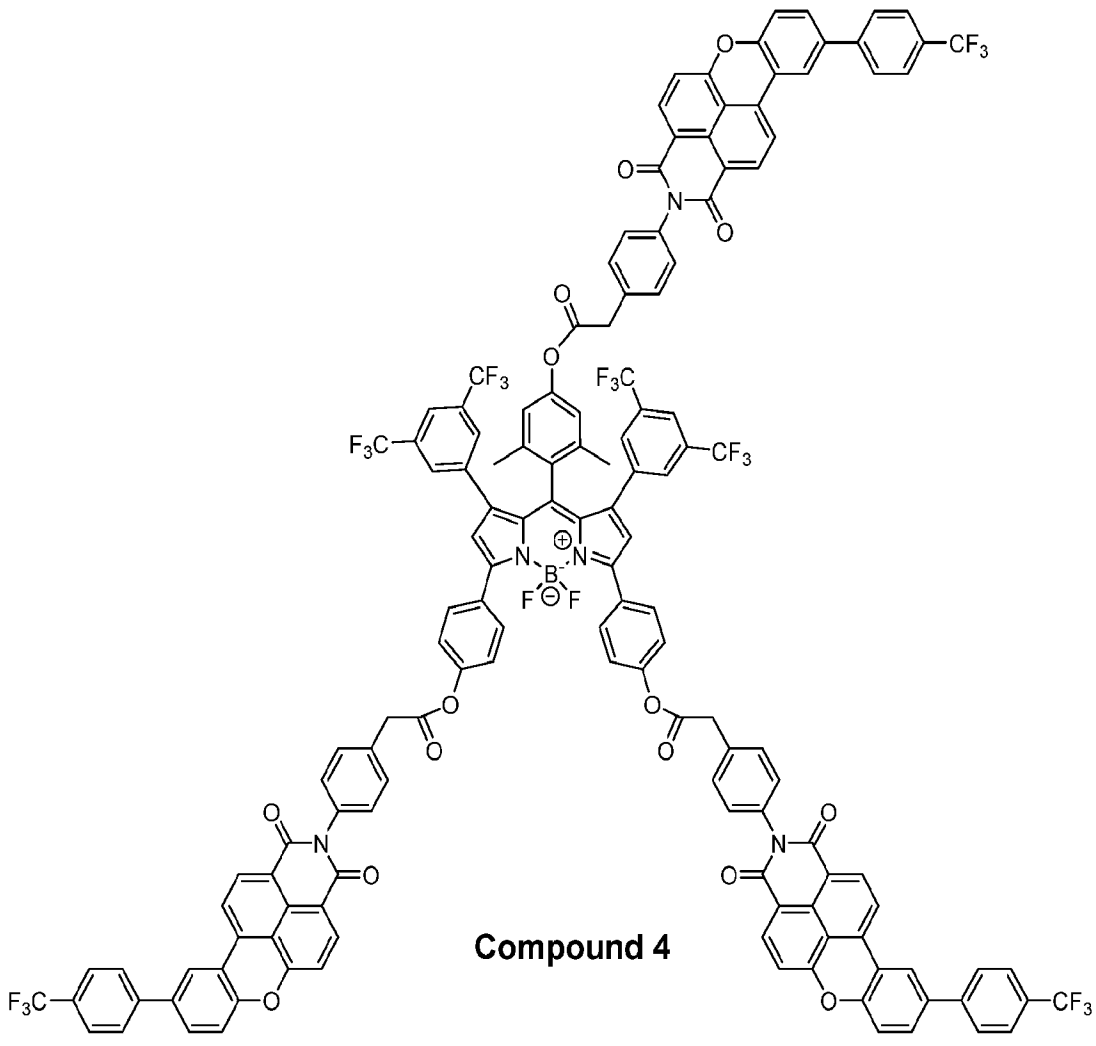


Compound 2,



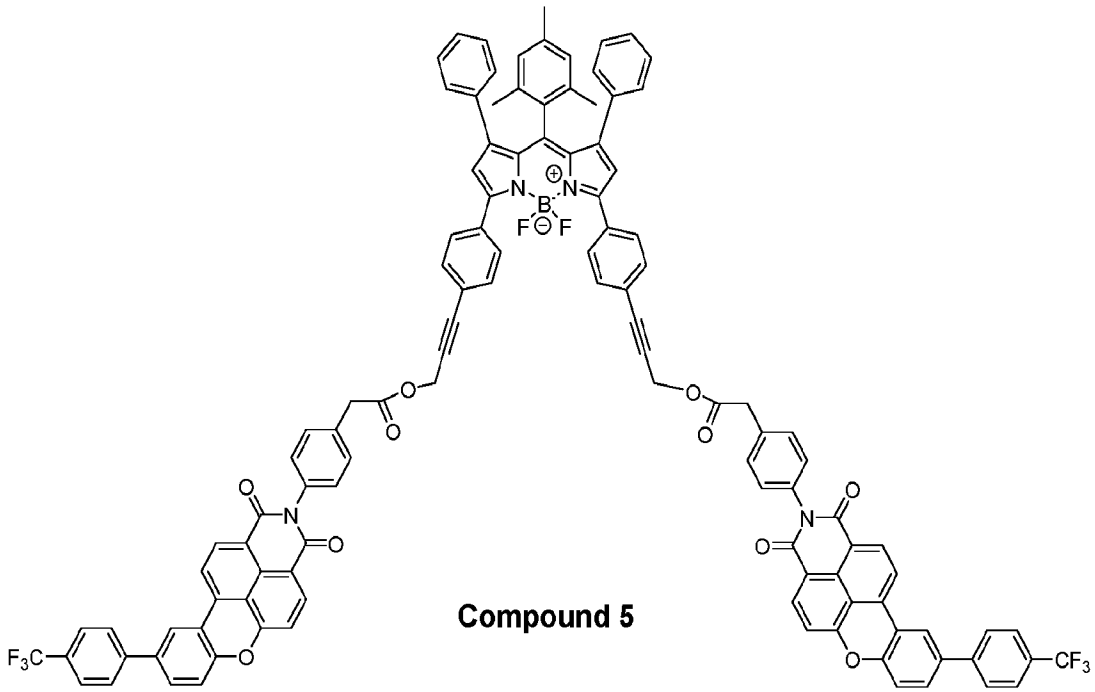
Compound 3

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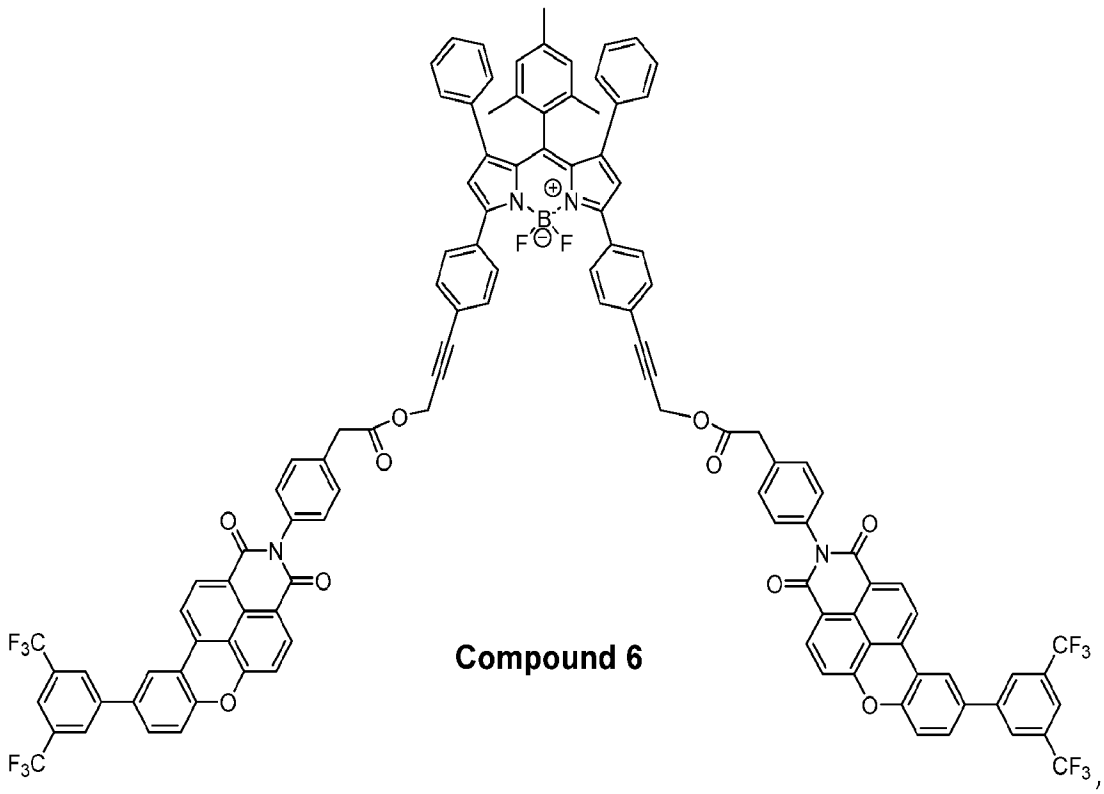


Compound 4

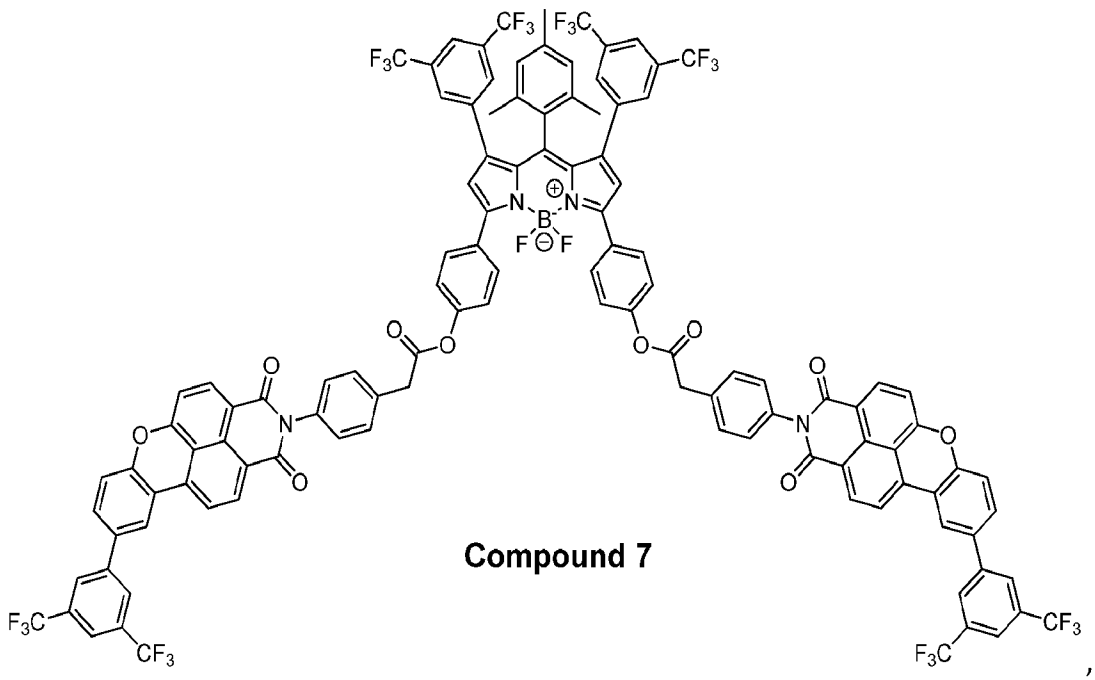
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Compound 5

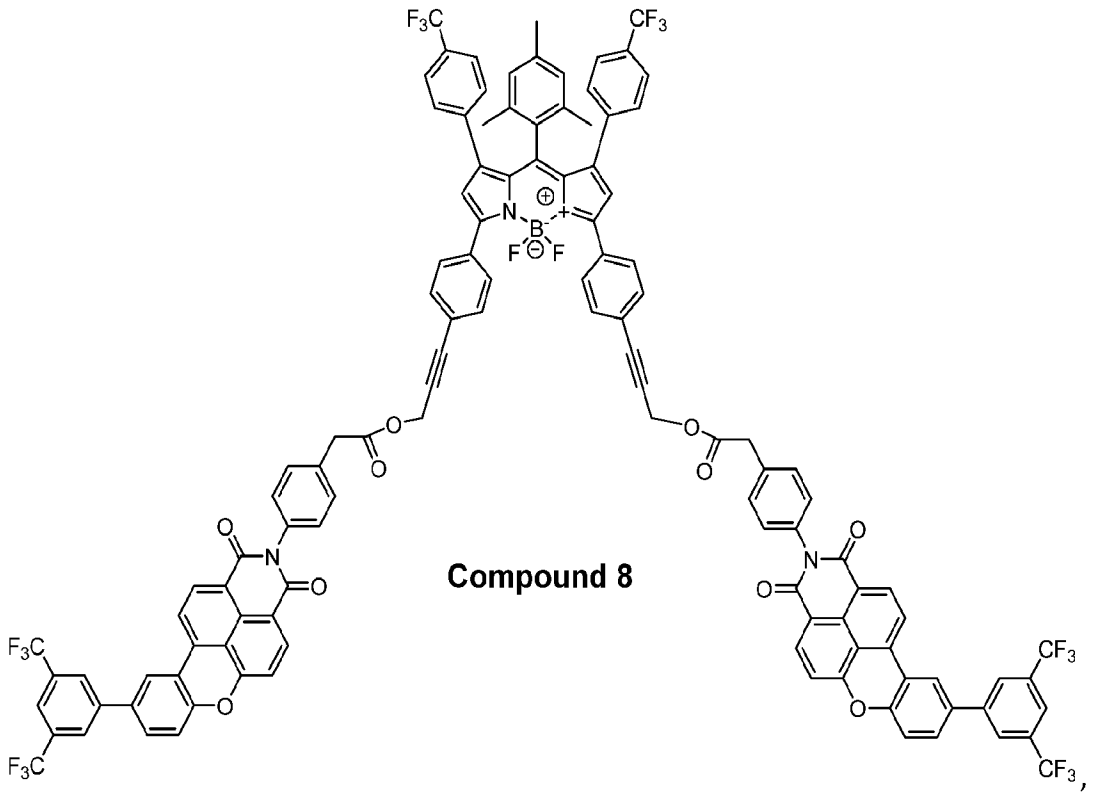


Compound 6



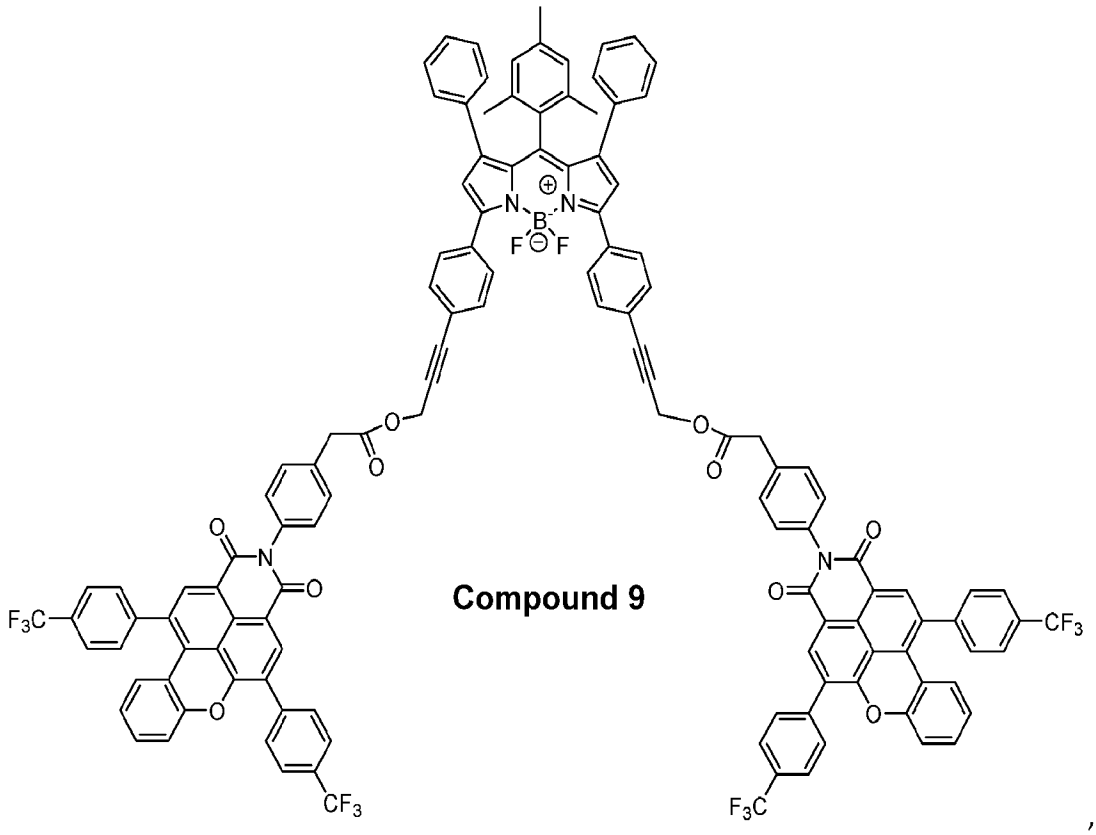
Compound 7

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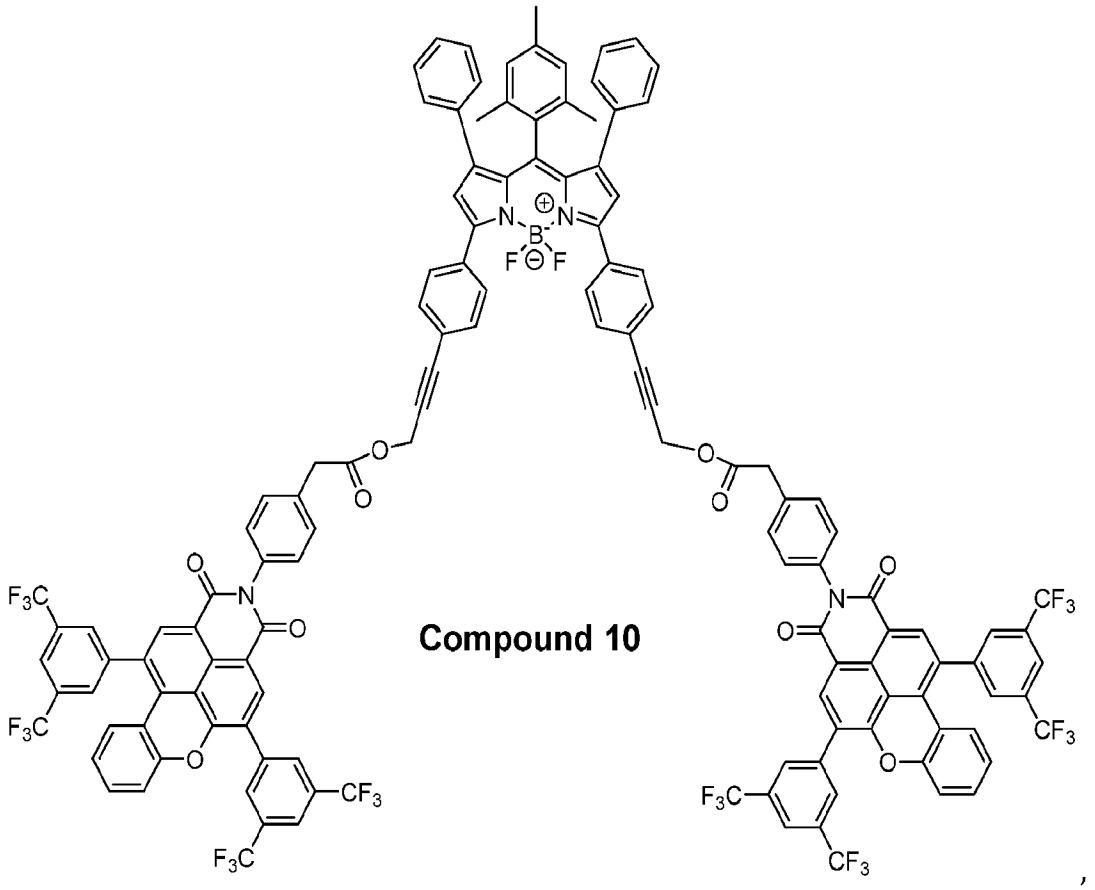
Compound 8

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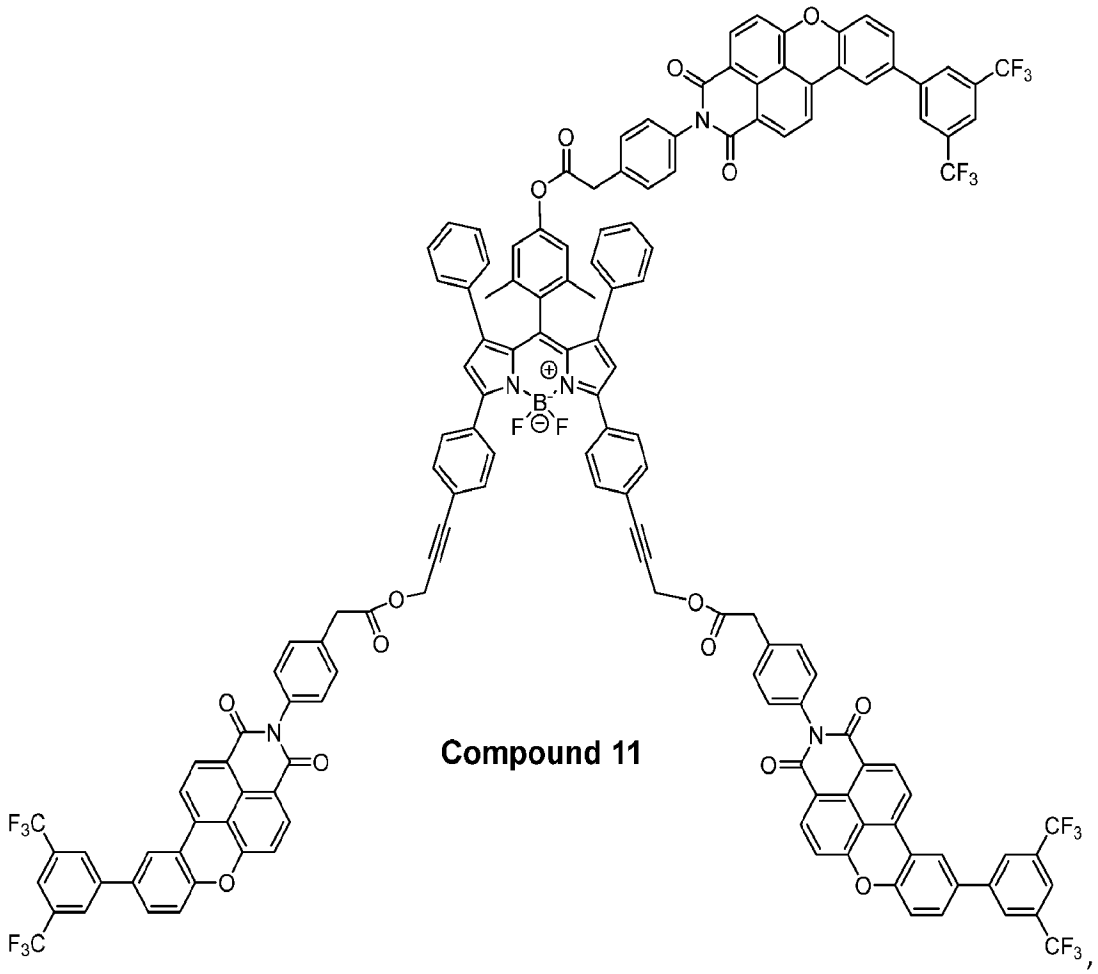
Compound 9

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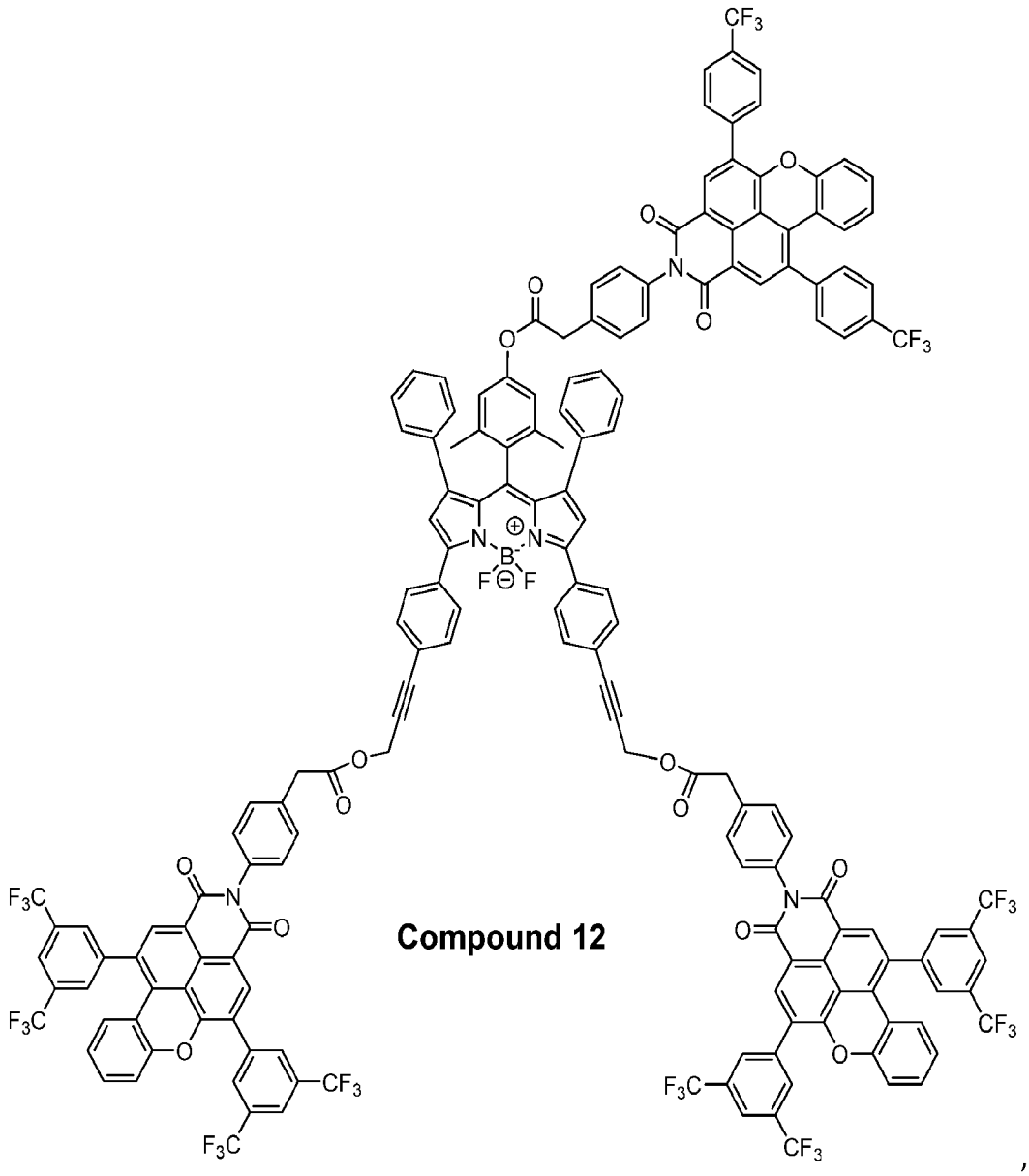


Compound 10

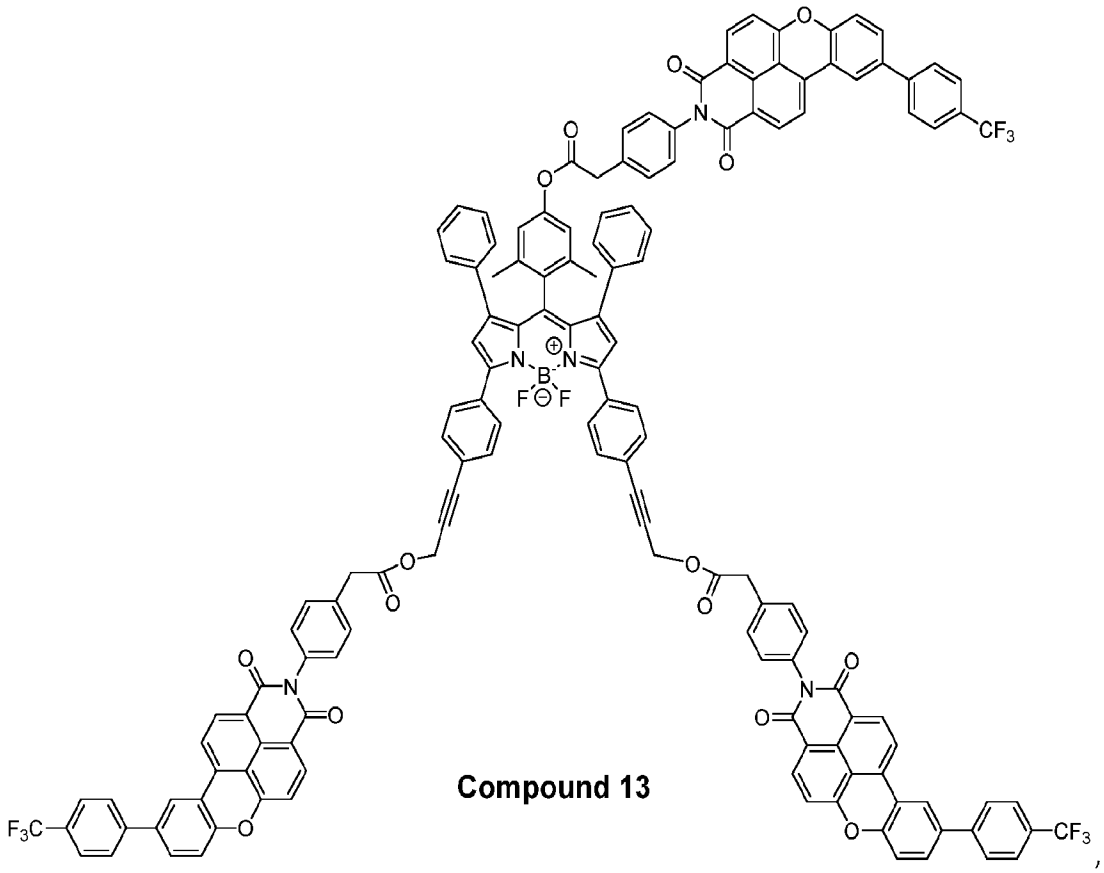
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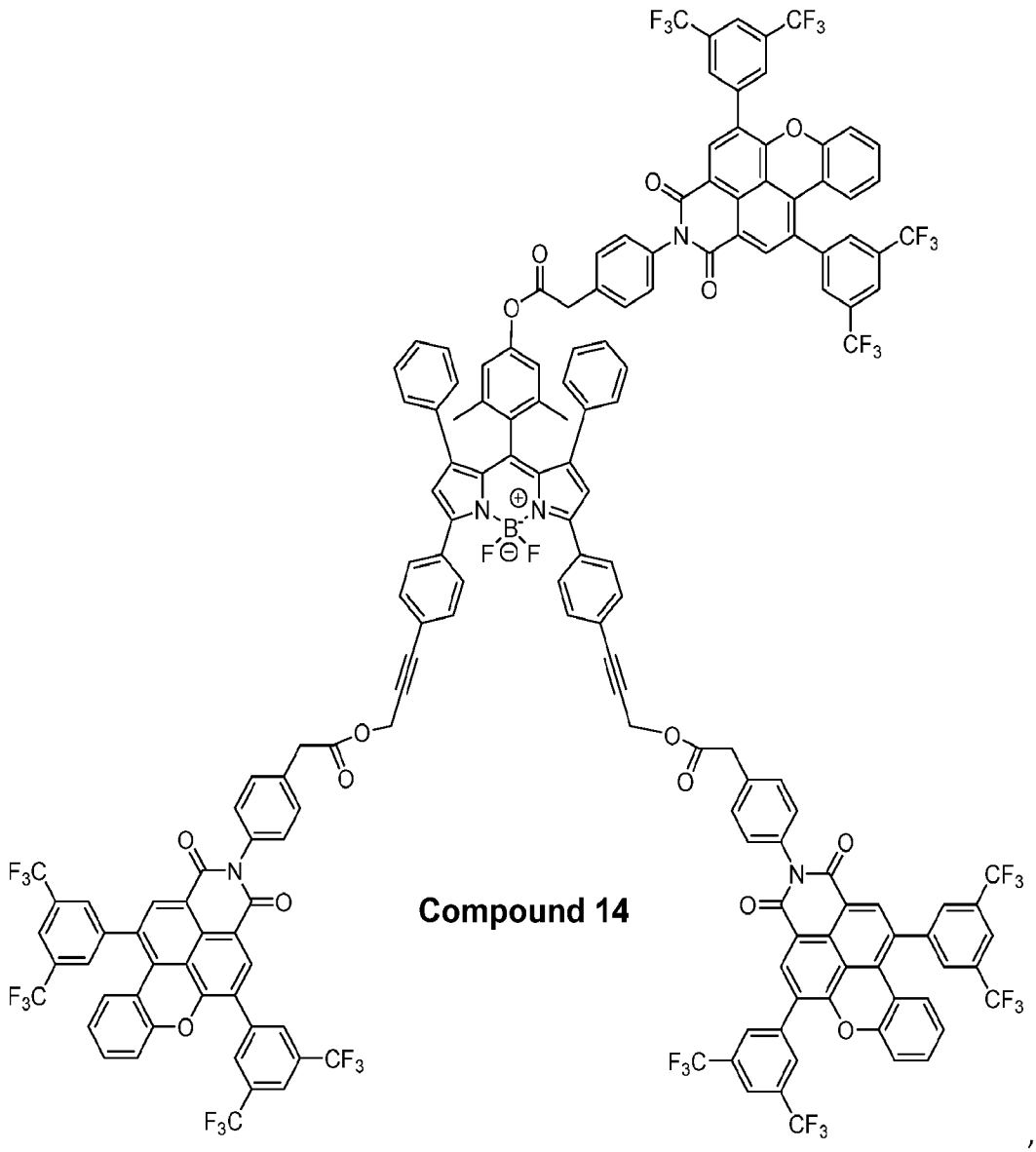
Compound 11



Compound 12



Compound 13



Compound 14

, or a combination of any of these compounds.

It is believed the compounds described herein may be suitable for combining with poly(butyl acrylate), also termed PBA.

Some embodiments include a color conversion film, comprising: a color conversion layer wherein the color conversion layer includes a resin matrix and photoluminescent complexes, described above, dispersed within the resin matrix. In some embodiments the color conversion film may be described as comprising one or more of the complexes described herein.

Some embodiments include a color conversion film which may have a thickness of about 1 μm to about 200 μm, about 1-5 μm, about 5-10 μm, about 10-15 μm, about 15-20

μm, about 20-40 μm, about 40-80 μm, about 80-120 μm, about 120-160 μm about 160-200 μm, or about 10 μm, or any thickness in a range bounded by any of these values.

In some embodiments, the color conversion film may further comprise a transparent substrate layer. The transparent substrate layer has two opposing surfaces, wherein the color conversion layer may be disposed on and in physical contact with the surfaces of the transparent layer that will be adjacent to a light emitting source. The transparent substrate is not particularly limited and one skilled in the art would be able to choose a transparent substrate from those used in the art. Some non-limiting examples of transparent substrates include PE (polyethylene), PP (polypropylene), PEN (polyethylene naphthalate), PC (polycarbonate), PMA (polymethyl acrylate), PMMA (polymethyl methacrylate), CAB (cellulose acetate butyrate), PVC (polyvinylchloride), PET (polyethyleneterephthalate), PETG (glycol modified polyethylene terephthalate), PDMS (polydimethylsiloxane), COC (cyclo olefin copolymer), PGA (polyglycolide or polyglycolic acid), PLA (polylactic acid), PCL (polycaprolactone), PEA (polyethylene adipate), PHA (polyhydroxy alkanoate), PHBV (poly(3-hydroxybutyrate-co-3-hydroxyvalerate)), PBE (polybutylene terephthalate), PTT (polytrimethylene terephthalate). Any of the aforedescribed resins may be corresponding/respective monomers and/or polymers.

In some embodiments, the binder resin may comprise poly(methyl methacrylate), also termed PMMA. In some embodiments, the binder resin may comprise poly(butyl acrylate), also termed PBA. In some embodiments, the binder resin may be a copolymer mixture comprising 50%, 75%, 95% butyl acrylate co-polymers/monomer. It is believed that, compared to PMMA, the poly(butyl acrylate) matrix may provide a more non-polar environment (having n-butyl alkyl chains in the structure). It is believed that the non-polar environment in PBA may cause chromophore dyes to aggregate or stack with each other within the matrix that may aid in charge transfer, and as a result a slightly lower quantum yield is generally obtained in PBA.

In some embodiments, the transparent substrate may have two opposing surfaces. In some embodiments, the color conversion film may be disposed on and in physical contact with one of the opposing surfaces. In some embodiments, the side of the transparent substrates without color conversion film disposed thereon, may be adjacent to a light source.

The substrate may function as a support during the preparation of the color conversion film. The type of substrates used are not particularly limited, and the material and/or thickness is not limited, as long as it is transparent and capable of functioning as a support. A person skilled in the art could determine which material and thickness to use as a supporting substrate.

Some embodiments include a method for preparing the color conversion film, wherein the method comprises: dissolving a photoluminescent compound, described herein, and a binder resin within a solvent; and applying the mixture on to the surface of the transparent substrate.

The binder resin which may be used with the photoluminescent complex(s) includes resins such as acrylic resins, polycarbonate resins, ethylene-vinyl alcohol copolymer resins, ethylene-vinyl acetate copolymer resins and saponification products thereof, AS resins, polyester resins, vinyl chloride-vinyl acetate copolymer resins, polyvinyl butyral resins, polyvinylphosphonic acid (PVPA), polystyrene resins, phenolic resins, phenoxy resins, polysulfone, nylon, cellulosic resins, and cellulose acetate resins. In some embodiments, the binder resin may be a polyester resin and/or acrylic resin. In some embodiments, the binder resin may comprise polymethacrylate (PMMA). In some embodiments, the binder resin may comprise poly (butyl acrylate) (PBA).

Any suitable solvent or combination of solvents may be used for dissolving or dispersing the complex and the resin. In some embodiments, the solvent may be an alkane, such as butane, pentane, hexane, heptane, and octane; cycloalkanes, such as cyclopentane, cyclohexane, cycloheptane, and cyclooctane; an alcohol, such as ethanol, propanol, butanol, amyl alcohol, hexanol, heptanol, octanol, decanol, undecanol, diacetone alcohol, and furfuryl alcohol; Cellosolves™, such as Methyl Cellosolve™, Ethyl Cellosolve™, Butyl Cellosolve™, Methyl Cellosolve™ acetate, and Ethyl Cellosolve™ acetate; propylene glycol and its derivatives, such as propylene glycol monomethyl ether, propylene glycol monoethyl ether, propylene glycol monobutyl ether, propylene glycol monomethyl ether acetate, propylene glycol monoethyl ether acetate, propylene glycol monobutyl ether acetate, and dipropylene glycol dimethyl ether; a ketone, such as acetone, methyl amyl ketone, cyclohexanone, and acetophenone; ethers, such as dioxane and tetrahydrofuran; an ester, such as butyl acetate,

amyl acetate, ethyl butyrate, butyl butyrate, diethyl oxalate, ethyl pyruvate, ethyl 2-hydroxybutyrate, ethyl acetoacetate, methyl lactate, ethyl lactate, and methyl 3-methoxypropionate; a halogenated hydrocarbon, such as chloroform, methylene chloride, and tetrachloroethane; an aromatic hydrocarbon, such as benzene, toluene, xylene, and cresol; and highly polar solvents, such as dimethyl formamide, dimethyl acetamide, and N-methylpyrrolidone.

Some embodiments include a backlight unit, wherein the backlight unit may include the aforedescribed color conversion film.

Other embodiments may include a display device, wherein the device may include the backlight unit described herein.

Unless otherwise indicated, all numbers expressing quantities of ingredients, properties, such as, molecular weight, reaction conditions, and so forth used in the specification and embodiments are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and attached embodiments are approximations that may vary depending upon the desired properties sought to be obtained. At the very least, and not as an attempt to limit the application of the doctrine of equivalents. To the scope of the embodiments, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

For the processes and/or methods disclosed, the functions performed in the processes and methods may be implemented in differing order, as may be indicated by context. Furthermore, the outlined steps and operations are only provided as examples and some of the steps and operations may be optional, combined into fewer steps and operations, or expanded into additional steps and operations.

This disclosure may sometimes illustrate different components contained within, or connected with, different other components. Such depicted architectures are merely examples, and many other architectures may be implemented which achieve the same or similar functionality.

The terms used in this disclosure and in the appended embodiments, (e.g., bodies of the appended embodiments) are generally intended as "open" terms (e.g., the term

"including" should be interpreted as "including, but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes, but not limited to," etc.). In addition, if a specific number of elements is introduced, this may be interpreted to mean at least the recited number, as may be indicated by context (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations of two or more recitations). As used in this disclosure, any disjunctive word and/or phrase presenting two or more alternative terms should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phase "A or B": will be understood to include the possibilities of "A" or "B" or "A and B."

The terms "a," "an," "the" and similar referents used in the context of describing the present disclosure (especially in the context of the following embodiments) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The use of any and all examples, or representative language (e.g., "such as") provided herein is intended merely to better illuminate the present disclosure and does not pose a limitation on the scope of any embodiments. No language in the specification should be construed as indicating any non-embodied element essential to the practice of the present disclosure.

Groupings of alternative elements or embodiments disclosed herein are not to be construed as limitations. Each group member may be referred to and embodied individually or in any combination with other members of the group or other elements found herein. It is anticipated that one or more members of a group may be included in, or deleted from, a group for reasons of convenience and/or patentability. When any such inclusion or deletion occurs, the specification is deemed to contain the group as modified thus fulfilling the written description of all Markush groups used in the appended embodiments.

Certain embodiments are described herein, including the best mode known to the inventors for carrying out the present disclosure. Of course, variations on these described embodiments, will become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventor expects skilled artisans to employ such variations as appropriate, and the inventors intend for the present disclosure to be practiced otherwise than specifically described herein. Accordingly, the embodiments include all modifications and equivalents of the subject matter recited in the embodiments as permitted by applicable

law. Moreover, any combination of the above-described elements in all possible variations thereof is contemplated unless otherwise indicated herein or otherwise clearly contradicted by context. In closing, it is to be understood that the embodiments disclosed herein are illustrative of the principles of the embodiments. Other modifications that may be employed are within the scope of the embodiments. Thus, by way of example, but not of limitation, alternative embodiments may be utilized in accordance with the teachings herein. Accordingly, the embodiments are not limited to the embodiments precisely as shown and described.

EMBODIMENTS

Embodiment 1 A photoluminescent complex comprising:

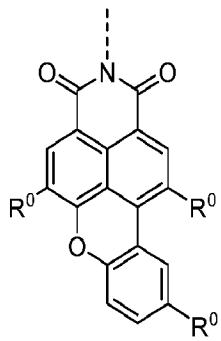
A blue light absorbing xanthenoisoquinoline derivative;

a linker complex, wherein the linker complex is an unsubstituted ester or substituted ester; and

a boron-dipyrromethene (BODIPY) moiety;

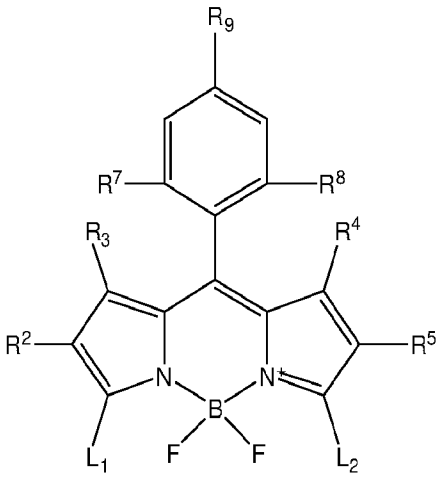
wherein the linker complex covalently links the xanthenoisoquinoline derivative and the BODIPY moiety, wherein the xanthenoisoquinoline derivative absorbs light energy of a first excitation wavelength and transfers an energy to the BODIPY moiety, wherein the BODIPY moiety absorbs the energy from the xanthenoisoquinoline derivative and emits a light energy of a second higher wavelength, and wherein the photoluminescent complex has an emission quantum yield greater than 80%.

Embodiment 2 The photoluminescent complex of embodiment 1, wherein the xanthenoisoquinoline derivative is of the general formula:



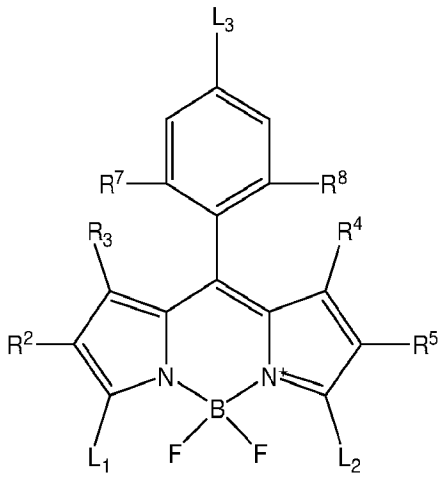
, wherein R^0 is a bond, an H, a C_1-C_4 alkyl group, or an optionally substituted aryl group.

Embodiment 3 The photoluminescent complex of embodiment 1 wherein the BODIPY moiety is of the general formula:



Formula 1

and / or



Formula 2 ;

wherein R^1, R^2, R^3, R^4, R^5, R^6 are independently selected from a bond, an H, C_1-C_3 alkyl, aryl and/ or an ether;

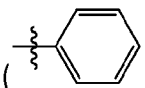
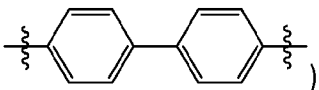
wherein R^7, R^8, and R^9 can be independently selected from a bond, H, or a methyl group (-CH_3); and

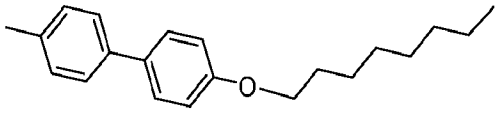
wherein L1, L2, and L3 are an independent linker complex, wherein the linker complex is an unsubstituted ester or substituted ester.

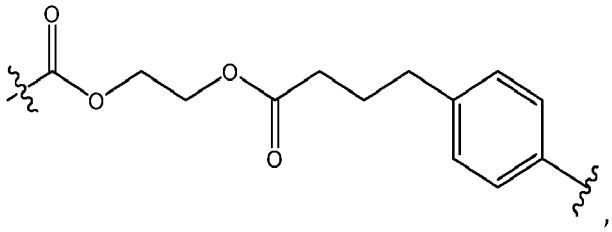
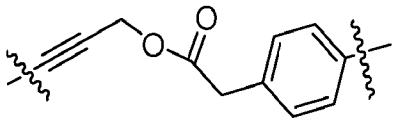
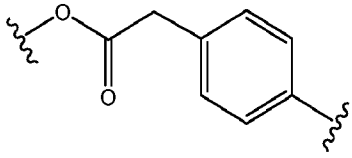
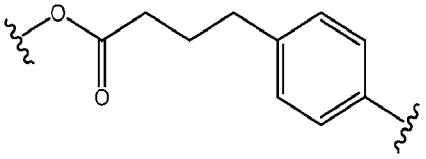
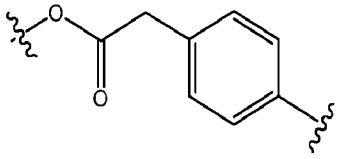
Embodiment 4 The photoluminescent complex of embodiment 3, wherein R3 and R4 can comprise an aryl group.

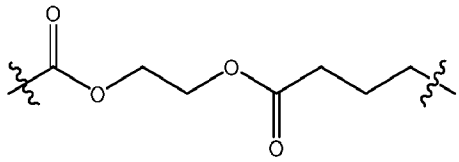
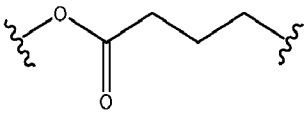
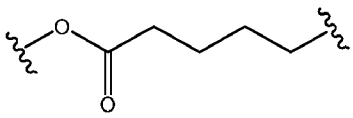
Embodiment 5 The photoluminescent complex of embodiment 4, wherein the aryl group comprises a phenyl group,

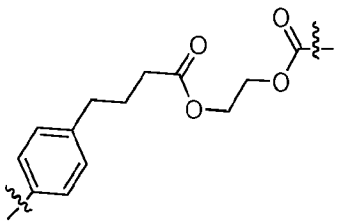
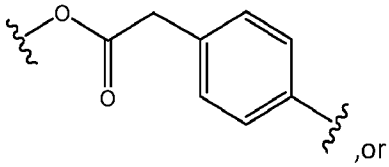
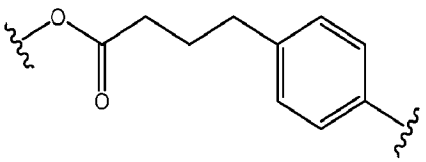
Embodiment 6 The photoluminescent complex of embodiment 4, wherein the phenyl group comprises a 4-trifluromethylphenyl group, or a 3,5-bis(trifluoromethyl)phenyl group.

Embodiment 7 The photoluminescent complex of embodiment 3, wherein the substituted aryl group can be a phenyl group (), or a diphenyl group ().

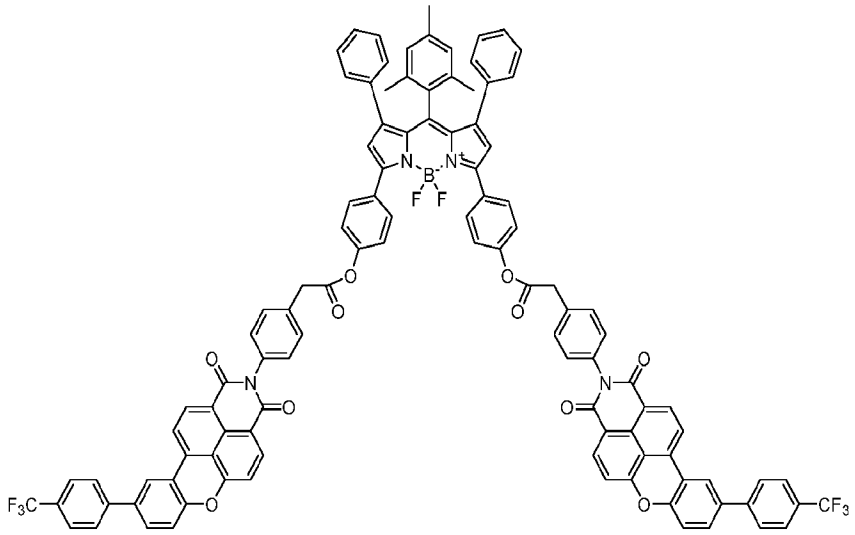
Embodiment 8 The photoluminescent complex of embodiment 3, wherein the ether group can be a C2-C10 alkyl ether group ().

Embodiment 9 The photoluminescent complex of embodiment 1, wherein the linker can be selected from , , , or , or .

Embodiment 10 The photoluminescent complex of embodiment 1, 2, 3, 4, 5, 6, 7, 8, or 9, wherein the unsubstituted ester linker is , , or .

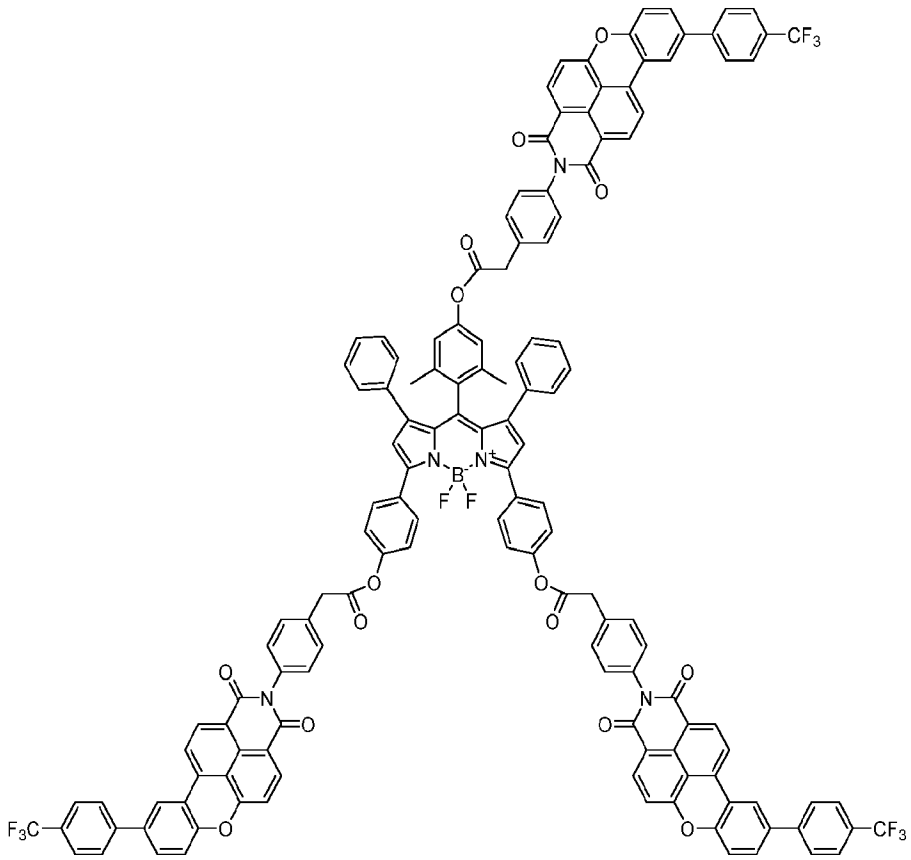
Embodiment 11 The photoluminescent complex of embodiment 1, 2, 3, 4, 5, 6, 7, 8, or 9, wherein the substituted ester of the linker complex is one of the following structures: , ,or .

Embodiment 12 The photoluminescent complex of embodiment 1, wherein the photoluminescent complex is one of the following structures:



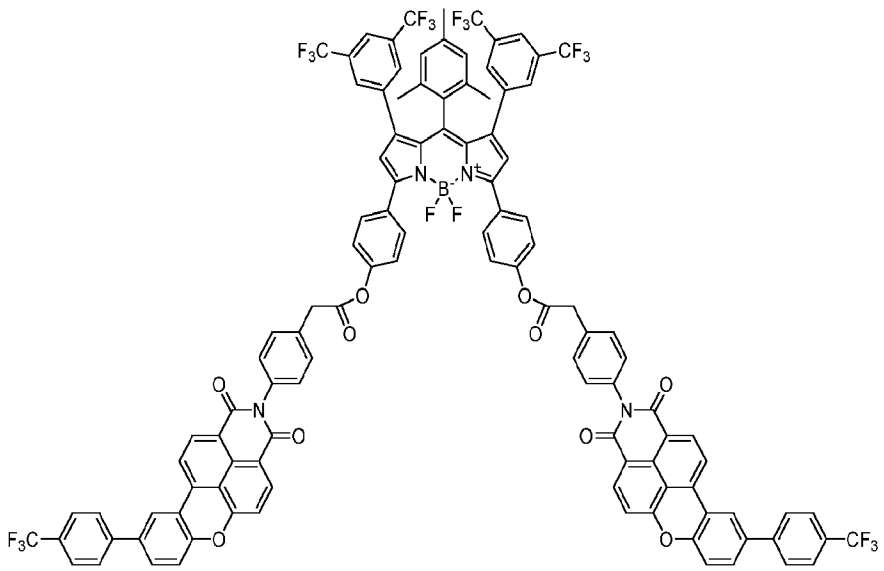
Compound 1

,



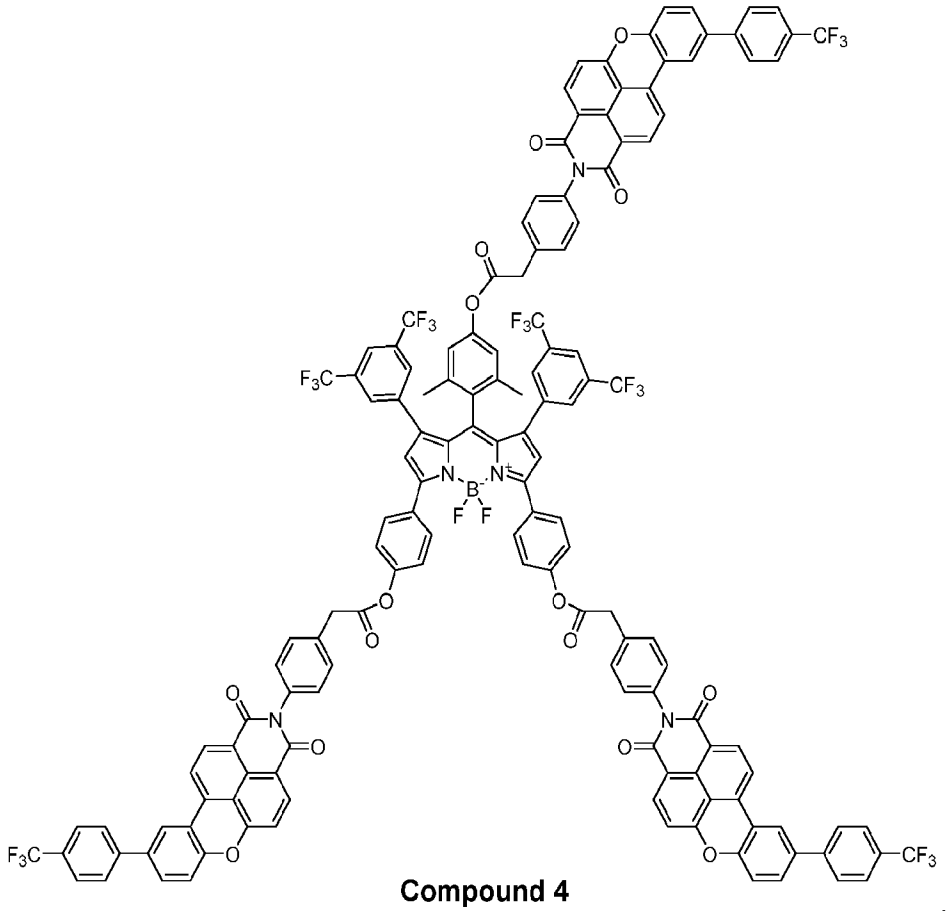
Compound 2

, ,



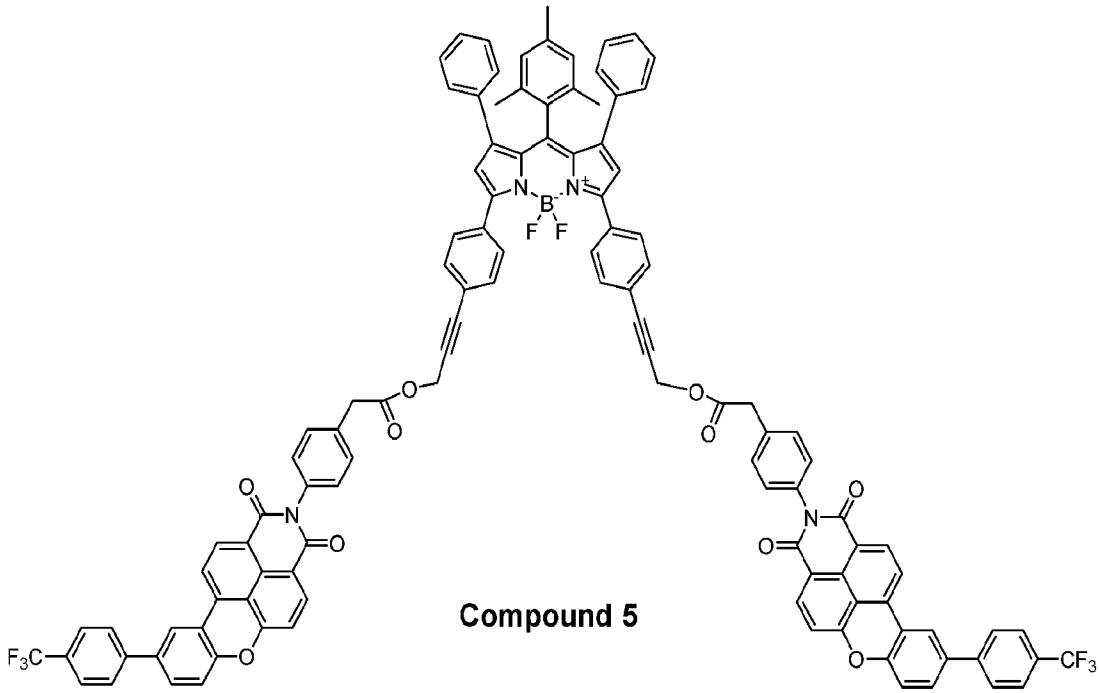
Compound 3

,

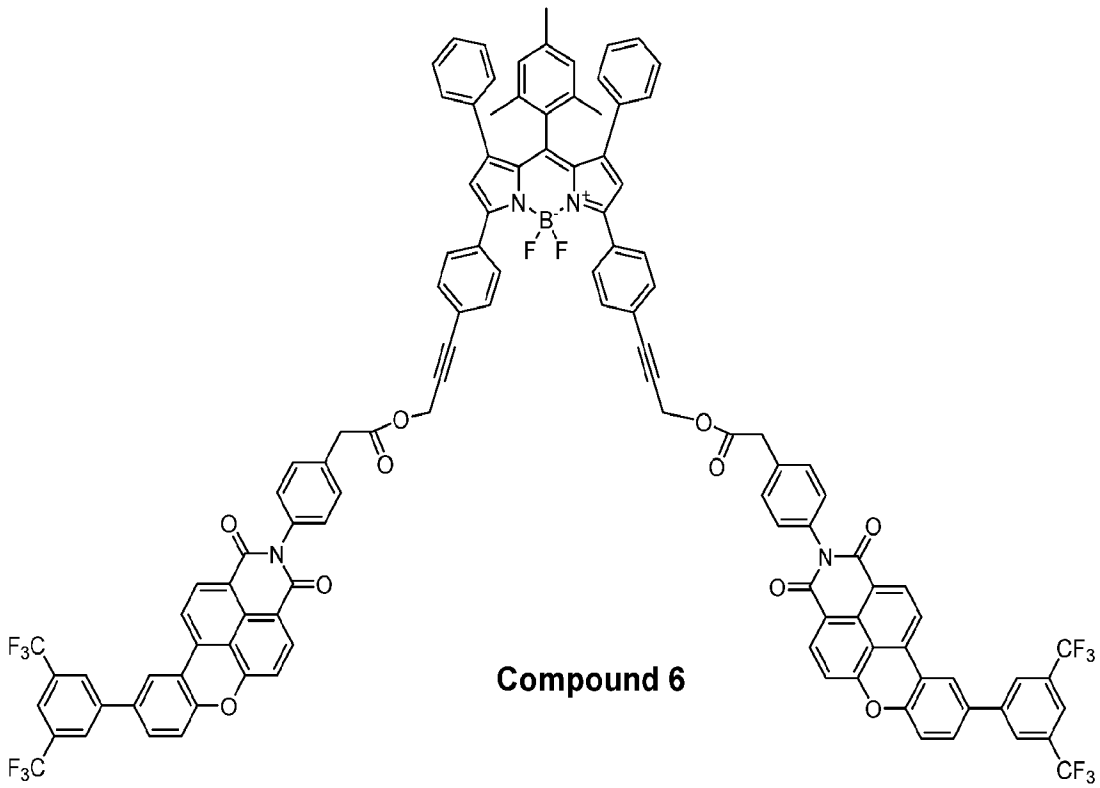


Compound 4

,

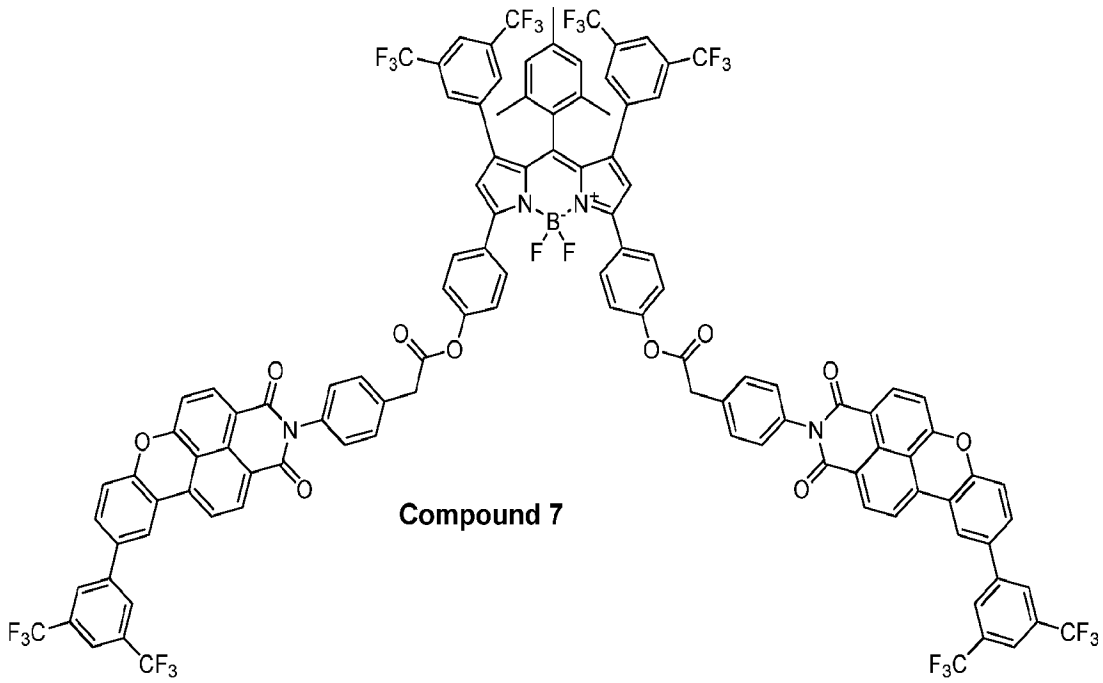


Compound 5

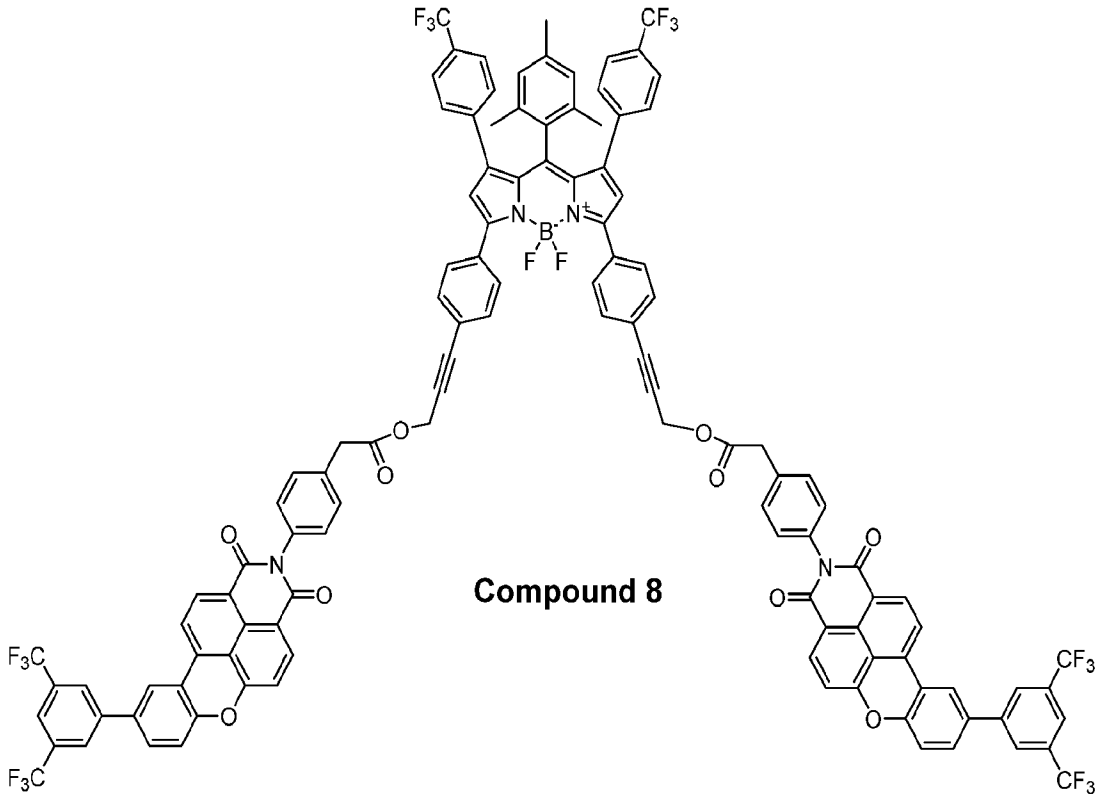


Compound 6

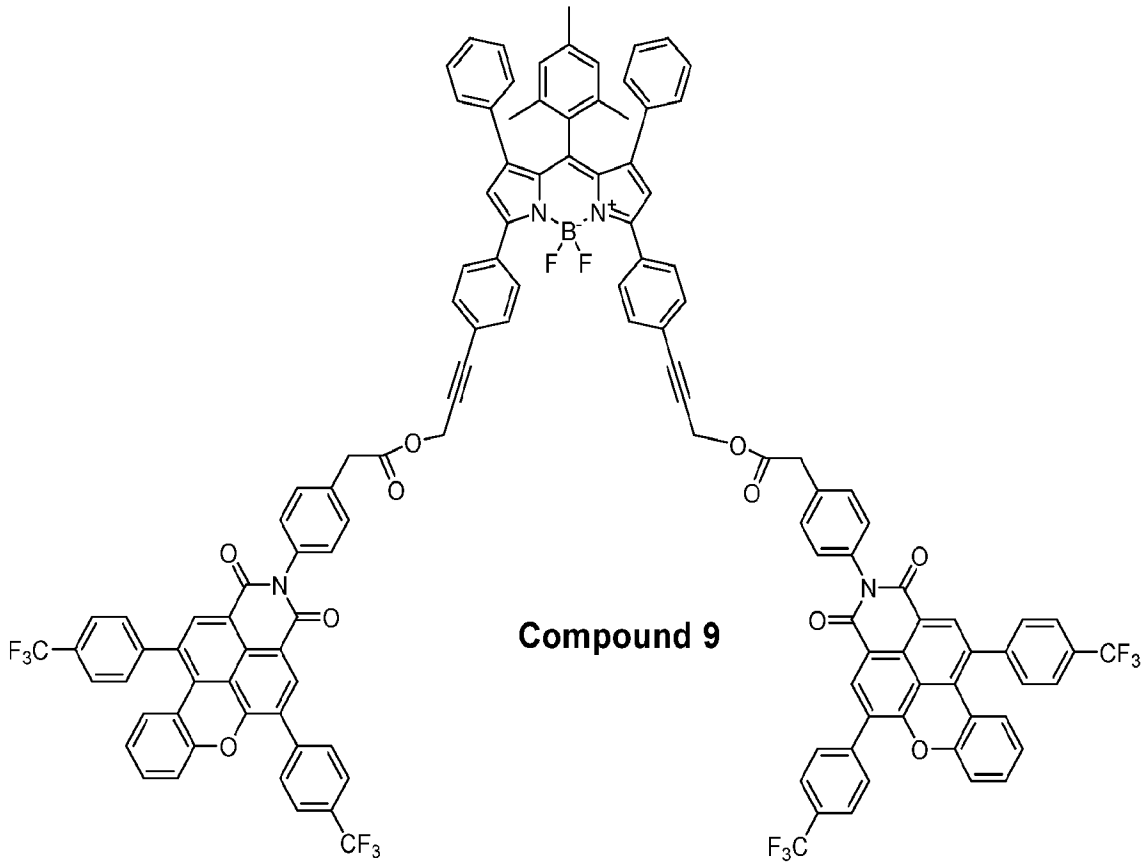
,



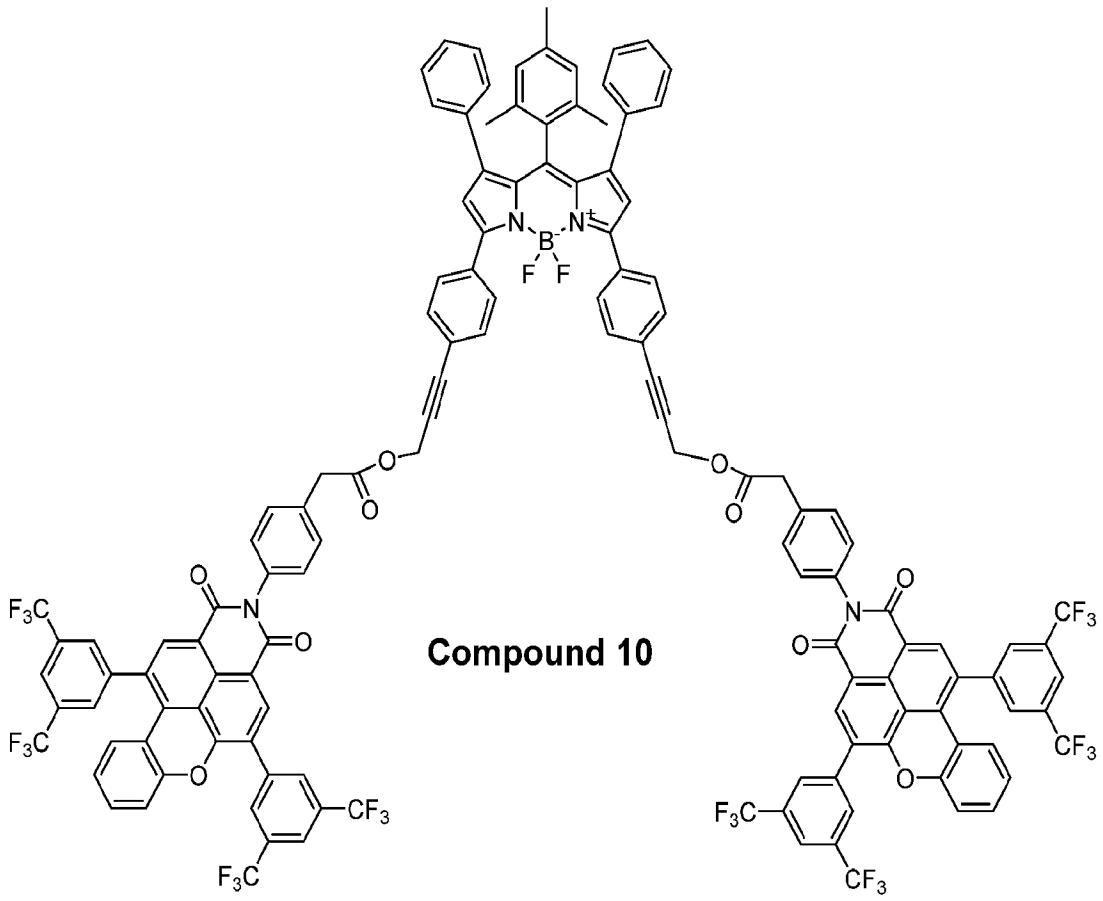
Compound 7



Compound 8

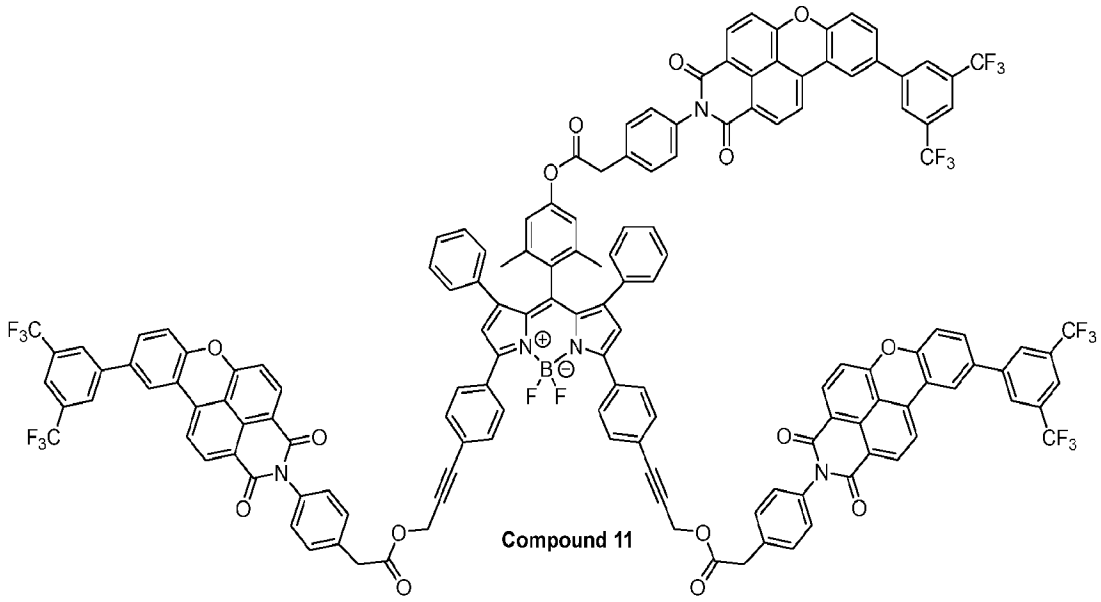


Compound 9

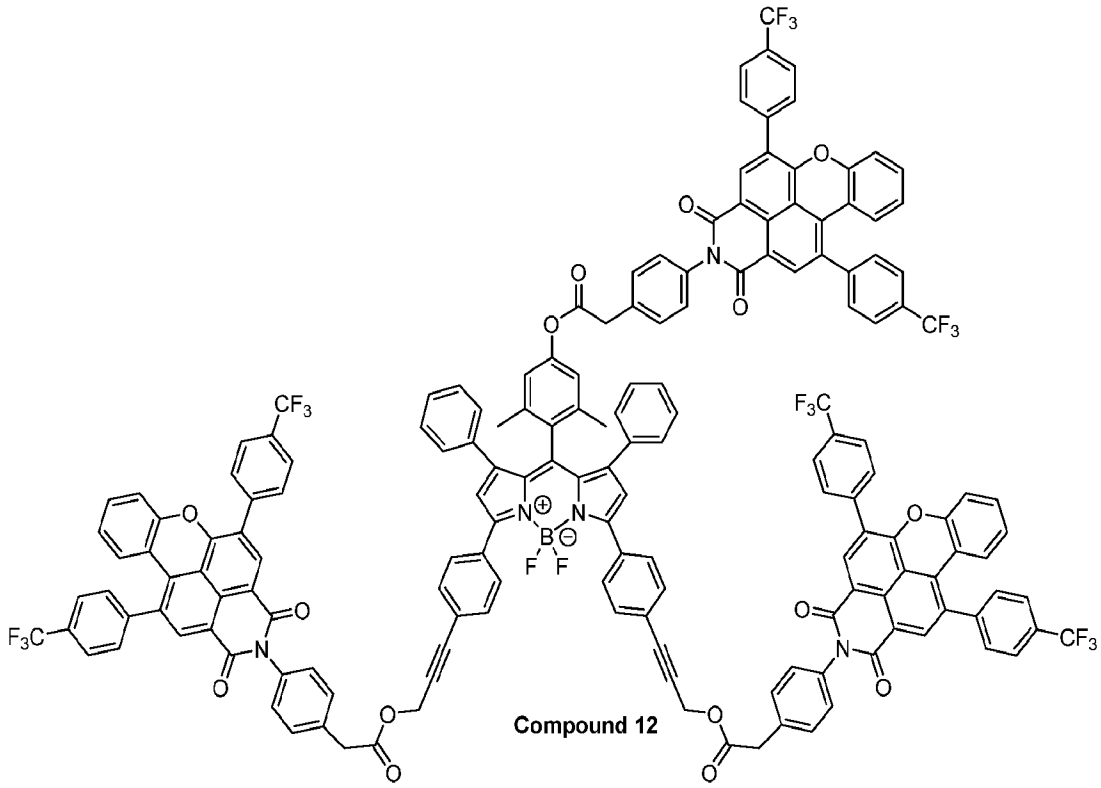


Compound 10

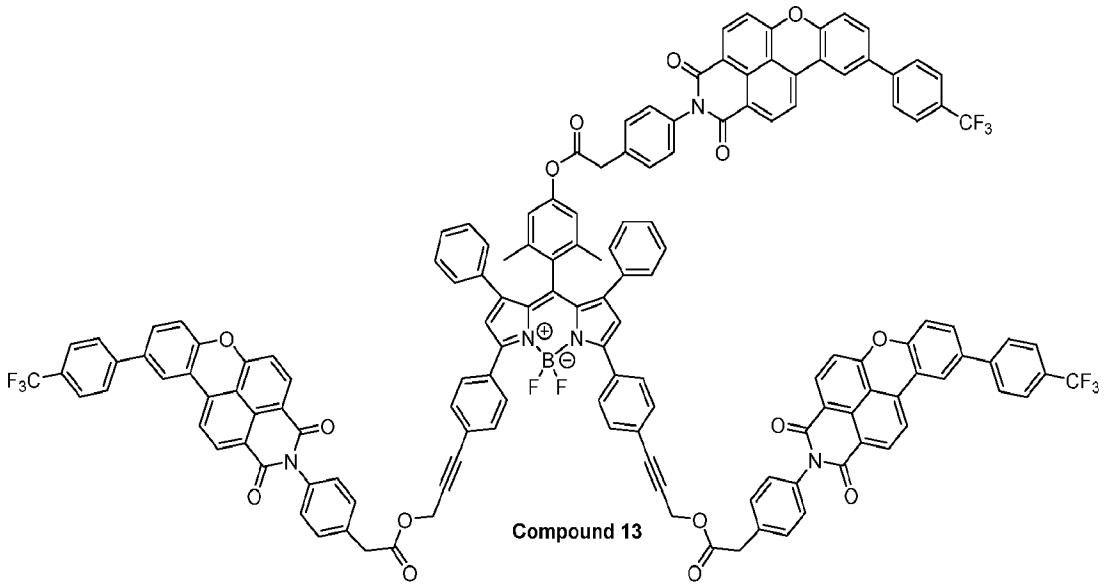
,



Compound 11

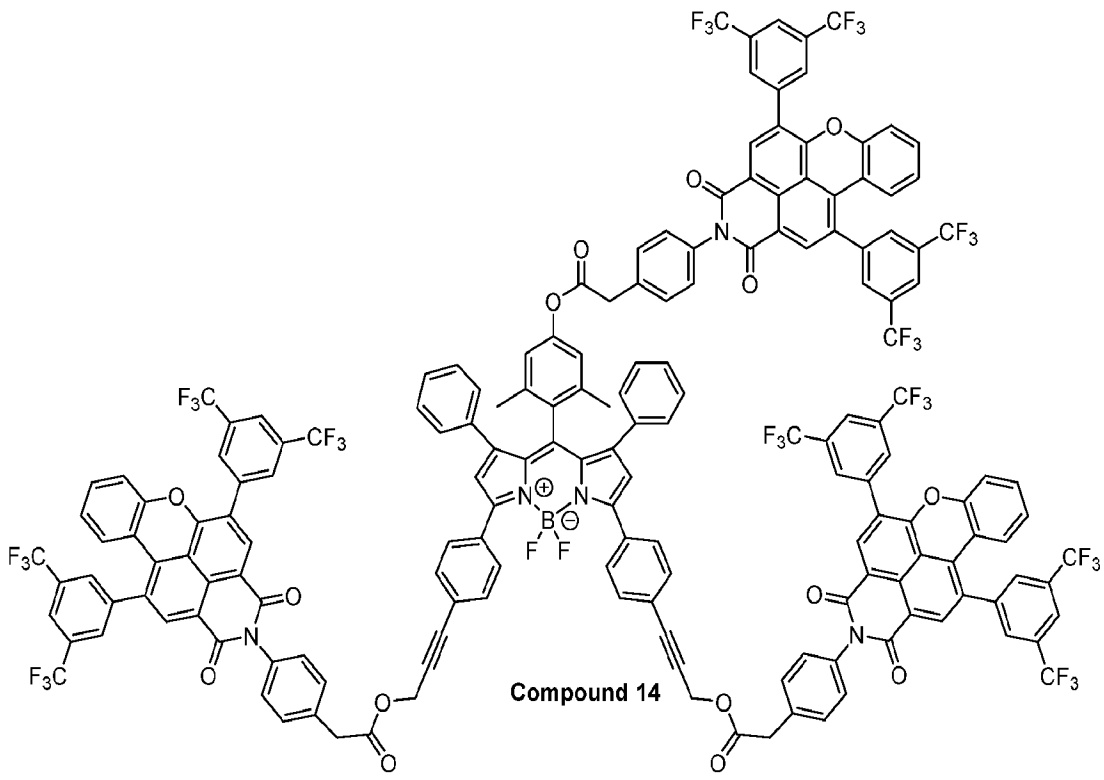


Compound 12



Compound 13

,



Compound 14

or a combination thereof.

Embodiment 13 A color conversion film, comprising:

a transparent substrate layer;

a color conversion layer, wherein the color conversion layer includes a resin matrix, wherein the resin matrix comprises butyl acrylate; and

at least one photoluminescent complex, wherein the at least one photoluminescent compound comprises the photoluminescent compound of embodiment, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12, dispersed within the resin matrix.

Embodiment 14 The color conversion film of embodiment 13, further comprising a singlet oxygen quencher.

Embodiment 15 The color conversion film of embodiment 13, further comprising a radical scavenger.

Embodiment 16 The color conversion film of embodiment 13, wherein the film has a thickness of between about 10 μm and about 200 μm.

Embodiment 17 The color conversion film of embodiment 13, wherein the film absorbs light in about 400 nm to about 600 nm wavelength range and emits light in the about 575 nm to about 645 nm wavelength range.

Embodiment 18 A method for preparing the color conversion film, the method comprising:

dissolving the photoluminescent complex of embodiment 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12, and a binder resin within a solvent; and

applying the mixture to one of the transparent substrates opposing surfaces.

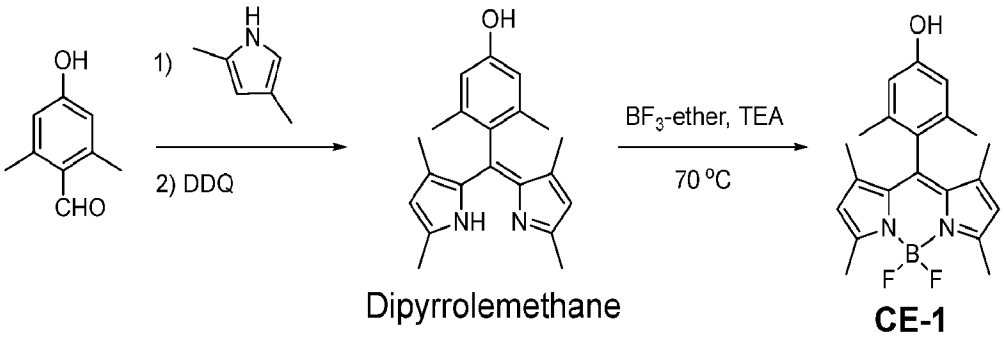
Embodiment 19 A backlight unit including the color conversion film of embodiment 13.

Embodiment 20 A display device including the back-light unit of embodiment 19.

EXAMPLES

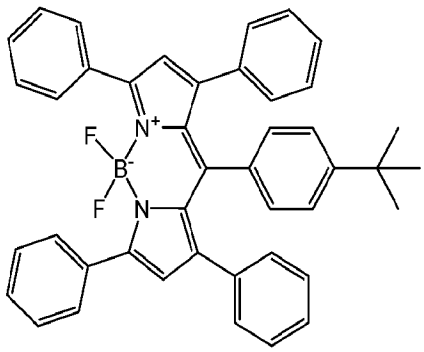
It has been discovered that embodiments of the photoluminescent complexes described herein have improved performance as compared to other forms of dyes used in color conversion films. These benefits are further demonstrated by the following examples, which are intended to be illustrative of the disclosure only but are not intended to limit the scope or underlying principles in any way.

Example 1.1 Comparative example 1 (CE-1):



CE-1: 0.75 g of 4-hydoxyl-2,6-dimethylbenzaldehyde (5 mmol) and 1.04 g of 2,4-dimethylpyrrole (11 mmol) was dissolved in 100 mL of anhydrous dichloromethane. The solution was degassed for 30 minutes. Then one drop of trifluoroacetic acid was added. The solution was stirred overnight under argon gas atmosphere at room temperature. To the resulting solution, DDQ (2,3-Dichloro-5,6-dicyano-1,4-benzoquinone) (2.0g) was added and the mixture was stirred overnight. The next day the solution was filtered and then washed with dichloromethane resulting in a dipyrrolemethane (1.9 g). Next, 1.0 g of dipyrrolemethane was dissolved in 60 mL of THF. 5 mL of trimethylamine was added to the solution and then degassed for 10 minutes. After degassing, 5 mL of trifluoroboron-diethylether was added slowly followed by heating for 30 minutes at 70 °C. The resulting solution was loaded on a silica gel and purified by flash chromatography using dichloromethane as the eluent. The desired fraction was collected and dried under reduced pressure to yield 0.9 g or an orange solid (76% yield). LCMS (APCI+): calculated for $C_{21}H_{24}BF_2N_2O$ (M+H) = 369; found: 369. 1H NMR (400 MHz, Chloroform-d) δ 6.64 (s, 2H), 5.97 (s, 2H), 4.73 (s, 1H), 2.56 (s, 6H), 2.09 (s, 6H), 1.43 (s, 6H).

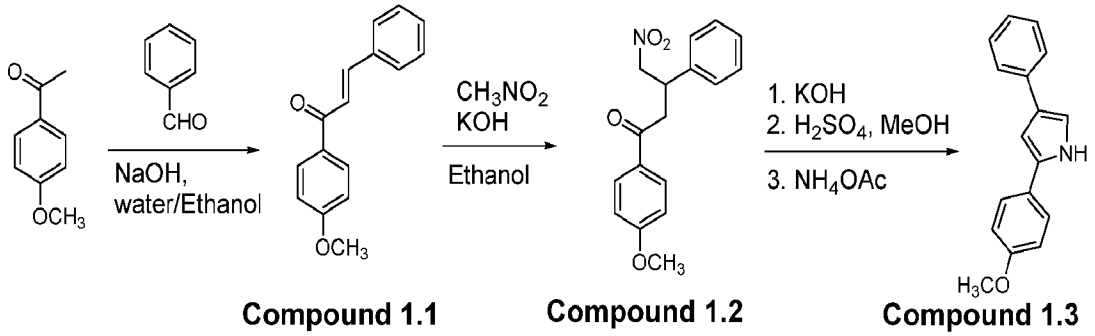
Example 1.2 Comparative Example 2 (CE-2): was synthesized as described in *Wakamiya, Atsushi et al. Chemistry Letters, 37(10), 1094-1095; 2008.* CE-2 has the following structure:



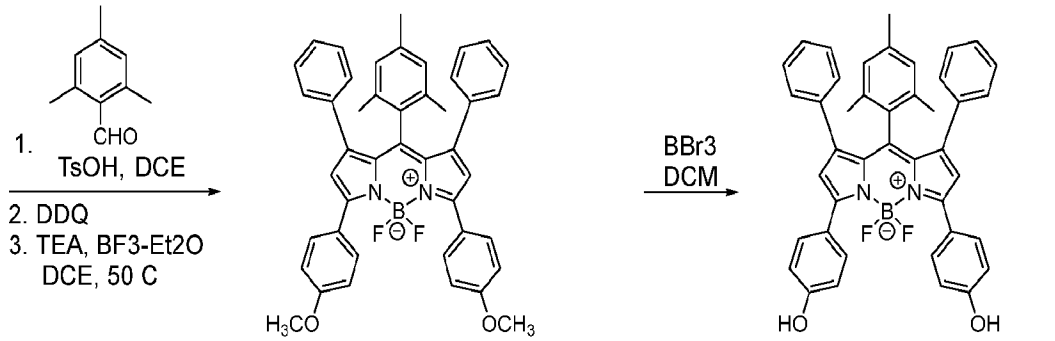
Example 2 Synthesis of Photoluminescent Complexes:

Example 2.1: PLC-1

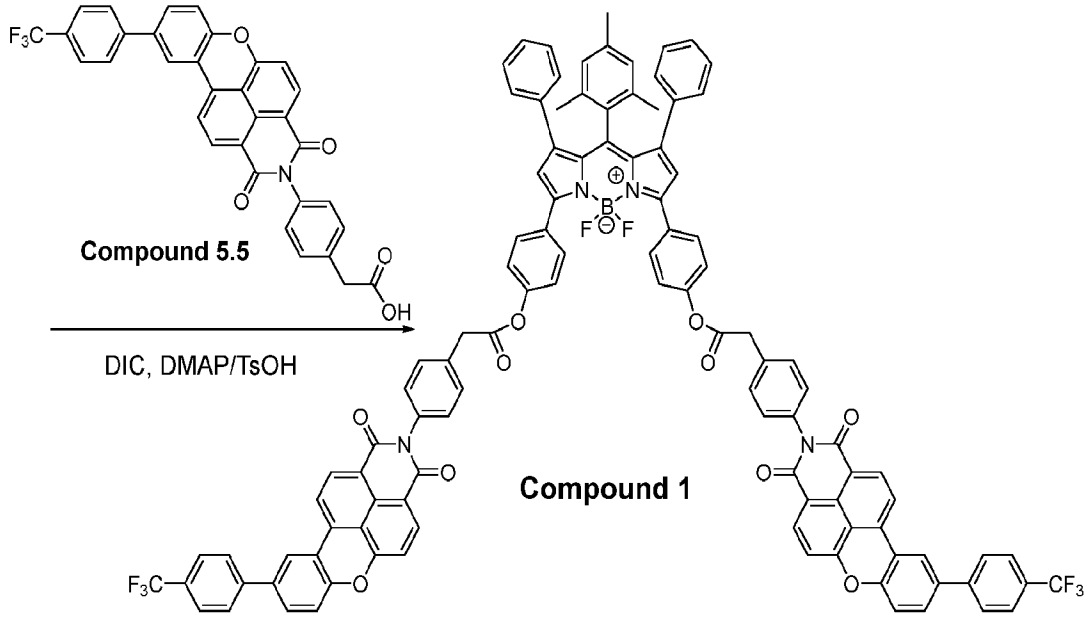
Synthesis of Compound 1



Compound 1.1 **Compound 1.2** **Compound 1.3**



Compound 1.4 **Compound 1.5**



Compound 1

Compound 1.1:

To a solution of benzaldehyde (5 mmol), 4-methoxyacetophenone (995 mg, 5 mmol) in 10 mL ethanol, will be added a 10% sodium hydroxide aqueous solution (5 mL) dropwise. The mixture will be stirred for 15 min, filtration and washing with 20 mL ethanol/water (1:1) will give a white solid.

Compound 1.2:

To a solution of **Compound 1.1** (4.2 mmol) in 15 mL ethanol, will be added nitromethane (2.7 mL, 50 mmol), then potassium hydroxide pellet (47 mg, 0.8 mmol). The mixture will be stirred at 70 °C for 30 min under inert atmosphere. To the solution, 100 mL water will be added, and the mixture will be extracted with ethyl acetate (EA) (50 mL x 3). The organic phase will be collected, loaded on silica gel, and purified by flash chromatography using eluents of hexanes/EA (0% to 25% DCM). The main peak will be collected, and after removal of solvent under reduced pressure, a colorless liquid will be obtained.

Compound 1.3:

Step-1: To a solution of **Compound 1.2** (10 mmol) in 80 mL tetrahydrofuran (THF) and 50 mL methanol (MeOH), will be added potassium hydroxide (KOH) powder (1.12 g, 20 mmol) at 0 °C. The mixture will be stirred for 10 min, then transferred into an additional funnel. This solution will be added dropwise into a solution of Conc. Sulfuric acid (H2SO4) (12 mL) in methanol (50 mL) at 0 °C over a period of one hour. The resulted mixture will be stirred at 0 ºC for additional one hour, then poured into 300 g ice slowly. The ice-organic mixture will be extracted with ethyl acetate (200 mL x2), washed with 10% Potassium carbonate (K2CO3) aqueous solution (100 mL), brine (100 mL), dried over magnesium sulfate (MgSO4). After filtered off the solid, the solvents will be removed under reduced pressure to give a liquid which will be submitted for next step reaction without further purification.

Step-2: A mixture of liquid from reaction above (9 mmol) and ammonium acetate (3.54 g, 46 mmol) in 20 mL acetic acid will be heated at 100 °C for 5 hours. After cooled to room temperature, the mixture will be worked up with water (200 mL), extracted with ethyl acetate (250 mL). The organic phase will be washed with brine, loaded on silica gel, and purified by flash chromatography using eluents of hexanes/dichloromethane (DCM) (0% to 50% DCM). The main peak will be collected, and removal of solvents will give a solid.

Compound 1.4:

To a mixture of **Compound 1.3** (1.36 mmol), 2,4,6-trimethylbenzaldehyde (0.101 g, 0.68 mmol) in 25 mL DCE, will be added p-TsOH (0.05 g), and stirred at 60 °C under argon atmosphere for 24 hours. The solution will be cooled to room temperature, then DDQ (0.17g, 0.75 mmol) will be added into this solution and stirred for one hour. To the resulted mixture, at 0 °C, TEA (0.75 mL, 5.25 mmol) and BF3-Et2O (2.0 mL, 16.5 mmol) will be added at 0 C. Then the mixture will be stirred at 50 °C for one hour, cooled to room temperature. The resulted mixture will be diluted with 100 mL DCM, washed with water, dried over MgSO4, loaded on silica gel, and purified by flash chromatography using eluents of hexanes/DCM (0% to 50% DCM). The desired peak will be collected, removal of solvents will give a dark purple solid.

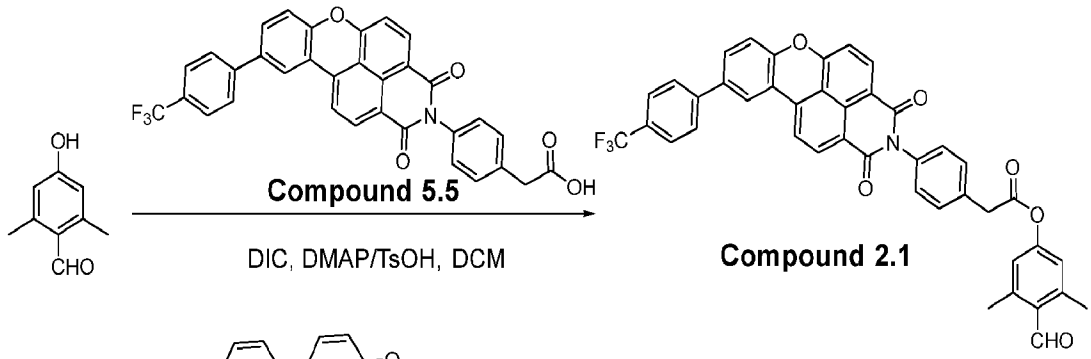
Compound 1.5:

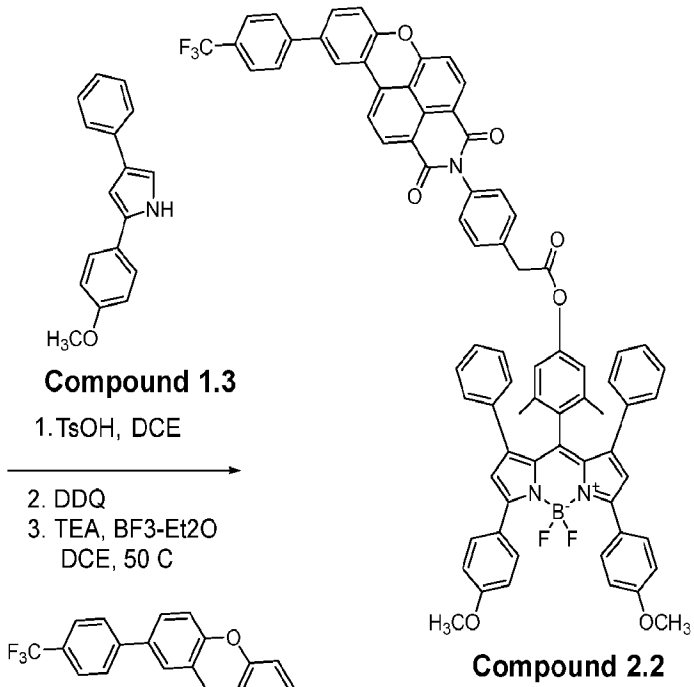
To a solution of **Compound 1.4** (1.0 mmol) in 20 mL anhydrous DCM, BBr3 (1.1 mmol) was added at -78 °C. The mixture was stirred at -78 °C for 2 hours, then poured into water and extracted with DCM. The organic phase was collected and dried over MgSO4. After removal of solvent at reduced pressure, the desired product is obtained.

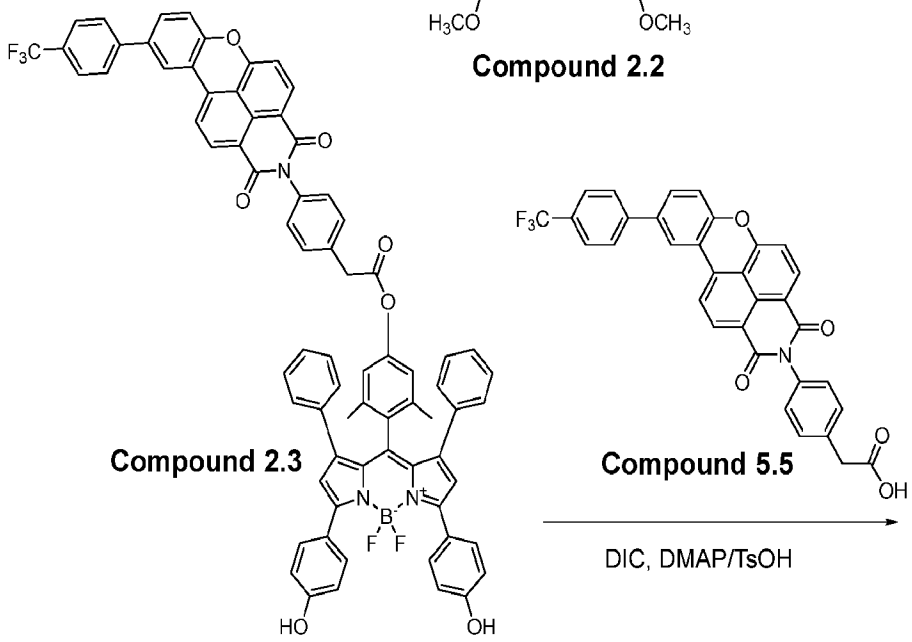
Compound 1:

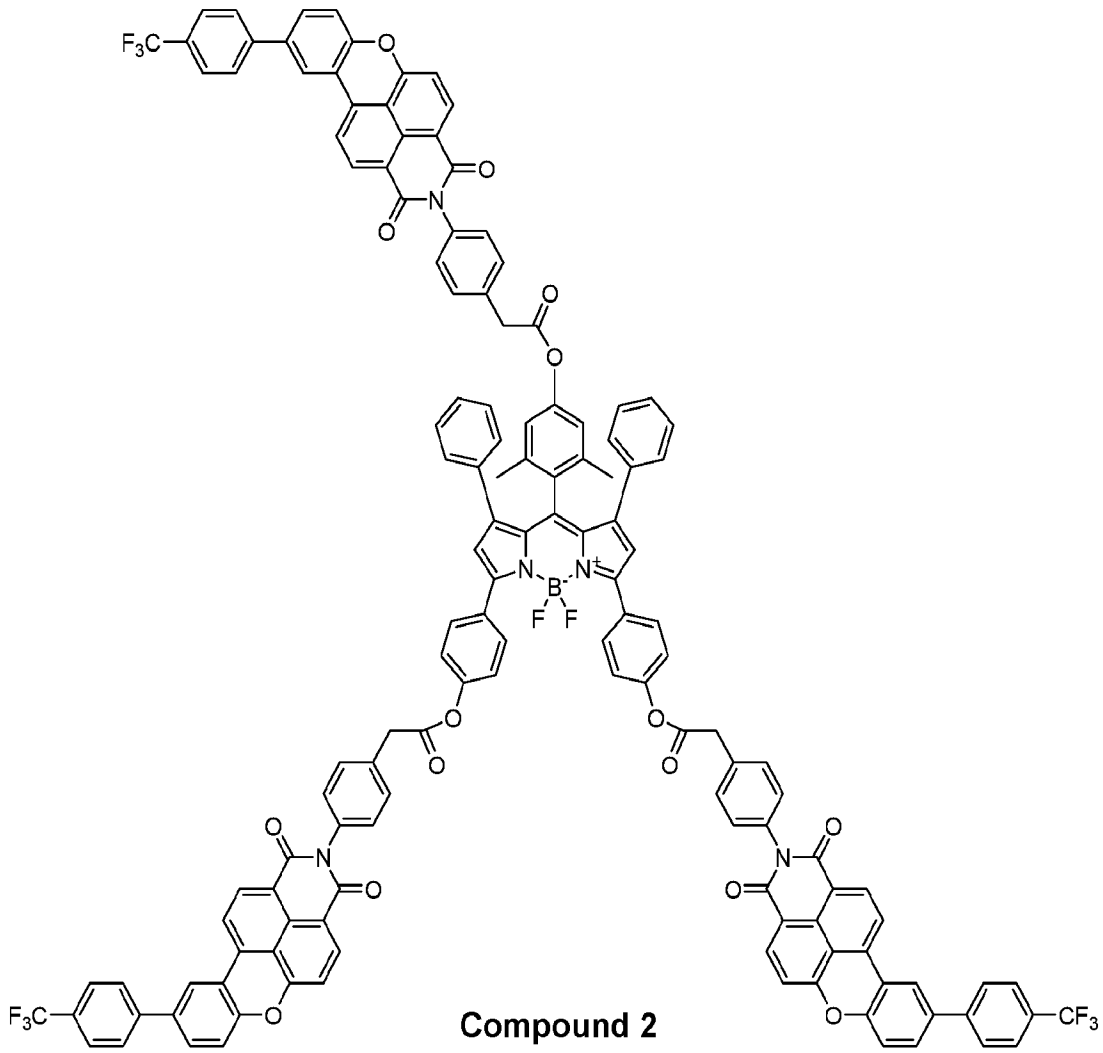
A mixture of **Compound 1.5** (0.1 mmol), 2-(4-(1,3-dioxo-9-(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 5.5**, *vide infra*, 0.3 mmol), diisopropylcarbodiimide (DIC) (0.63 mmol), dimethylaminopyridine (DMAP)/TsOH salt (58 mg, 0.2 mmol) in DCM (10 mL) will be stirred at room temperature overnight. The resulted solution will be loaded on silica gel and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The desired peak will be collected, and removal of solvent will give the product as solid.

Synthesis of Compound 2


Compound 5.5
DIC, DMAP/TsOH, DCM
Compound 2.1


Compound 1.3
1. TsOH, DCE
2. DDQ
3. TEA, BF3-Et2O
DCE, 50 C
BBr3, DCM
Compound 2.2


Compound 2.3
Compound 5.5
DIC, DMAP/TsOH



Compound 2

Compound 2.1:

A mixture of 4-hydroxy-2,4-dimethylbenzaldehyde (0.1 mmol), 2-(4-(1,3-dioxo-9-(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 5.5** *vide infra*, 0.15 mmol), DIC (0.63 mmol), DMAP/TsOH salt (58 mg, 0.2 mmol) in DCM (10 mL) will be stirred at room temperature overnight. The resulted solution will be loaded on silica gel and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The desired peak will be collected, and removal of solvent will give the product as solid.

Compound 2.2

To a mixture of **Compound 1.3** (1.36 mmol) and **Compound 2.1** (0.68 mmol) in 25 mL DCE, will be added p-TsOH (0.05 g), and stirred at 60 °C under argon atmosphere for 24 hours. The solution will be cooled to room temperature, then DDQ (0.17 g, 0.75 mmol) will be added into

this solution and stirred for one hour. To the resulted mixture, at 0 °C, TEA (0.75 mL, 5.25 mmol) and BF3-Et2O (2.0 mL, 16.5 mmol) will be added at 0 °C. Then the mixture will be stirred at 50 °C for one hour, cooled to room temperature. The resulted mixture will be diluted with 100 mL DCM, washed with water, dried over MgSO4, loaded on silica gel, and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The desired peak will be collected, removal of solvents will give a dark purple solid.

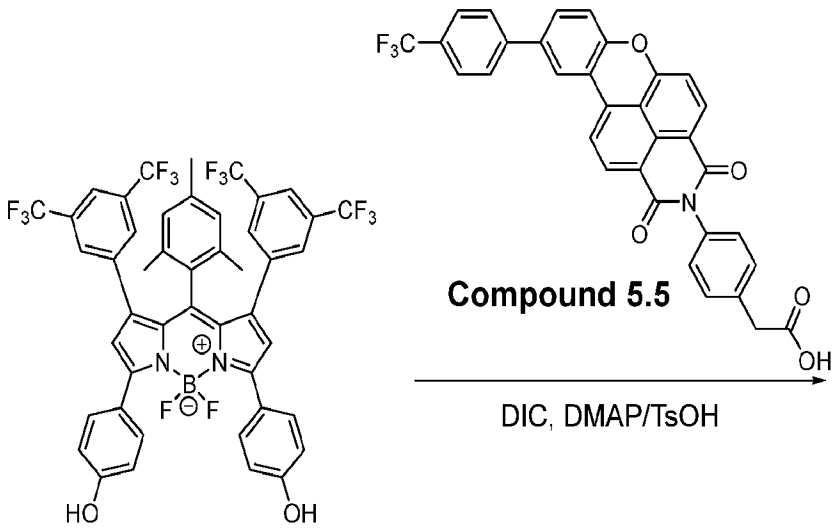
Compound 2.3

To a solution of **Compound 2.2** (1.0 mmol) in 20 mL anhydrous DCM, BBr3 (1.1 mmol) will be added at -78 C. The mixture will be stirred at -78 °C for 2 hours, then poured into water and extracted with DCM. The organic phase will be collected and dried over MgSO4. After removal of solvent at reduced pressure, the desired product can be obtained.

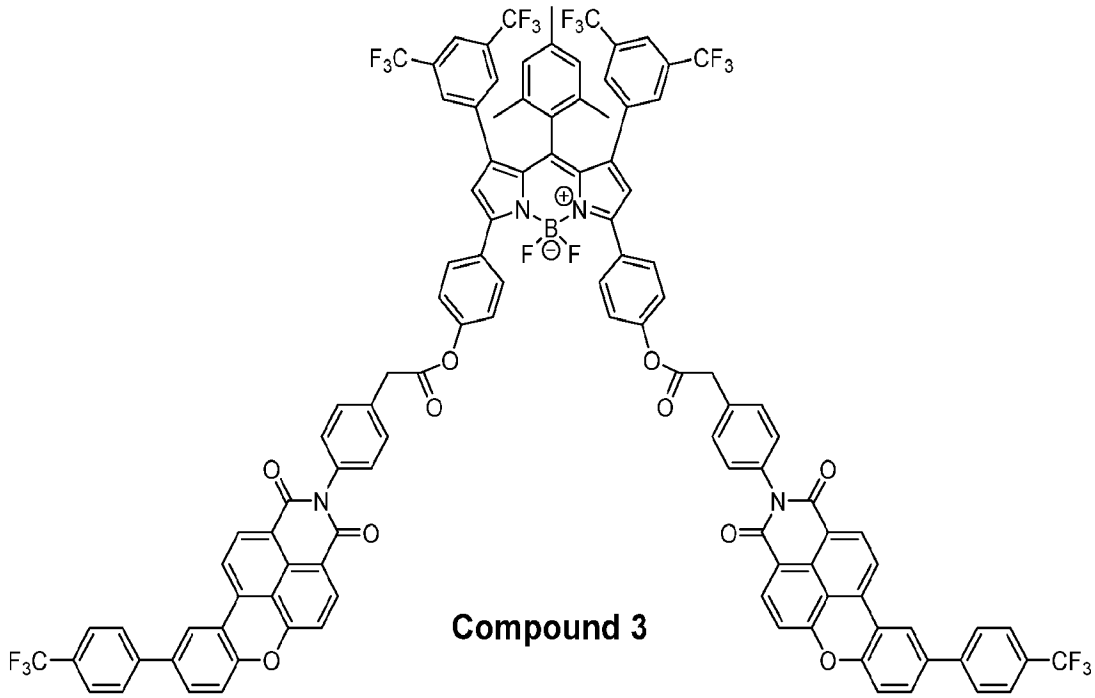
Compound 2:

A mixture of **Compound 2.3** (0.1 mmol), 2-(4-(1,3-dioxo-9-(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 5.5**, 0.3 mmol), DIC (0.63 mmol), DMAP/TsOH salt (58 mg, 0.2 mmol) in DCM (10 mL) will be stirred at room temperature overnight. The resulted solution will be loaded on silica gel and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The desired peak will be collected, and removal of solvent will give the product as solid.

Synthesis of Compound 3



Compound 7.7

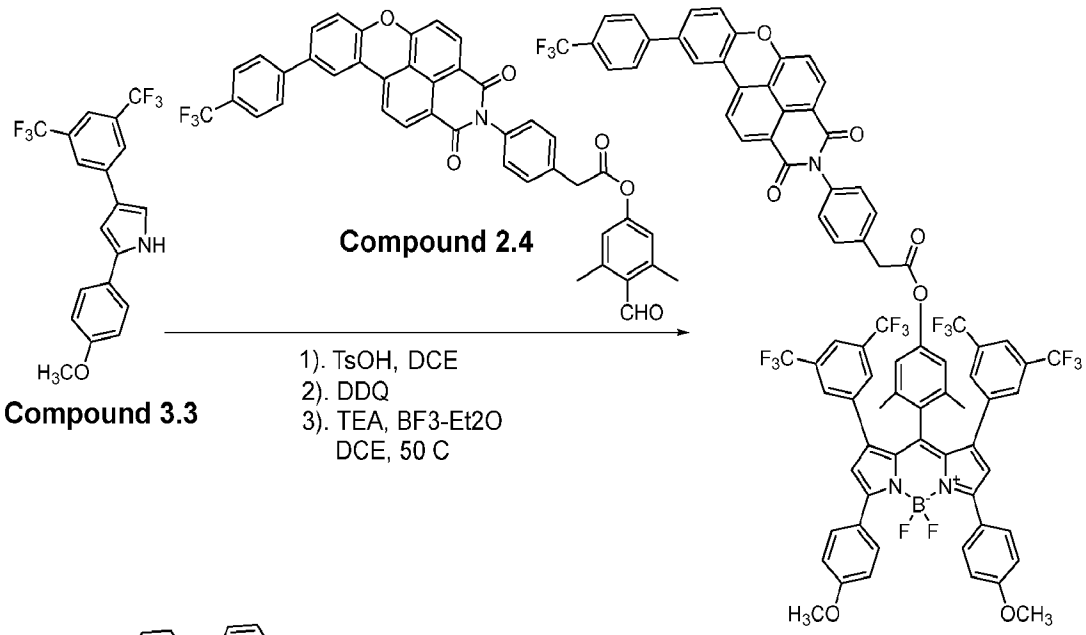


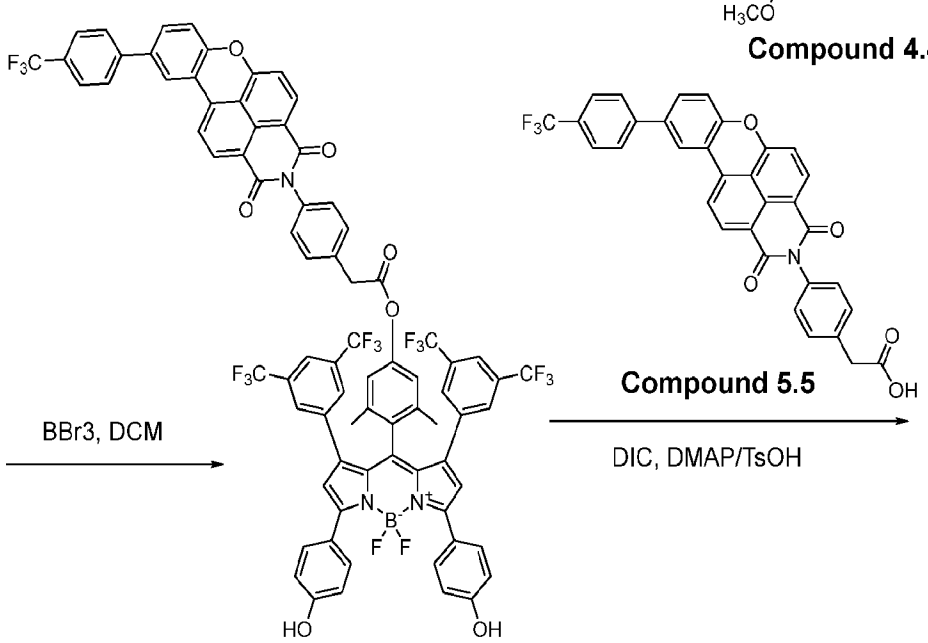
Compound 3

Compound 3:

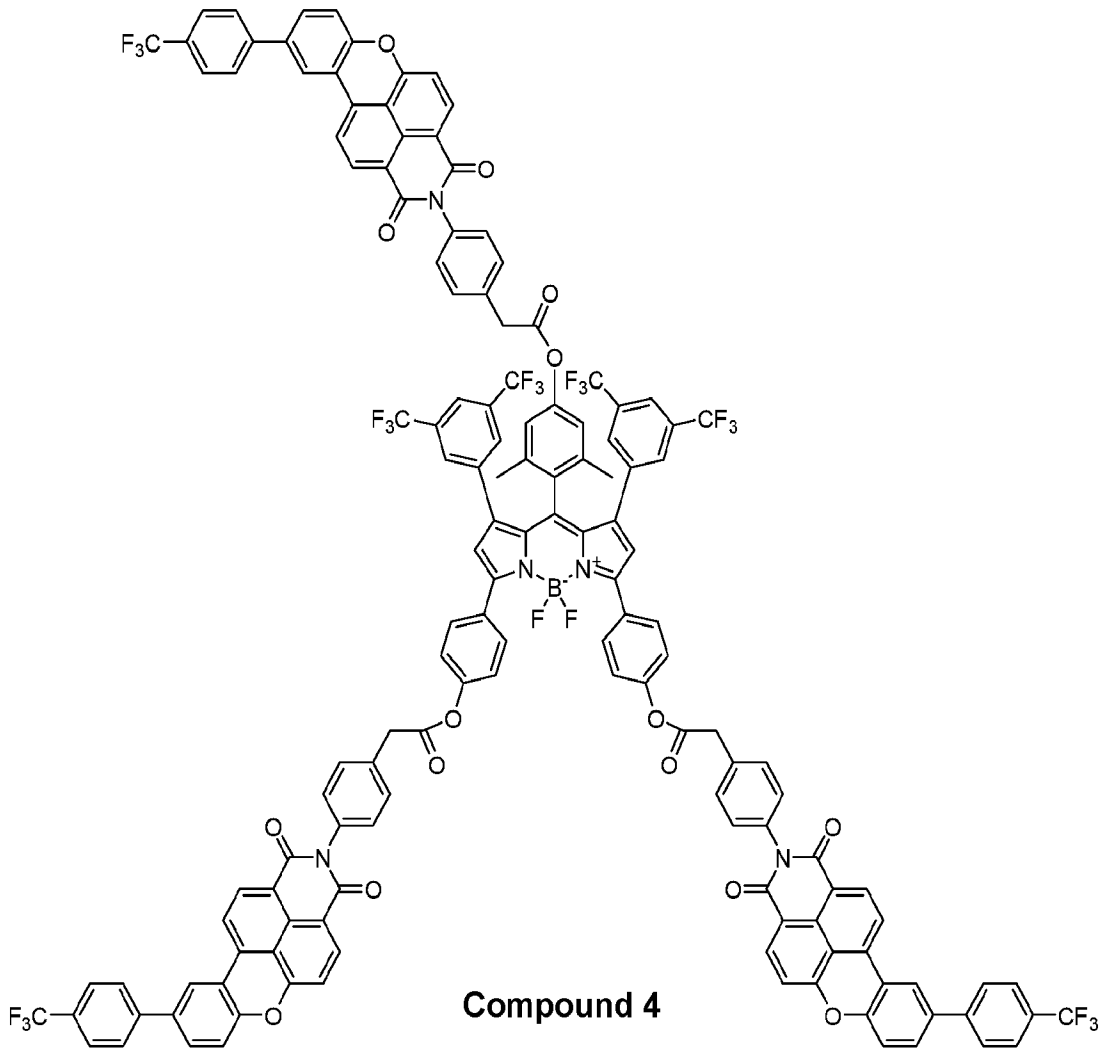
A mixture of **Compound 7.7** (*vide infra*, 0.1 mmol), 2-(4-(1,3-dioxo-9-(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 5.5**, *vide infra*, 0.3 mmol), DIC (0.63 mmol), DMAP/TsOH salt (58 mg, 0.2 mmol) in DCM (10 mL) will be stirred at room temperature overnight. The resulted solution will be loaded on silica gel and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The desired peak will be collected, and removal of solvent will give the product as solid.

Synthesis of Compound 4





Compound 4.5



Compound 4

Compound 4.4

To a mixture of **Compound 3.3** (1.36 mmol) and **Compound 2.4** (0.68 mmol) in 25 mL DCE, will be added p-TsOH (0.05 g), and stirred at 60 °C under argon atmosphere for 24 hours. The solution will be cooled to room temperature, then DDQ (0.17 g, 0.75 mmol) will be added into this solution and stirred for one hour. To the resulted mixture, at 0 °C, TEA (0.75 mL, 5.25 mmol) and BF3-Et2O (2.0 mL, 16.5 mmol) will be added at 0 °C. Then the mixture will be stirred at 50 °C for one hour, cooled to room temperature. The resulted mixture will be diluted with 100 mL DCM, washed with water, dried over MgSO4, loaded on silica gel, and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The desired peak will be collected, removal of solvents will give a dark purple solid.

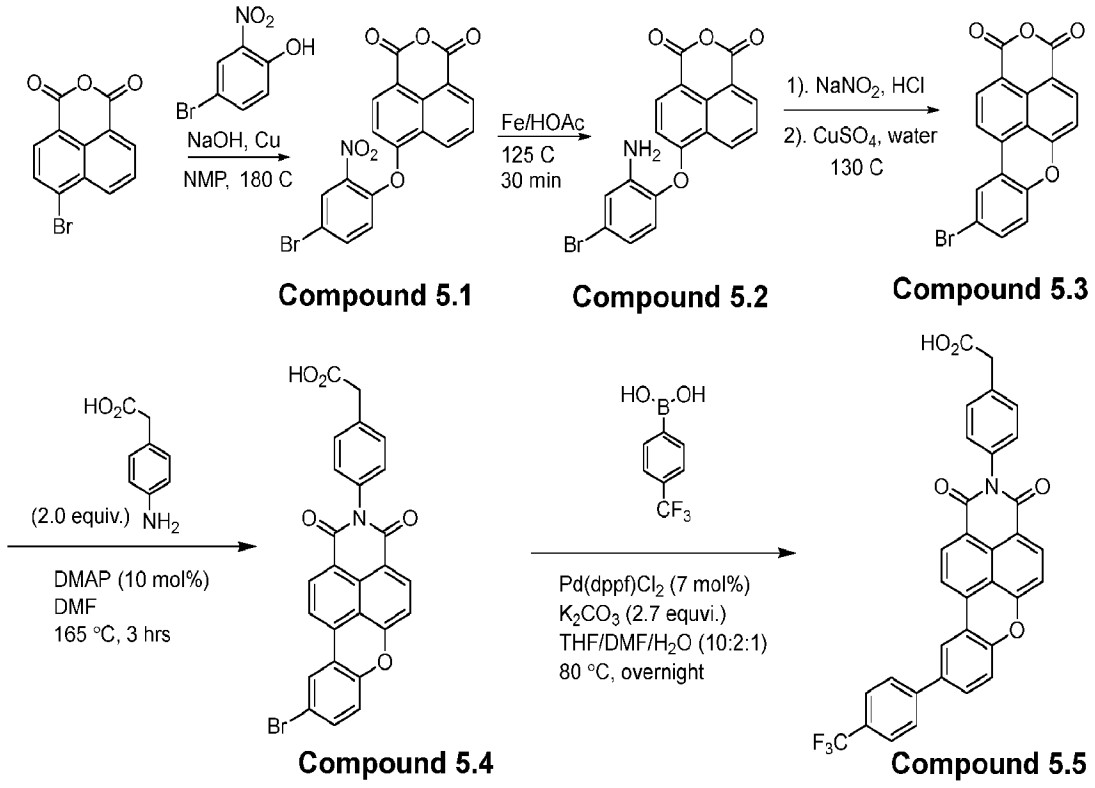
Compound 4.5

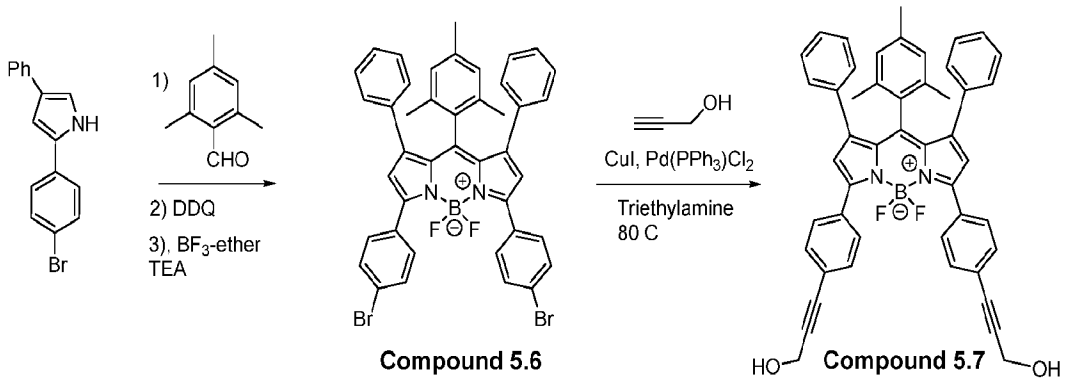
To a solution of **Compound 4.4** (1.0 mmol) in 20 mL anhydrous DCM, BBr3 (1.1 mmol) will be added at -78 °C. The mixture will be stirred at -78 °C for 2 hours, then poured into water and extracted with DCM. The organic phase will be collected and dried over MgSO4. After removal of solvent at reduced pressure, the desired product will be obtained.

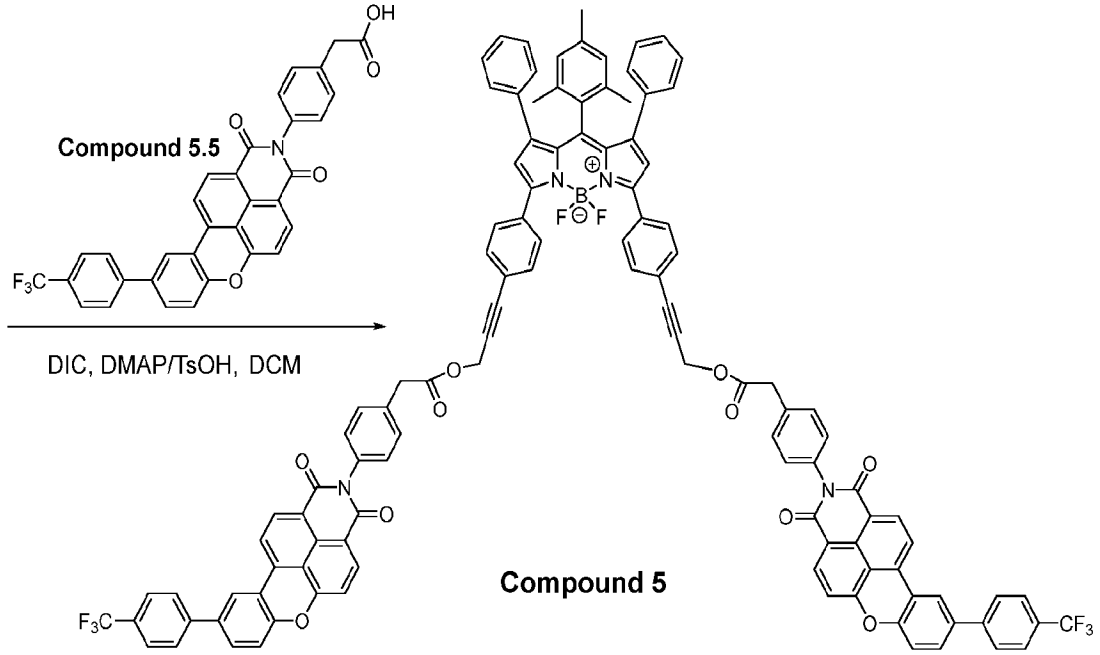
Compound 4:

A mixture of **Compound 4.5** (0.1 mmol), 2-(4-(1,3-dioxo-9-(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 5.5**, 0.3 mmol), DIC (0.63 mmol), DMAP/TsOH salt (58 mg, 0.2 mmol) in DCM (10 mL) will be stirred at room temperature overnight. The resulted solution was loaded on silica gel and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The desired peak was collected, and removal of solvent will give the product as solid.

Synthesis of Compound 5







Compound 5.1: (6-(4-bromo-2-nitrophenoxy)-1H,3H-benzo[de]isochromene-1,3-dione): A mixture of 4-bromo-1,8-naphthalic anhydride (2.77 g, 10 mmol), 4-bromo-2-nitrophenol (3.27 g, 15 mmol) was degassed under vacuum for 30 min, then anhydrous NMP (50 mL) was added, followed by addition of sodium hydroxide (0.2 g, 5 mmol) and copper powder (0.318 g, 5 mmol). The mixture was sparged with argon for 20 min, then heated at 180 °C overnight under argon atmosphere. After cooled down to room temperature, to the solution, 50 mL 20% hydrochloride acid aqueous solution was added dropwise, then added 50 mL water. The resulted mixture was allowed to stand for 3 hrs., then filtered to collect the precipitate, which was dried in vacuum to afford 4.6 g crude product. The crude product was dispersed in 30 mL acetone and stirred overnight at room temperature to dissolve the impurities. Filtration and dried in vacuum gave a brown, yellow solid as desired product (**Compound 5.1**) (3.3 g, in 80%

yield). LCMS (APCI+): calculated for $C_{18}H_9BrNO_6$ (M+H) = 413.95; Found: 414. 1H NMR (400 MHz, TCE-d_2) δ 8.70 (dd, J = 8.4, 1.2 Hz, 1H), 8.63 (dd, J = 7.3, 1.2 Hz, 1H), 8.41 (d, J = 8.3 Hz, 1H), 8.24 (d, J = 2.4 Hz, 1H), 7.89 – 7.79 (m, 2H), 7.20 (d, J = 8.7 Hz, 1H), 6.82 (d, J = 8.3 Hz, 1H).

Compound 5.2 (6-(2-amino-4-bromophenoxy)-1H,3H-benzo[de]isochromene-1,3-dione): A mixture of **Compound 5.1** (1.5 g, 3.6 mmol), iron powder (0.60 g, 10.8 mmol) in acetic acid (50 mL) was heated at 125 °C for 30 min. After cooled to room temperature, to the mixture, 100 mL water was added while stirring. The resulted mixture was filtered and washed with water, dried in air and vacuum to give a solid (**Compound 5.2**) (1.35 g, in 82% yield). LCMS (APCI-): calculated for $C_{18}H_{10}BrNO_4$ = 382.98; Found: 383. 1H NMR (400 MHz, DMSO-d_6) δ 9.01 – 8.26 (m, 3H), 7.96 (s, 1H), 6.93 (dd, J = 85.2, 36.5 Hz, 4H), 5.54 (s, 2H).

Compound 5.3 (9-bromo-1H,3H-isochromeno[6,5,4-mna]xanthene-1,3-dione): Compound 5.2 (2.65 g, 6.9 mmol) was dispersed in acetic acid (50 mL)/water (10 mL) and cooled to 0 ºC. While being stirred, precooled hydrochloric acid (2.8 mL, 34.5 mmol) was added, then sodium nitrite solution (3.57 g, 52 mmol) in 15 mL water was added dropwise at 0 °C. The whole was stirred for one hour at 0 °C, then was transferred into additional funnel, and dropped into a copper sulfate solution (12 g, 47 mmol, in 140 mL water) over one hour period at 130 °C. After cooled to room temperature, the precipitate was collected by filtration, washed with water (100 mL × 3), then stirred in 50 mL acetone at 40 °C for 30 min. Filtration, dried in air then in vacuum gave a brown, yellow solid (**Compound 5.3**) (1.76g, in 70% yield). LCMS (APCI+): calculated for $C_{18}H_8BrO_4$ (M+H) = 366.95; Found: 367. 1H NMR (400 MHz, d_2-TCE) δ 8.51 (dd, J = 12.3, 8.1 Hz, 2H), 8.12 (d, J = 2.3 Hz, 1H), 7.86 (d, J = 7.9 Hz, 1H), 7.60 (dd, J = 8.8, 2.3 Hz, 1H), 7.28 (d, J = 8.3 Hz, 1H), 7.23 (d, J = 8.8 Hz, 1H).

Compound 5.4 (2-(4-(9-bromo-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid): A mixture of **Compound 5.3** (400.0 mg, 1.1 mmol), 4-aminophenylacetic acid (329.4 mg, 2.2 mmol) and DMAP (9.3 mg, 0.080 mmol) in DMF (8 mL) was degassed at room temperature. Then the mixture was heated up to 165 °C and has been kept at this temperature for 3 hrs. TLC and LCMS showed ~95% conversion without observable side-reaction. The mixture was cooled down to 50 °C. Then it was poured into an acetone solution (40 mL), which has been pre-chilled by water-ice bath. The mixture has been kept at 0 °C for 2 hrs. and then has been kept stirring at room temperature overnight. The

solid was collected through vacuum filtration and washed by acetone (4 mL). And it was dried by vacuum oven at 100 °C for 3 hrs. to provide the pure **Compound 5.4** as a yellow brown solid 395.0 mg, 73% yield. MS (APCI): calculated for $C_{26}H_{14}BrNO_5$ ([M+H]+) = 500 found: 500. 1H NMR (400 MHz, $CDCl_2CDCl_2$) δ 8.65 (d, J = 8.0 Hz, 1H), 8.62 (d, J = 8.0 Hz, 1H), 8.21 (dd, J = 6.4 Hz, 2.4 Hz, 1H), 7.99 (bs, 1H), 7.95 (t, J = 7.6 Hz, 1H), 7.67 (dd, J = 8.4 Hz, 2.4 Hz, 1H), 7.53 (d, J = 8.0 Hz, 2H), 7.37 (d, J = 8.4 Hz, 1H), 7.32 (m, 3H), 2.94 (s, 2H).

Compound 5.5 (2-(4-(1,3-dioxo-9-(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid): A mixture of **Compound 5.4** (400.0 mg, 0.80 mmol), 4-(trifluoromethyl)phenylboronic acid (262.2 mg, 1.6 mmol), $Pd(dppf)Cl_2$ (41.0 mg, 0.056 mmol) and K_2CO_3 (298.0 mg, 2.2 mmol) in THF/DMF/H_2O (22 ml/ 4.4 ml/ 2.2 ml) was degassed at room temperature. The reaction mixture was heated up to 80 °C and the reaction has been kept at this temperature overnight. TLC was used to monitor the reaction. After the completion, the reaction was worked up by the addition of 0.1N HCl (150 ml) and EtOAc (150 ml). The aqueous phase was further extracted by THF (150 ml*3). The combined organic phases were dried over anhydrous Na_2SO_4, concentrated under rotavapor, and purified by flash chromatography, using DCM in EtOAc (0-40%, with 0.1% TFA) as an eluant to provide pure **Compound 5.5** as a yellow/ yellow brown solid. 363.0 mg, 80% yield. MS (APCI): calculated for $C_{33}H_{18}F3NO5$ ([M+H]+) = 566 found: 566. 1H NMR (400 MHz, DMSO-d_6) 8.76 (m, 1H), 8.56 (m, 2H), 8.52 (dd, J = 8.0 Hz, J = 3.2 Hz, 1H), 8.15 (m, 2H), 8.06 (m, 1H), 7.94 (d, J = 8.0 Hz, 2H), 7.66 (dd, J = 8.0 Hz, J = 4.0 Hz, 1H), 7.53 (m, 1H), 7.45 (d, J = 8.0 Hz, 2H), 7.33 (d, J = 8.0 Hz, 2H), 3.72 (s, 2H).

Compound 5.6. (3,7-bis(4-bromophenyl)-5,5-difluoro-10-mesityl-1,9-diphenyl-5H-4λ^4,5λ^4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine):

Step 1: A mixture of 2-(4-bromophenyl)-4-phenyl-1H-pyrrole (synthesized according to literature: Synlett, 2016, 27(11), 1738-1742; 1.0 g, 3.36 mmol), 2,4,6-trimethylbenzaldehyde (also referred to as mesitaldehyde, 0.249 g, 1.68 mmol) and p-TsOH•H_2O (100 mg) in 80 mL 1,2-dichloroethane was degassed, then heated at 60 °C for 40 hr. LCMS analysis indicates that the major product is desired product with the peak of m/e$^+$ =727.

Step 2: At room temperature, DDQ (454 mg, 2 mmol) was added into the resulting mixture from step 1, and the whole was stirred for one hour at room temperature. LCMS analysis

indicates that the starting material was fully converted to desired product with the peak of $m/e^- = 724$.

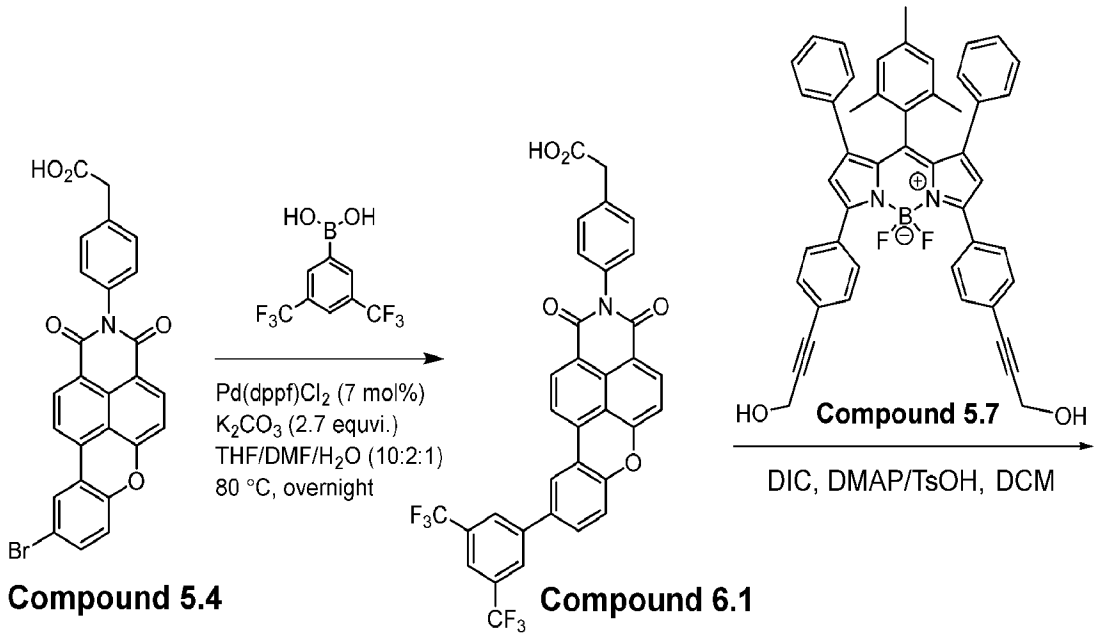
Step 3: With ice-bath cooling, triethylamine (0.85 mL, 6 mmol), and BF_3-diethyl etherate (1.1 mL, 9 mmol) was added to the mixture from step 2. The whole was heated at 50 °C for one hour, then another potion of triethylamine (0.5 mL) and BF_3-diethyl etherate (0.5 mL) was added, and the mixture was heated for another one hour. LCMS analysis indicates that the reaction completed with main peak of m/e- = 772. The mixture was diluted with 50 mL dichloromethane, washed with water twice and brine once. The organic phase was collected and concentrated to 100 mL, then loaded on silica gel and purified by flash chromatography using eluents of hexanes/dichloromethane (with gradient of 40% → 100% dichloromethane). The main fractions were collected and concentrated under reduced pressure to remove the solvents to give a solid, which was washed with methanol, then filtered and dried in air to afford a purple solid (1.06 g, in 81.6% yield). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.81 – 7.73 (m, 4H), 7.61 – 7.54 (m, 4H), 6.97 – 6.90 (m, 2H), 6.85 (dd, *J* = 8.3, 6.9 Hz, 4H), 6.78 – 6.71 (m, 4H), 6.42 (s, 2H), 6.00 (s, 2H), 1.98 (s, 6H), 1.85 (s, 3H). LCMS (APCI-): calcd for $C_{42}H_{31}BBr_2F_2N_2$: 772.1; found: 772.

Compound 5.7 (3,3'-((5,5-difluoro-10-mesityl-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yn-1-ol)): A mixture of **Compound 5.6** (200 mg, 0.258 mmol), CuI (10 mg, 0.052 mmol), $Pd(PPh_3)_2Cl_2$ (36 mg, 0.052 mmol), and propargyl alcohol (56 mg, 1.0 mmol) in 5 mL triethylamine was degassed then heated at 80 °C overnight under argon atmosphere. The resulted mixture was diluted with 200 mL DCM. The DCM solution was washed with 0.1N HCl aqueous solution (100 mL), and water (100 mL), then loaded on silica gel and purified by flash chromatography using eluents of DCM/ethyl acetate (0% to 50% ethyl acetate). The main peak was collected and concentrated under reduced pressure to give a red solid (**Compound 5.7**) (150 mg, in 80.4% yield).

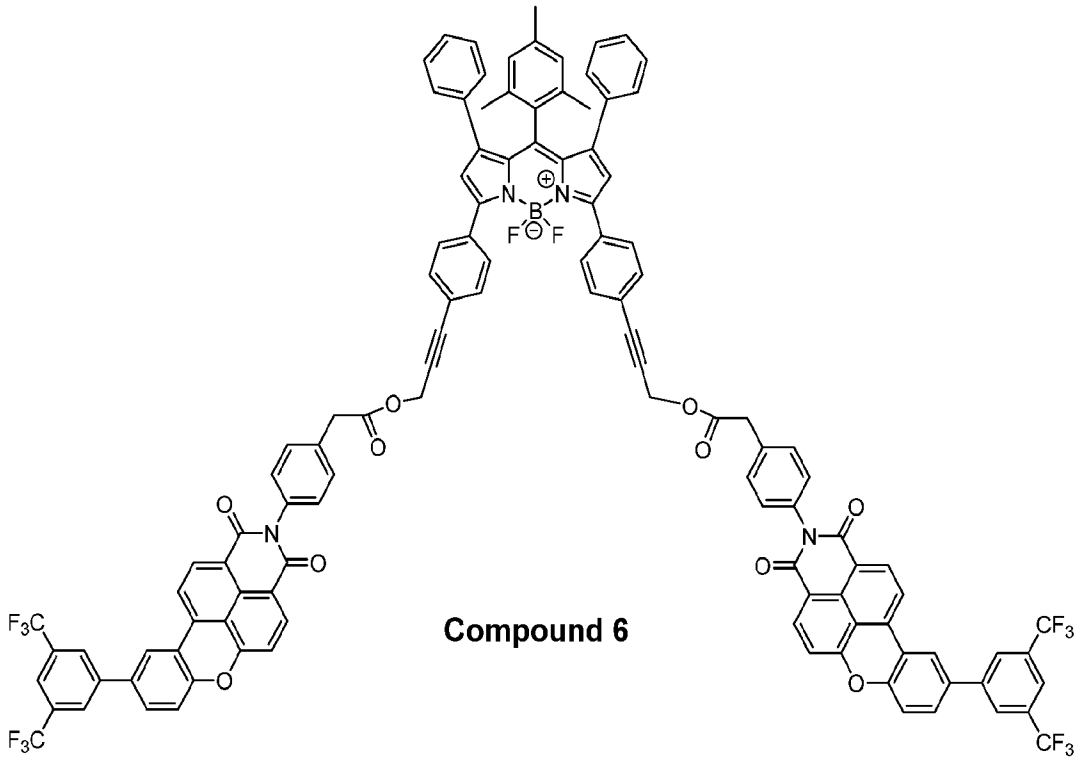
Compound 5 ((5,5-difluoro-10-mesityl-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yne-3,1-diyl) bis(2-(4-(1,3-dioxo-9-(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetate): A mixture of **Compound 5.7** (30 mg, 0.0415 mmol), 2-(4-(1,3-dioxo-9-(4-

(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 5.5**, 70 mg, 0.124 mmol), DIC (0.1 mL, 0.63 mmol), DMAP/TsOH salt (29 mg, 0.1 mmol) in DCM (8 mL) was stirred at room temperature overnight. The resulted solution was loaded on silica gel and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The desired peak was collected; and removal of solvent should give the product as solid (**Compound 5**) (20 mg, in 26% yield). LCMS (APCI-): Calcd for C114H69BF8N4O10: 1816.50; Found: 1816. ^{1}H NMR (400 MHz, d2-TCE) δ 8.50 (dd, *J* = 14.5, 8.1 Hz, 4H), 8.12 (d, *J* = 2.1 Hz, 2H), 7.91 (d, *J* = 8.1 Hz, 2H), 7.83 (d, *J* = 8.2 Hz, 4H), 7.75 – 7.61 (m, 10H), 7.49 (dd, *J* = 18.5, 8.2 Hz, 8H), 7.39 (d, *J* = 8.6 Hz, 2H), 7.24 (t, *J* = 7.9 Hz, 6H), 6.87 (t, *J* = 7.4 Hz, 2H), 6.77 (t, *J* = 7.5 Hz, 4H), 6.66 (d, *J* = 7.5 Hz, 4H), 6.41 (s, 2H), 5.95 (s, 2H), 4.93 (s, 4H), 3.76 (s, 4H), 1.88 (s, 6H), 1.77 (s, 3H).

Synthesis of Compound 6



Compound 5.4 **Compound 6.1**



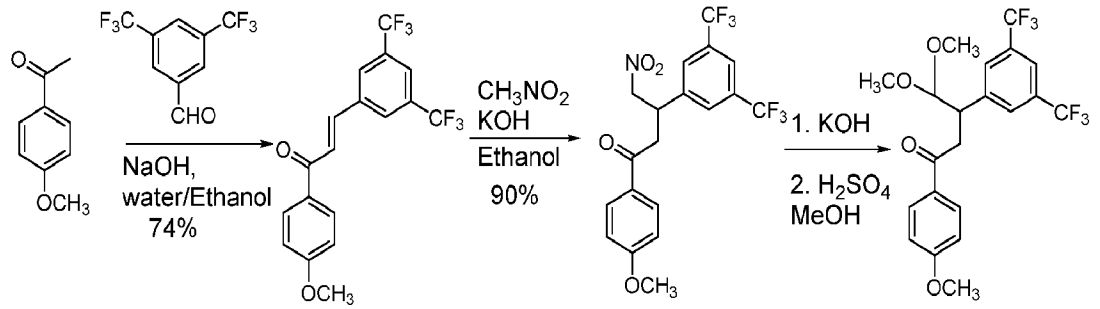
Compound 6

Compound 6.1 (2-(4-(9-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid): A 100 mL vial was fitted with a stir bar. To the vial, **Compound 5.4** (400.0 mg, 0.80 mmol), 3,5-bis(trifluoromethyl)phenylboronic acid (262.2 mg, 1.6 mmol), $Pd(dppf)Cl_2$ (41.0 mg, 0.056 mmol) and K_2CO_3 (412.6 mg, 2.2 mmol) in THF/DMF/H_2O (22 ml/ 4.4 ml/ 2.2 ml) was degassed at room temperature. The reaction mixture was heated up to 80 °C and the reaction has been kept at this temperature overnight. TLC was used to monitor the reaction. After the completion, the reaction was worked up by the addition of 0.1N HCl (150 ml) and EtOAc (150 ml). The aqueous phase was further extracted by THF (150 ml*3). The combined organic phases were dried over anhydrous Na_2SO_4, concentrated under rotavapor, and purified by flash chromatography, using DCM in EtOAc (0-40%, with 0.1% TFA) as an eluant to provide the pure **Compound 6.1** as a yellow/ yellow brown solid. 311.0 mg, 61% yield. MS (APCI): calculated for $C_{34}H_{17}F_6NO_5$ ($[M+H]^+$) = 634 found: 634. ^1H NMR (400 MHz, DMSO-d6) 8.73 (m, 1H), 8.46 (m, 5H), 8.10 (m, 2H), 7.57 (m, 1H), 7.42 (d, J = 8.0 Hz, 2H), 7.40 (m, 1H), 7.30 (d, J = 8.0 Hz, 2H), 3.72 (s, 2H).

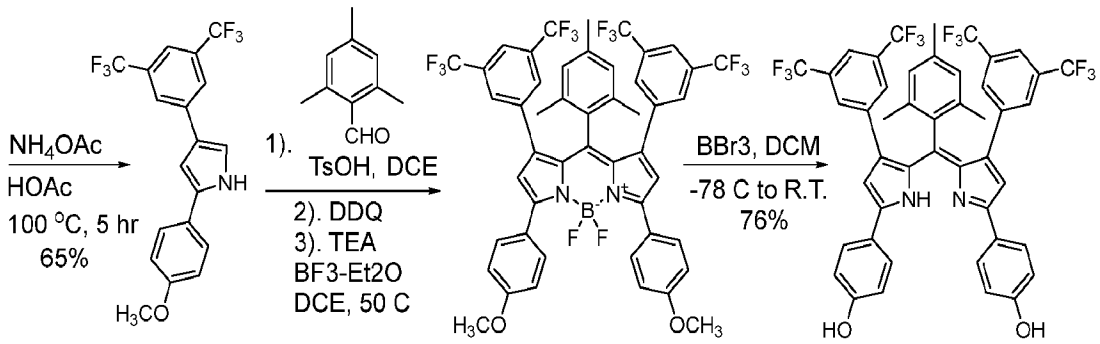
Compound 6 ((5,5-difluoro-10-mesityl-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yne-3,1-diyl) bis(2-(4-(9-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-

yl)phenyl)acetate): A mixture of **Compound 5.7** (93 mg, 0.129 mmol), 2-(4-(9-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 6.1**) (325 mg, 0.514 mmol), DIC (0.2 mL, 1.26 mmol), DMAP (61 mg, 0.5 mmol) in 10 mL anhydrous DCM was stirred at room temperature overnight. The resulted solution was loaded on silica gel, purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The main peak was collected, concentrated under reduced pressure then triturated with MeOH containing 5% water to crash out the product. The desired product was collected via filtration and dried in air as a dark red-brown solid (**Compound 6**) (100 mg, in 48.6% yield). ^{1}H NMR (400 MHz, TCE) δ 8.53 (dd, *J* = 14.6, 8.1 Hz, 4H), 8.12 (d, *J* = 2.2 Hz, 2H), 7.97 (d, *J* = 8.3 Hz, 6H), 7.90 – 7.78 (m, 6H), 7.68 (dd, *J* = 8.6, 2.1 Hz, 2H), 7.57 – 7.38 (m, 10H), 7.25 (dd, *J* = 17.0, 8.3 Hz, 6H), 6.87 (t, *J* = 7.4 Hz, 2H), 6.77 (t, *J* = 7.5 Hz, 4H), 6.70 – 6.58 (m, 4H), 6.41 (s, 2H), 4.93 (s, 4H), 3.76 (s, 4H), 1.88 (s, 6H), 1.77 (s, 3H).

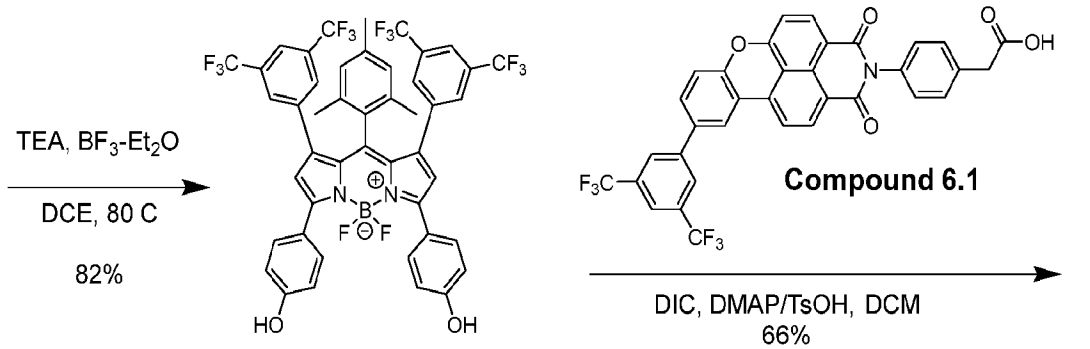
Synthesis of Compound 7



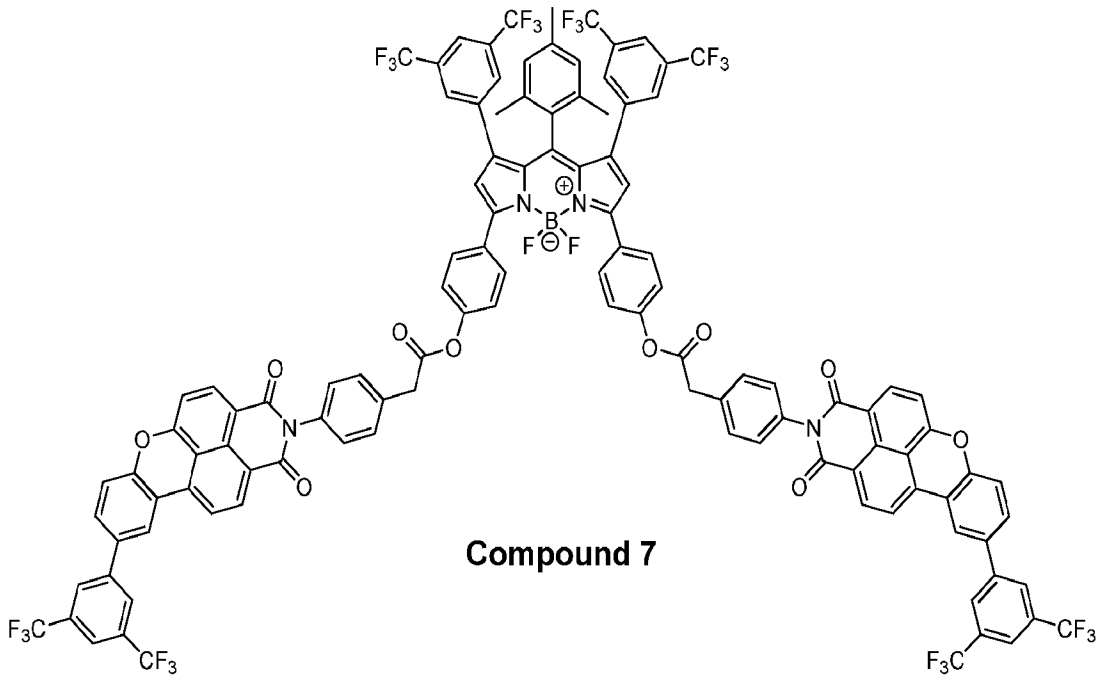
Compound 7.1 **Compound 7.2** **Compound 7.3**



Compound 7.4 **Compound 7.5** **Compound 7.6**



Compound 7.7 **Compound 6.1**



Compound 7

Compound 7.1 ((E)-3-(3,5-bis(trifluoromethyl)phenyl)-1-(4-methoxyphenyl)prop-2-en-1-one): To a solution of 3,5-bis(trifluoromethyl)benzaldehyde (1.21 g, 5 mmol), 4'-methoxyacetophenone (0.75 g, 5 mmol) in 10 mL ethanol, was added NaOH aqueous solution (0.5 g in 5 mL water) precooled by ice-bath. The resulted mixture was stirred at room temperature for 20 min, and white precipitate was observed. To the mixture, 5 mL water was added, and stirred for additional 10 min. the resulted suspension was filtered; and white solid (Compound 7.1) was obtained after dried in air (1.38 g, in 74% yield). ^{1}H NMR (400 MHz, d2-TCE) δ 8.02 – 7.94 (m, 4H), 7.82 (s, 1H), 7.71 (d, *J* = 15.7 Hz, 1H), 7.56 (d, *J* = 15.7 Hz, 1H), 6.98 – 6.91 (m, 2H), 3.82 (s, 3H), 1.51 (s, 2H).

Compound 7.2 (3-(3,5-bis(trifluoromethyl)phenyl)-1-(4-methoxyphenyl)-4-nitrobutan-1-one): A mixture of **Compound 7.1** (4.233 g, 11.3 mmol), nitromethane (10 mL, 186 mmol) and KOH (150 mg, 2.68 mmol) was sparged with argon for 10 min, then heated at 70 ºC for 30 min. The resulted mixture was poured into 300 mL water, extracted with EA. The organic phase was collected, dried over $MgSO_4$, then removal of solvents gave a liquid (**Compound 7.2**) (5.21 g, in quantitative yield). LCMS (APCI+): Calcd for $C_{19}H_{16}F_6NO_4$: 436.09 (M+H); Found: 436.

^{1}H NMR (400 MHz, d2-TCE) δ 7.87 – 7.78 (m, 2H), 7.78 – 7.66 (m, 3H), 6.91 – 6.82 (m, 2H), 4.84 (dd, *J* = 13.2, 5.9 Hz, 1H), 4.67 (dd, *J* = 13.2, 8.7 Hz, 1H), 4.33 – 4.22 (m, 1H), 3.79 (s, 3H), 3.34 (d, *J* = 6.9 Hz, 2H).

Compound 7.3 (3-(3,5-bis(trifluoromethyl)phenyl)-4,4-dimethoxy-1-(4-methoxyphenyl)butan-1-one): To a solution of **Compound 7.2** (11 mmol), in 80 mL THF/50 mL MeOH, was added KOH powder (1.23 g, 22 mmol) at 0 °C. the mixture was stirred at 0 °C for 10 min, then transferred into an additional funnel. The solution was added dropwise into a solution of methanol (50 mL) with 12 mL conc. H_2SO_4 at 0 °C over a period of one hour. The resulted mixture was stirred at 0 °C for additional hour, then poured into 300 g ice. The mixture was extracted with EA (200 mL x 2). The organic phase was collected, washed with brine, dried over $MgSO_4$. After filtered off solid, the solvents were removed under reduced pressure to give a liquid (**Compound 7.3**) (4.5 g, in 90% yield), which was submitted to next step without further purification. LCMS (APCI-): Calcd for $C_{21}H_{19}F_6O_4$: 449.13 (M-H); Found: 449. ^{1}H NMR (400 MHz, d2-TCE) δ 7.86 – 7.81 (m, 2H), 7.75 – 7.70 (m, 2H), 7.65 (s, 1H), 6.87 – 6.82 (m, 2H), 4.35 (d, *J* = 4.8 Hz, 1H), 3.77 (s, 3H), 3.77 – 3.71 (m, 1H), 3.49 (dd, *J* = 17.8, 4.7 Hz, 1H), 3.31 (s, 3H), 3.26 (s, 3H).

Compound 7.4 (4-(3,5-bis(trifluoromethyl)phenyl)-2-(4-methoxyphenyl)-1H-pyrrole): A mixture of **Compound 7.3** (10 mmol), NH_4OAc (3.85 g, 50 mmol) in acetic acid (20 mL) was heated at 100 °C for 5 hours. The resulted mixture was poured into 300 mL water, extracted with EA (200 mL), washed with brine, dried loaded on silica gel, and purified with flash chromatography using eluents of hexanes/DCM (0% to 50% DCM). The main peak was collected, and the solvents were removed to give a bluish solid (2.5 g, in 65% yield). LCMS (APCI+): Calcd for $C_{19}H_{14}F_6NO$: 386.09 (M+H); Found: 386. ^{1}H NMR (400 MHz, d2-TCE) δ 8.49 (s, 1H), 7.87 (s, 2H), 7.58 (s, 1H), 7.44 – 7.37 (m, 2H), 7.19 – 7.13 (m, 1H), 6.93 – 6.85 (m, 2H), 6.69 – 6.64 (m, 1H), 3.77 (s, 3H).

Compound 7.5 (1,9-bis(3,5-bis(trifluoromethyl)phenyl)-5,5-difluoro-10-mesityl-3,7-bis(4-methoxyphenyl)-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine):

Step 1: A mixture of **Compound 7.4** (0.524 g, 1.36 mmol), 2,4,6-trimethylbenzaldehyde (0.101 g, 0.68 mmol) in 25 mL DCE with 0.05 g TsOH as catalyst, was degassed and heated at 60 °C

overnight. LCMS analysis indicates that the reaction completed with one main peak of m/e^+ = 901.

Step 2: To the resulted mixture above, DDQ (0.22 g, 0.97 mmol) was added and stirred at room temperature for 30 min. LCMA analysis indicates there is one main peak with m/e^- = 898.

Step 3: To the solution above, TEA (1.0 mL), BF_3-Et_2O (2 mL) was added, then heated at 50 °C for one hour. The resulted mixture was diluted with DCM (200 mL), washed with water, then loaded on silica gel and purified by flash chromatography using eluents of hexanes/DCM (0% to 50 % DCM). The desired peak was collected, and removal of solvents gave a blue solid (400mg, in 62% yield). LCMS (APCI-): Calcd for $C_{48}H_{33}BF_{14}N_2O_2$: 936.24; Found: 946. ^{1}H NMR (400 MHz, d2-TCE) δ 7.89 – 7.83 (m, 4H), 7.38 (s, 2H), 7.21 – 7.16 (m, 4H), 6.97 – 6.91 (m, 4H), 6.46 (s, 2H), 5.94 (s, 2H), 3.81 (s, 6H), 1.92 (s, 6H), 1.69 (s, 3H).

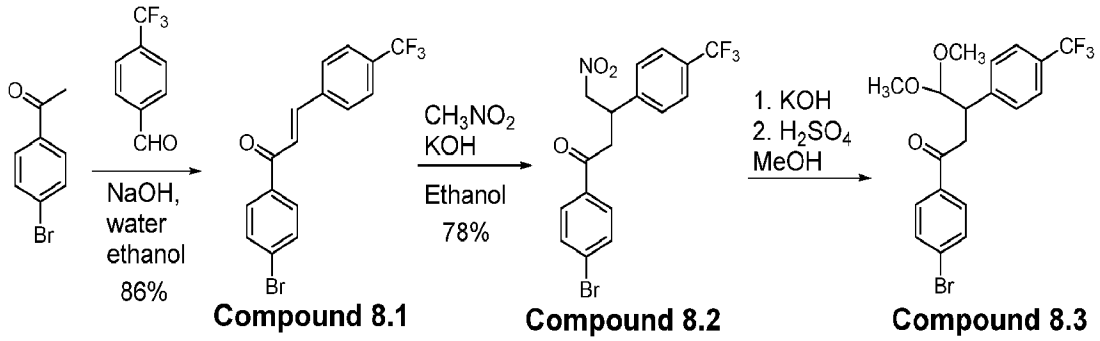
Compound 7.6 ((Z)-4-(3-(3,5-bis(trifluoromethyl)phenyl)-2-((3-(3,5-bis(trifluoromethyl)phenyl)-5-(4-hydroxyphenyl)-1H-pyrrol-2-yl)(mesityl)methylene)-2H-pyrrol-5-yl)phenol): To a solution of **Compound 7.5** (215 mg, 0.227 mmol), in 10 mL anhydrous DCM, was added BBr_3 (0.15 mL, 1.5 mmol) at -78 C. The whole was stirred at -78 °C to room temperature overnight. To the mixture, 10 mL MeOH was added to quench the excess BBr3. The mixture was stirred at room temperature for 2 hours, then diluted with 100 mL DCM, washed with water, then concentrated to ~20 mL. To the solution, hexanes (30 mL) was added to precipitate the desired product. Filtration and drying in air to give a golden green solid (150 mg, in 76% yield). LCMS (APCI-): Calcd for $C_{46}H_{30}F_{12}N_2O_2$: 870.21; Found: 870. ^{1}H NMR (400 MHz, MeOD) δ 8.10 (d, *J* = 12.3 Hz, 2H), 7.95 (d, *J* = 8.3 Hz, 2H), 7.84 – 7.73 (m, 3H), 7.60 (s, 1H), 7.53 (s, 2H), 7.49 (s, 1H), 7.29 (d, *J* = 8.6 Hz, 2H), 7.03 (d, *J* = 8.3 Hz, 2H), 6.91 (d, *J* = 8.5 Hz, 2H), 6.81 (d, *J* = 8.5 Hz, 2H), 6.72 (s, 1H), 6.11 (s, 1H), 2.14 (d, *J* = 6.8 Hz, 3H), 2.09 (s, 3H), 1.96 (s, 3H).

Compound 7.7 (4,4'-(1,9-bis(3,5-bis(trifluoromethyl)phenyl)-5,5-difluoro-10-mesityl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)diphenol): To a mixture of **Compound 7.6** (140 mg, 0.16 mmol) in 10 mL DEC, was added TEA (0.154 mL, 1 mmol), BF_3-Et_2O (0.185 mL, 1.5 mmol) at room temperature. The resulted mixture was heated at 60 °C

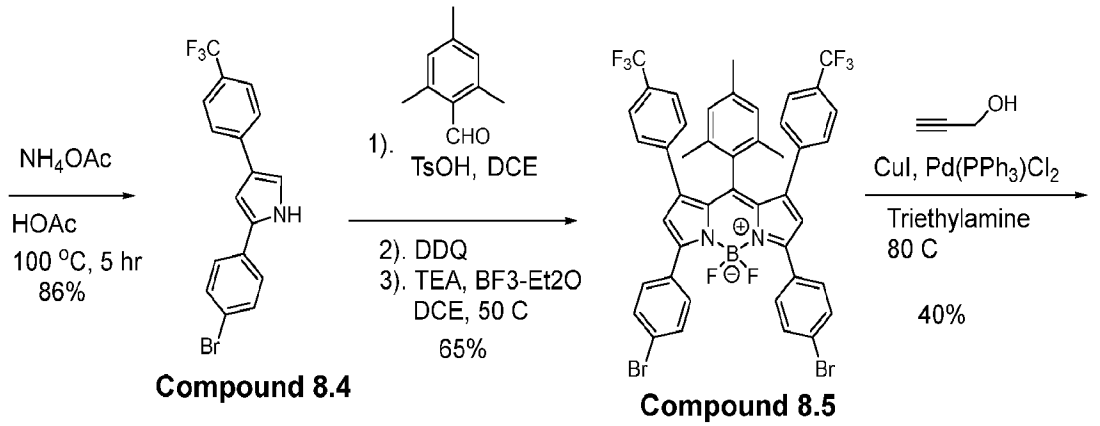
for 2 hours. After cooled to room temperature, the mixture was loaded on silica gel, purified by flash chromatography using eluents of DCM/EA (0% to 20 % EA). The main peak was collected, removal of solvents under reduced pressure gave a dark blue solid (120 mg, in 82% yield). LCMA (APCI-): Calcd for $C_{46}H_{29}BF_{14}N_2O_2$: 918.21; Found: 918. ^{1}H NMR (400 MHz, TCE) δ 7.85 – 7.77 (m, 4H), 7.38 (s, 2H), 7.20 – 7.15 (m, 4H), 6.91 – 6.83 (m, 4H), 6.46 (s, 2H), 5.94 (s, 2H), 5.91 (s, 18H), 5.09 (s, 2H), 1.92 (s, 6H), 1.69 (s, 3H).

Compound 7 (1,9-bis(3,5-bis(trifluoromethyl)phenyl)-5,5-difluoro-10-mesityl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene) bis(2-(4-(9-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetate): A mixture of **Compound 7.7** (80 mg, 0.087 mmol), 2-(4-(9-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 6.1**) (220 mg, 0.348 mmol), DIC (0.1 mL, 0.63 mmol), DMAP/TsOH salt (29 mg, 0.1 mmol) in DCM (10 mL) was stirred at room temperature overnight. The resulted mixture was diluted with 20 mL DCM, then loaded on silica gel, and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The main peak was collected, concentrated under reduced pressure, then triturated with MeOH to crash out the solid. After filtration and dried in air, a dark purple crystalline solid was obtained (123 mg, in 66% yield). ^{1}H NMR (400 MHz, TCE) δ 8.59 – 8.39 (m, 4H), 8.09 (d, *J* = 2.2 Hz, 2H), 7.97 (s, 4H), 7.92 (dd, *J* = 8.4, 6.0 Hz, 6H), 7.85 (s, 2H), 7.72 (dd, *J* = 8.6, 2.1 Hz, 2H), 7.56 (d, *J* = 8.2 Hz, 4H), 7.46 (d, *J* = 8.6 Hz, 2H), 7.39 (s, 2H), 7.30 (d, *J* = 8.1 Hz, 4H), 7.27 – 7.16 (m, 10H), 6.51 (s, 2H), 5.96 (s, 2H), 3.95 (s, 4H), 1.94 (s, 6H), 1.70 (s, 3H).

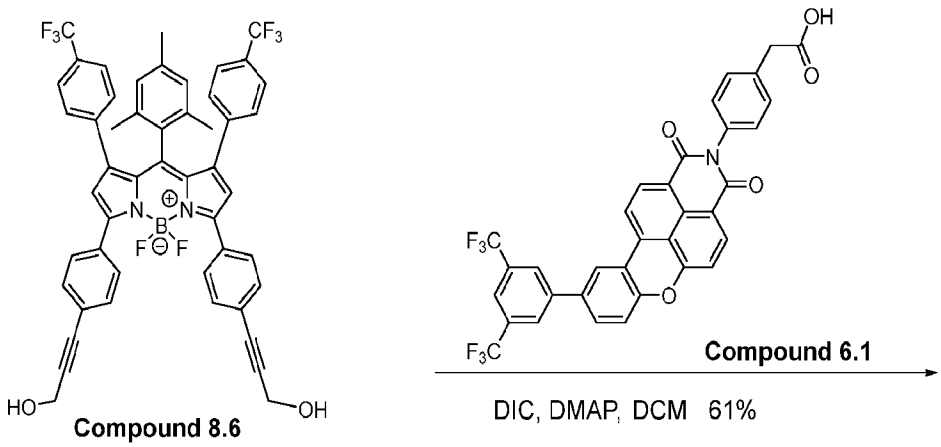
Synthesis of Compound 8



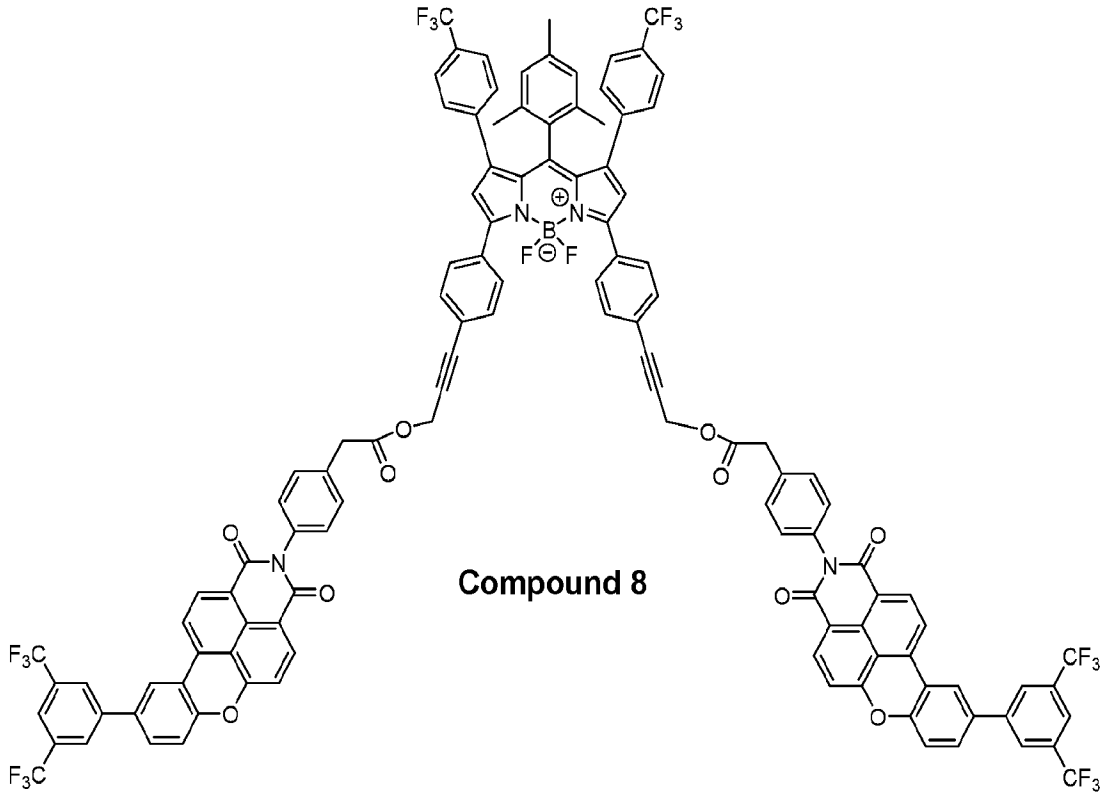
Compound 8.1 Compound 8.2 Compound 8.3



Compound 8.4 Compound 8.5



Compound 8.6 Compound 6.1



Compound 8

Compound 8.1 ((E)-1-(4-bromophenyl)-3-(4-(trifluoromethyl)phenyl)prop-2-en-1-one): 4-Trifluoromethylbenzaldehyde (870 mg, 5 mmol) and 4-bromoacetophenone (995 mg, 5 mmol) was dissolved in 10 mL ethanol. To the solution was added a solution of sodium hydroxide (0.5 g in 5 mL water) dropwise at room temperature. A white precipitate formed immediately. The mixture was stirred for 15 min, filtered, washed with 20 mL ethanol/water (1:1 v/v) to give a white solid. LCMS (APCI-): Calcd for $C_{16}H_{10}BrF_3O$: 353.99; Found: 354. ^1H NMR (400 MHz, d2-TCE) δ 7.85 – 7.77 (m, 2H), 7.76 – 7.65 (m, 3H), 7.61 (dd, *J* = 8.6, 2.5 Hz, 4H), 7.44 (d, *J* = 15.7 Hz, 1H).

Compound 8.2 (1-(4-bromophenyl)-4-nitro-3-(4-(trifluoromethyl)phenyl)butan-1-one): A mixture of (E)-1-(4-bromophenyl)-3-(4-(trifluoromethyl)phenyl)prop-2-en-1-one (**Compound 8.1**, 1.5 g, 4.2 mmol), nitromethane (2.7 mL, 50 mmol), KOH (47 mg, 0.8 mmol) in 15 mL ethanol was sonicated for 1 min, then heated at 70 °C for 30 min. The resulted solution was poured into water (100 mL), extracted with ethyl acetate (50 mL for 3 times). The organic phase was collected, dry loaded on silica gel, purified by flash chromatography using eluents of hexanes/EA (0% to 25% EA). The main peak was collected, removal of solvents gave a colorless liquid (**Compound 8.2**) (1.36 g, in 77.8% yield). LCMS (APCI-): Calcd for $C_{17}H_{13}BrF_3NO_3$: 415.00; Found: 415. ^1H NMR (400 MHz, d2-TCE) δ 7.73 – 7.65 (m, 2H), 7.59 –

7.50 (m, 4H), 7.34 (d, *J* = 8.1 Hz, 2H), 4.77 (dd, *J* = 12.8, 6.3 Hz, 1H), 4.63 (dd, *J* = 12.8, 8.4 Hz, 1H), 4.24 – 4.13 (m, 1H), 3.41 – 3.25 (m, 2H).

Compound 8.3 (1-(4-bromophenyl)-4,4-dimethoxy-3-(4-(trifluoromethyl)phenyl)butan-1-one): To a solution of **Compound 8.2** (4.16 g, 10 mmol) in 80 mL THF/50 mL MeOH, was added KOH powder (1.12 g, 20 mmol) at 0 ºC. The mixture was stirred for 10 min at room temperature, then transferred into an additional funnel. The solution was added dropwise into a solution of MeOH (50 mL) with 12 mL conc. H_2SO_4 over a period of one hour. The resulted mixture was stirred at 0 ºC for additional one hour, then poured into 300 g ice slowly. The ice-organic mixture was extracted with ethyl acetate (200 mL x 2). The organic phased was washed with 10% K_2CO_3 aqueous solution (100 mL), brine (100mL), dried over $MgSO_4$. After filtered off solid, the solution was concentrated under reduced pressure to give a liquid (4.2 g, in 90% yield), which was submitted for next step without further purification.

Compound 8.4 (2-(4-bromophenyl)-4-(4-(trifluoromethyl)phenyl)-1H-pyrrole): A mixture of **Compound 8.3** (4.0g, 9.28 mmol), ammonium acetate (3.54 g, 46 mmol) in 20 mL acetic acid was heated at 100 °C for 5 hours. After cooled to room temperature, the reaction mixture was worked up water (200 mL), extracted with ethyl acetate (250 mL). the organic phase was collected and washed with brine, dry loaded on silica gel, purified by flash chromatography using eluents of hexanes/DCM (0% to 50% DCM). The main peak was collected, after removed solvents, a bluish solid was obtained as desired product (**Compound 8.4**) (2.7g, in 86% yield). LCMS (APCI+): Calcd for $C_{17}H_{12}BrF_3N$: 366.00 (M+H); Found: 366. ^{1}H NMR (400 MHz, d2-TCE) δ 8.54 (s, 1H), 7.62 – 7.50 (m, 4H), 7.50 – 7.42 (m, 2H), 7.39 – 7.28 (m, 2H), 7.16 (dd, *J* = 2.8, 1.7 Hz, 1H), 6.76 (dd, *J* = 2.8, 1.7 Hz, 1H).

Compound 8.5 (3,7-bis(4-bromophenyl)-5,5-difluoro-10-mesityl-1,9-bis(4-(trifluoromethyl)phenyl)-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine):

Step 1: A mixture of compound 8.4 (0.5 g, 1.36 mmol), 2,4,6-trimethylbenzaldehyde (0.101 g, 0.68 mmol), TsOH (0.05 g) in anhydrous DCE (25 mL) was heated at 60 °C under argon overnight. LCMS analysis indicates that the condensation reaction has completed.

Step 2: To the solution above, DDQ (0.27 g, 01.2 mmol) was added and stirred at room temperature for 45 min. LCMS analysis indicated that the oxidation reaction has completed.

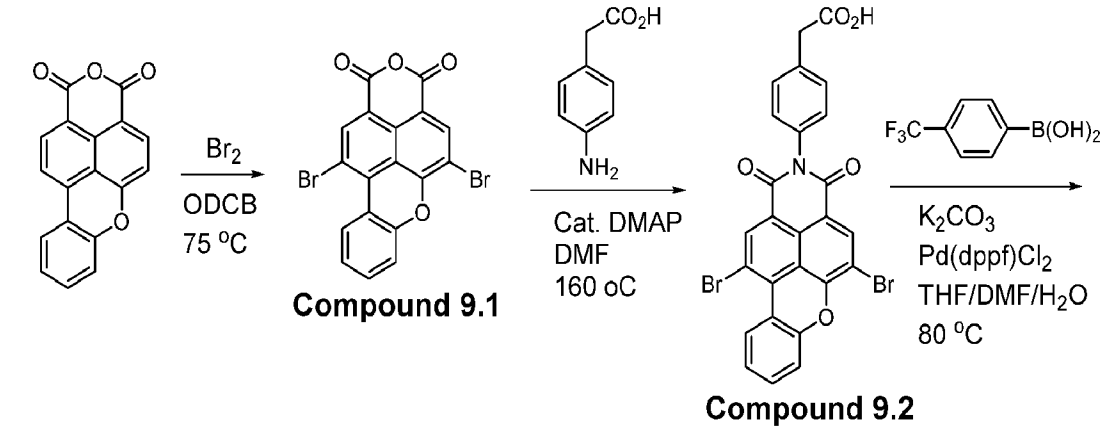
Step 3: To the mixture from above, TEA (0.75 mL, 5.25 mmol), BF_3-Et_2O (2.0 mL, 16.5 mmol) was added at room temperature. The resulted mixture was heated at 50 °C for one hour. After cooled to room temperature, the mixture was diluted with 100 mL DCM, washed with water, dried over $MgSO_4$, then loaded on silica gel and purified by flash chromatography using eluents of hexanes/DCM (0% to 50% DCM). The main peak was collected, and the solvents was removed under reduced pressure to give a dark purple solid (400 mg, in 65% yield). LCMS (APCI-): Calcd for $C_{44}H_{29}BBr_2F_8N_2$: 906.07; Found: 906. ^{1}H NMR (400 MHz, d2-TCE) δ 7.80 – 7.67 (m, 4H), 7.58 – 7.47 (m, 4H), 7.04 (d, *J* = 8.1 Hz, 4H), 6.79 (d, *J* = 7.9 Hz, 4H), 6.42 (s, 2H), 5.93 (s, 2H), 1.87 (s, 6H), 1.76 (s, 3H).

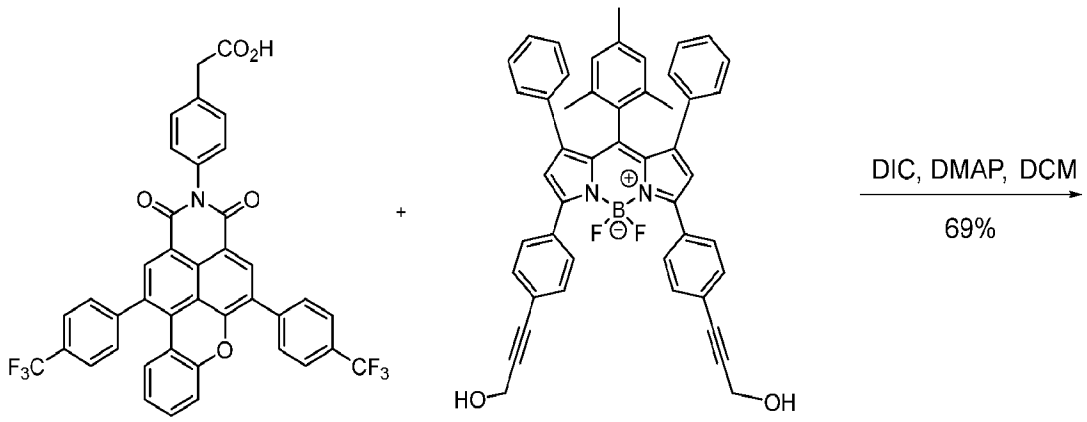
Compound 8.6 (3,3'-((5,5-difluoro-10-mesityl-1,9-bis(4-(trifluoromethyl)phenyl)-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yn-1-ol)): A mixture of **Compound 8.5** (220 mg, 0.242 mmol), CuI (10 mg, 0.052 mmol), $Pd(PPh_3)_2Cl_2$ (36 mg, 0.052 mmol), prop-2-yn-1-ol (56 mg, 1.0 mmol) in 8 mL TEA was degassed with freeze-thaw protocol three times, then heated at 80 °C under argon overnight. The resulted mixture was diluted with DCM (100 mL), washed with 0.1 N HCl aqueous solution. The organic phase was collected, loaded on silica gel, and purified by flash chromatography using eluents of DCM/EA (0% to 50% EA). After removal of solvents, a dark solid was obtained as desired product (**Compound 8.6**, 60 mg, in 40% yield). LCMS (APCI-): Calcd for $C_{50}H_{35}BF_8N_2O_2$: 858.27; Found; 858. ^{1}H NMR (400 MHz, TCE) δ 7.90 – 7.76 (m, 4H), 7.52 – 7.40 (m, 4H), 7.04 (d, *J* = 8.1 Hz, 4H), 6.79 (d, *J* = 8.0 Hz, 4H), 6.46 (s, 2H), 5.93 (s, 2H), 4.45 (d, *J* = 5.6 Hz, 4H), 1.87 (s, 6H), 1.76 (s, 3H).

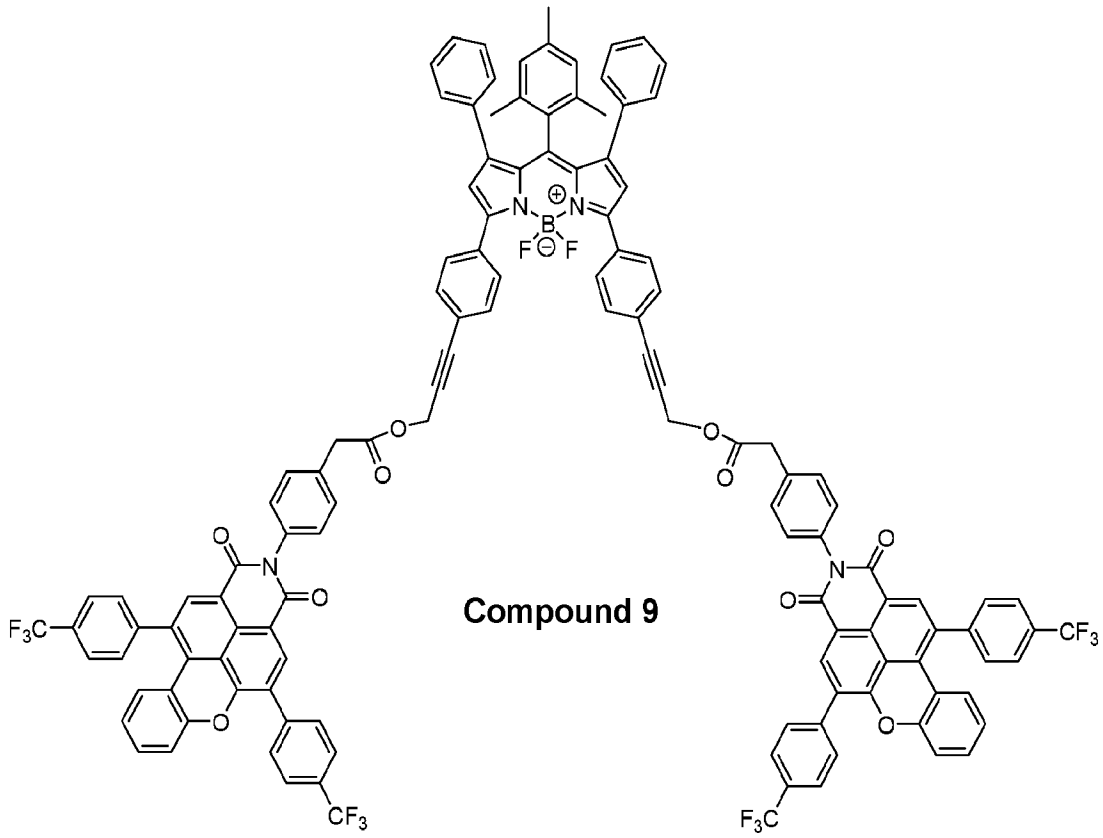
Compound 8 ((5,5-difluoro-10-mesityl-1,9-bis(4-(trifluoromethyl)phenyl)-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yne-3,1-diyl) bis(2-(4-(9-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetate): A mixture of **Compound 8.6** (60 mg, 0.07 mmol), 2-(4-(9-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 6.1**, 176 mg, 0.28 mmol), DIC (0.1 mL, 0.63 mmol), DMAP (24 mg, 0.2 mmol) in 10 mL anhydrous DCM was stirred at room temperature overnight. The resulted solution was diluted with 20 mL DCM, loaded on silica gel, and purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The desired main peak was

collected, concentrated under reduced pressure, then triturated with MeOH to give a dark solid (90 mg, in 61% yield). ^{1}H NMR (400 MHz, TCE) δ 8.53 (dd, *J* = 15.4, 8.1 Hz, 4H), 8.12 (d, *J* = 2.2 Hz, 2H), 8.04 – 7.93 (m, 6H), 7.91 – 7.79 (m, 6H), 7.69 (dd, *J* = 8.6, 2.1 Hz, 2H), 7.59 – 7.39 (m, 10H), 7.31 – 7.17 (m, 6H), 7.04 (d, *J* = 8.1 Hz, 4H), 6.79 (d, *J* = 7.9 Hz, 4H), 6.46 (s, 2H), 5.93 (s, 2H), 4.93 (s, 4H), 3.76 (s, 4H), 1.87 (s, 6H), 1.76 (s, 3H).

Synthesis of Compound 9







Compound 9

Compound 9.1 (5,11-dibromo-1H,3H-isochromeno[6,5,4-mna]xanthene-1,3-dione): A 2L 2N round bottom flask was charged with a stir bar and fitted with a long finned condenser. To the flask was added 1H,3H-isochromeno[6,5,4-mna]xanthene-1,3-dione (synthesized according to literature: ***RSC Adv.***, 2014, **4**, 53072-53078) (34.688 mmol, 10.00 g), followed by ortho-dichlorobenzene (1000 mL). The reaction mixture was stirred at room temperature and Br_2 (416.26 mmol, 21.3 mL) was added. The second neck was stoppered, and the reaction mixture was heated with an aluminum heat block at 75 °C open to air over the weekend. The reaction mixture was cooled to room temperature and a solid was filtered off. The filtrate was diluted with hexanes (~20% of volume) and a second precipitate was filtered off. Both of these precipitates were dried in vacuo at 100 °C. Orangish solids, 10.866 g total (69.9% yield). Both had similar LCMS and NMR. MS (APCI): calculated for Chemical Formula: $C_{18}H_6Br_2O_4$ (M+H) = 445; found: 445. 1H NMR (400 MHz, TCE) δ 9.47 (dd, *J* = 8.4, 1.5 Hz, 1H), 8.76 (d, *J* = 14.2 Hz, 2H), 7.72 – 7.63 (m, 1H), 7.56 (dd, *J* = 8.3, 1.4 Hz, 1H), 7.46 (ddd, *J* = 8.5, 6.7, 1.9 Hz, 1H).

Compound 9.2 (2-(4-(5,11-dibromo-1,3-dioxo-1H-xantheno[2,1,9- def]isoquinolin-2(3H)-yl)phenyl)acetic acid): **Compound 9.2** was synthesized from **Compound 9.1** (7.000 mmol, 3.136 g), 2-(4-aminophenyl)acetic acid (14.00 mmol, 2.117 g), and DMAP (2.100 mmol, 257

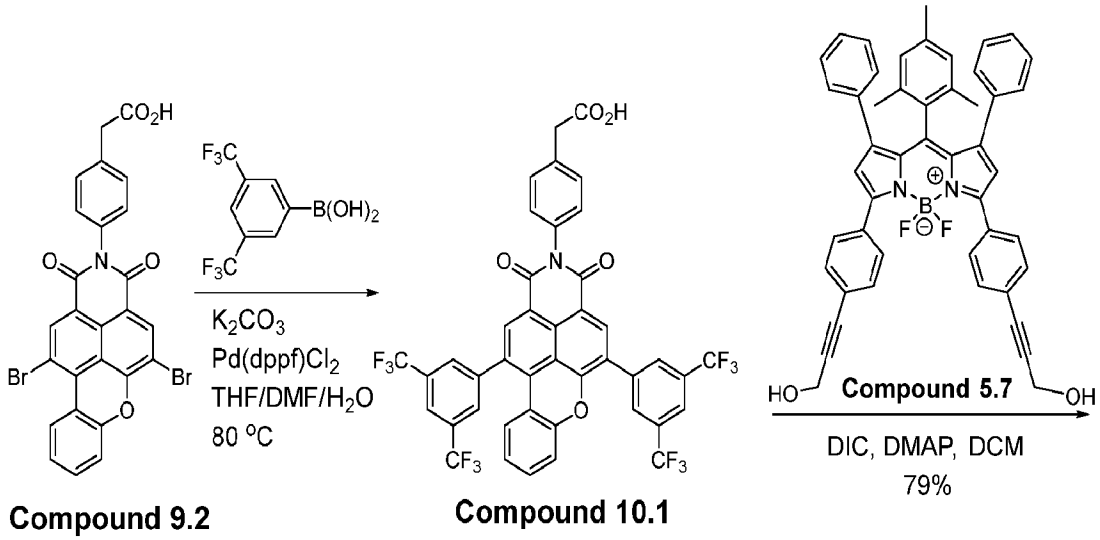
mg) in anhydrous DMF (65 mL) at 160 °C in a manner similar to Compound 5.4, above. The crude reaction mixture was cooled to 0 °C and quenched with 6N HCl (~5 mL) and diluted with water (up to ~350 mL). The precipitate was filtered off, washing with water. The product (**Compound 9.2**) was dried by suction and used without further purification in the next reactions. Assume 100% yield. MS (APCI): calculated for Chemical Formula: $C_{26}H_{13}Br_2NO_5$ (M+H) = 578; found: 578.

Compound 9.3 (2-(4-(1,3-dioxo-5,11-bis(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid): **Compound 9.3** was synthesized from **Compound 9.2** (3.500 mmol, 2.034 g), (4-(trifluoromethyl)phenyl)boronic acid (14.00 mmol, 2.659 g), K_2CO_3 (19.25 mmol, 2.661 g), and $Pd(dppf)Cl_2$ (0.0245 mmol, 179 mg) in THF (/60 mL), DMF (12 mL), and water (6 mL) with heating at 80 °C under argon atmosphere overnight. The crude reaction mixture was evaporated to dryness in vacuo, taken up in DCM, and evaporated in vacuo onto ~35 g of flash silica gel. Purified by flash chromatography on silica gel (220g, equilibrate 0% EtOAc/DCM, eluting 0% (10 CV) to 15.3% EtOAc/DCM (15.3 CV) to 40% EtOAc/DCM (10 CV) to isocratic 40% EtOAc/DCM). EtOAc contains 0.1% v/v TFA. Fractions containing product were evaporated to dryness in vacuo. Gives a brown-yellow solid, 2.000 g (80.3%). MS (APCI): calculated for Chemical Formula: $C_{40}H_{21}F_6NO_5$ (M+H) = 710; found: 710. 1H NMR (400 MHz, DMSO) δ 12.44 (s, 1H), 8.47 (s, 1H), 8.23 (s, 1H), 8.02 (d, *J* = 8.1 Hz, 2H), 7.97 – 7.88 (m, 4H), 7.75 (d, *J* = 8.0 Hz, 2H), 7.49 – 7.37 (m, 3H), 7.31 (d, *J* = 8.2 Hz, 1H), 7.30 – 7.24 (m, 2H), 7.02 – 6.91 (m, 2H), 3.68 (s, 2H).

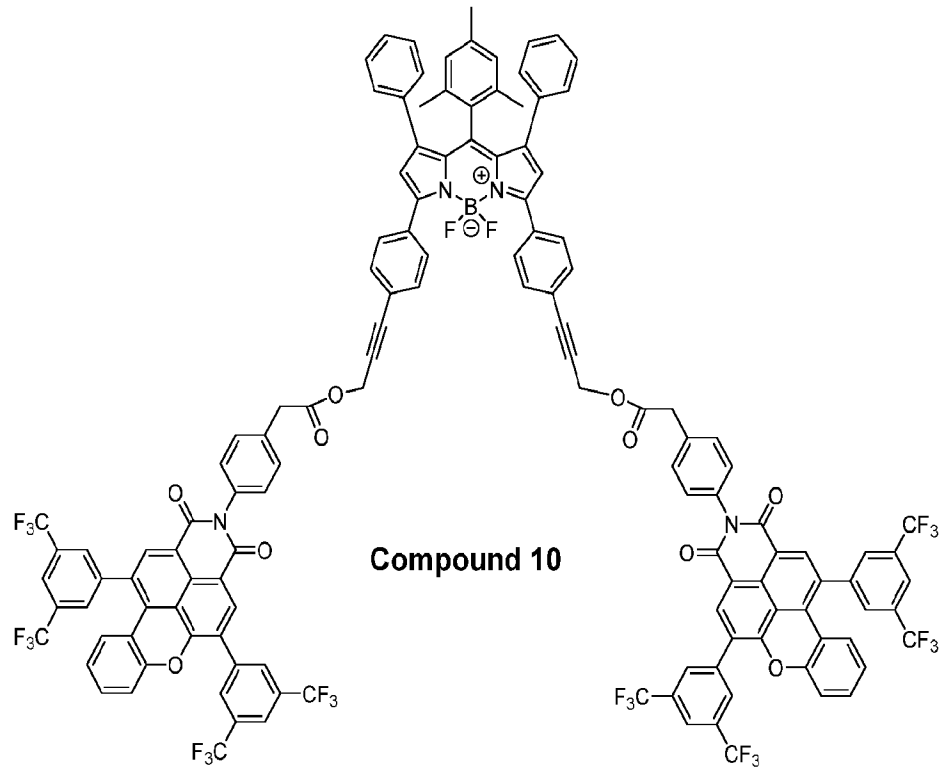
Compound 9 ((5,5-difluoro-10-mesityl-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yne-3,1-diyl) bis(2-(4-(1,3-dioxo-5,11-bis(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetate): A mixture of **Compound 5.7** (50 mg, 0.069 mmol), 2-(4-(1,3-dioxo-5,11-bis(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 9.3**, 200 mg, 0.28 mmol), DMAP (24 mg, 0.2 mmol), DIC (0.1 mL, 0.63 mmol) in anhydrous DCM (10 mL) was stirred at room temperature over the weekend. The resulted mixture was loaded on silica gel, purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The main red color peak was collected, concentrated under reduced pressure. The resulted solid was triturated with MeOH, filtered, and dried in air to afford a dark solid

(**Compound 9**, 100mg, in 69% yield). ^{1}H NMR (400 MHz, CD_2Cl_2) δ 8.69 (s, 2H), 8.46 (s, 2H), 7.95 – 7.77 (m, 16H), 7.68 – 7.61 (m, 4H), 7.58 – 7.47 (m, 8H), 7.38 (ddd, *J* = 8.5, 7.2, 1.5 Hz, 2H), 7.34 – 7.27 (m, 4H), 7.23 (dd, *J* = 8.3, 1.3 Hz, 2H), 7.11 (dd, *J* = 8.4, 1.5 Hz, 2H), 6.98 – 6.82 (m, 8H), 6.80 – 6.73 (m, 4H), 6.48 (s, 2H), 6.01 (s, 2H), 5.00 (s, 4H), 3.83 (s, 4H), 1.97 (s, 6H), 1.85 (s, 3H).

Synthesis of Compound 10



Compound 9.2 **Compound 10.1**

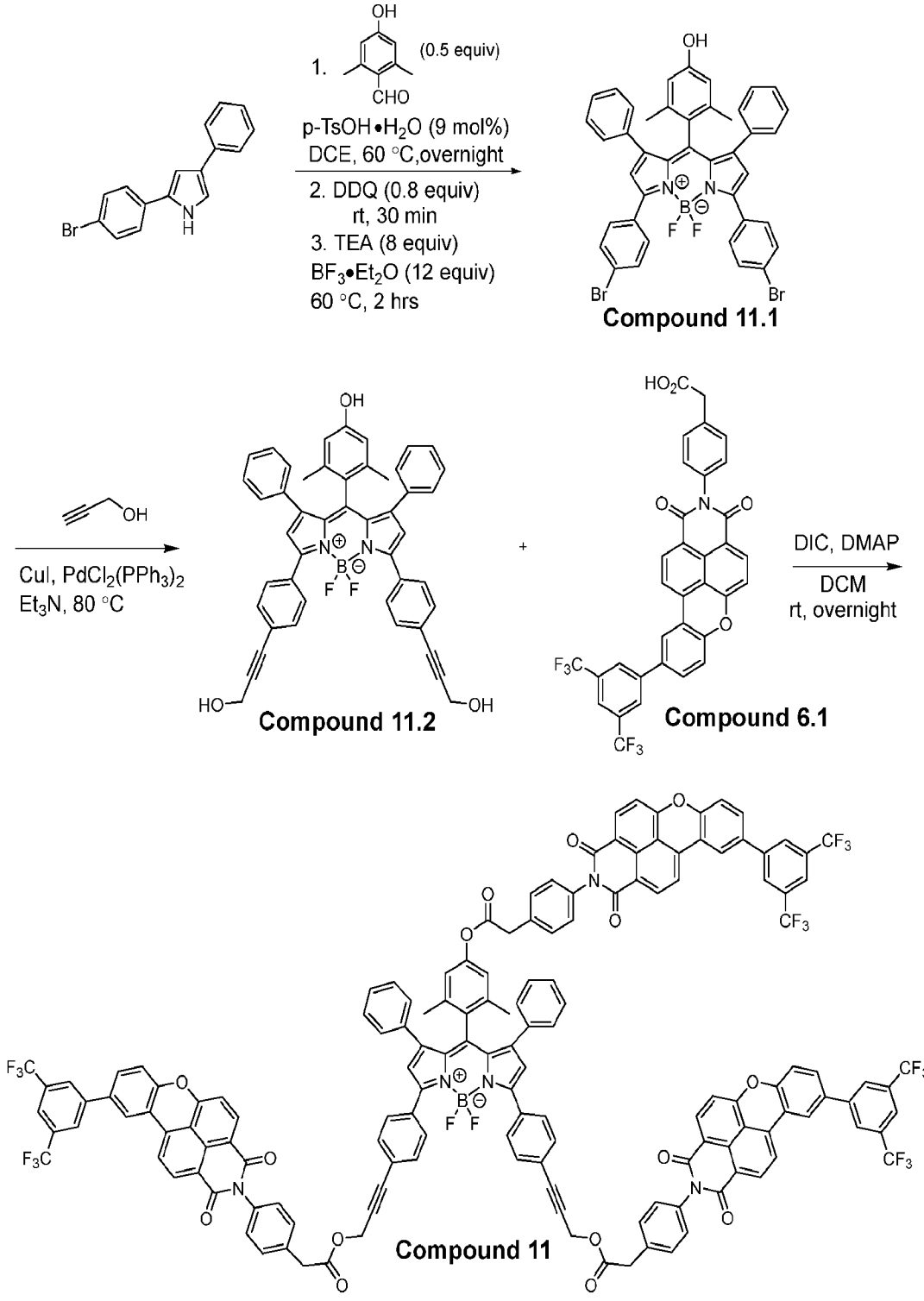


Compound 10

Compound 10.1 (2-(4-(5,11-bis(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid): **Compound 10.1** was synthesized from **Compound 9.2** (3.500 mmol, 2.034 g), (3,5-bis(trifluoromethyl)phenyl)boronic acid (14.00 mmol, 3.611), K_2CO_3 (19.25 mmol, 2.661 g), and $Pd(dppf)Cl_2$ (0.0245 mmol, 179 mg) in THF (/60 mL), DMF (12 mL), and water (6 mL) with heating at 80 °C under argon atmosphere overnight. The crude reaction mixture was evaporated to dryness in vacuo, taken up in DCM, and evaporated in vacuo onto ~35 g of flash silica gel. Purified by flash chromatography on silica gel (220g, equilibrate 0% EtOAc/DCM, eluting 0% (10 CV) to 15.3% EtOAc/DCM (15.3 CV) to 0% EtOAc/DCM (10 CV) to isocratic 40% EtOAc/DCM). EtOAc contains 0.1% v/v TFA. Gives a brownish-yellow solid, 1.710 g (57.6% yield. MS (APCI): calculated for Chemical Formula: $C_{42}H_{19}F_{12}NO_5$ (M+H) = 846; found: 846. 1H NMR (400 MHz, DMSO) δ 12.45 (s, 1H), 8.62 (s, 1H), 8.52 (d, *J* = 1.7 Hz, 2H), 8.36 (s, 1H), 8.30 (s, 1H), 8.26 (d, *J* = 1.6 Hz, 2H), 8.24 (s, 1H), 7.50 (ddd, *J* = 8.5, 7.2, 1.5 Hz, 1H), 7.46 – 7.38 (m, 2H), 7.37 – 7.27 (m, 2H), 7.14 (dd, *J* = 8.3, 1.2 Hz, 1H), 6.98 (ddd, *J* = 8.4, 7.2, 1.3 Hz, 1H), 6.85 (dd, *J* = 8.3, 1.5 Hz, 1H), 3.69 (s, 2H).

Compound 10 ((5,5-difluoro-10-mesityl-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yne-3,1-diyl) bis(2-(4-(5,11-bis(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetate): A mixture of **Compound 5.7** (50 mg, 0.069 mmol), 2-(4-(5,11-bis(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetic acid (**Compound 10.1**, 236 mg, 0.28 mmol), DMAP (24 mg, 0.2 mmol), DIC (0.1 mL, 0.63 mmol) in anhydrous DCM (10 mL) was stirred at room temperature over the weekend. The resulted mixture was loaded on silica gel, purified by flash chromatography using eluents of DCM/EA (0% to 10% EA). The main red color peak was collected, concentrated under reduced pressure. The resulted solid (**Compound 10**) was triturated with MeOH, filtered, and dried in air to afford a dark solid (130mg, in 79% yield). ^{1}H NMR (400 MHz, CD_2Cl_2) δ 8.75 (s, 2H), 8.51 (s, 2H), 8.31 – 8.26 (m, 4H), 8.05 (d, *J* = 16.1 Hz, 8H), 7.91 – 7.84 (m, 4H), 7.59 – 7.48 (m, 8H), 7.44 (ddd, *J* = 8.6, 6.9, 1.7 Hz, 2H), 7.36 – 7.28 (m, 4H), 7.23 (dd, *J* = 8.3, 1.3 Hz, 2H), 7.03 – 6.90 (m, 6H), 6.85 (dd, *J* = 8.4, 6.8 Hz, 4H), 6.80 – 6.73 (m, 4H), 6.48 (s, 2H), 6.01 (s, 2H), 5.01 (s, 4H), 3.84 (s, 4H), 1.98 (s, 6H), 1.85 (s, 3H).

Synthesis of Compound 11



Compound 11.1: 4-(3,7-bis(4-bromophenyl)-5,5-difluoro-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinin-10-yl)-3,5-dimethylphenol: A 100 mL 2 neck round bottomed flask was fitted with an air condenser and a stir bar. To the flask, 2-(4-

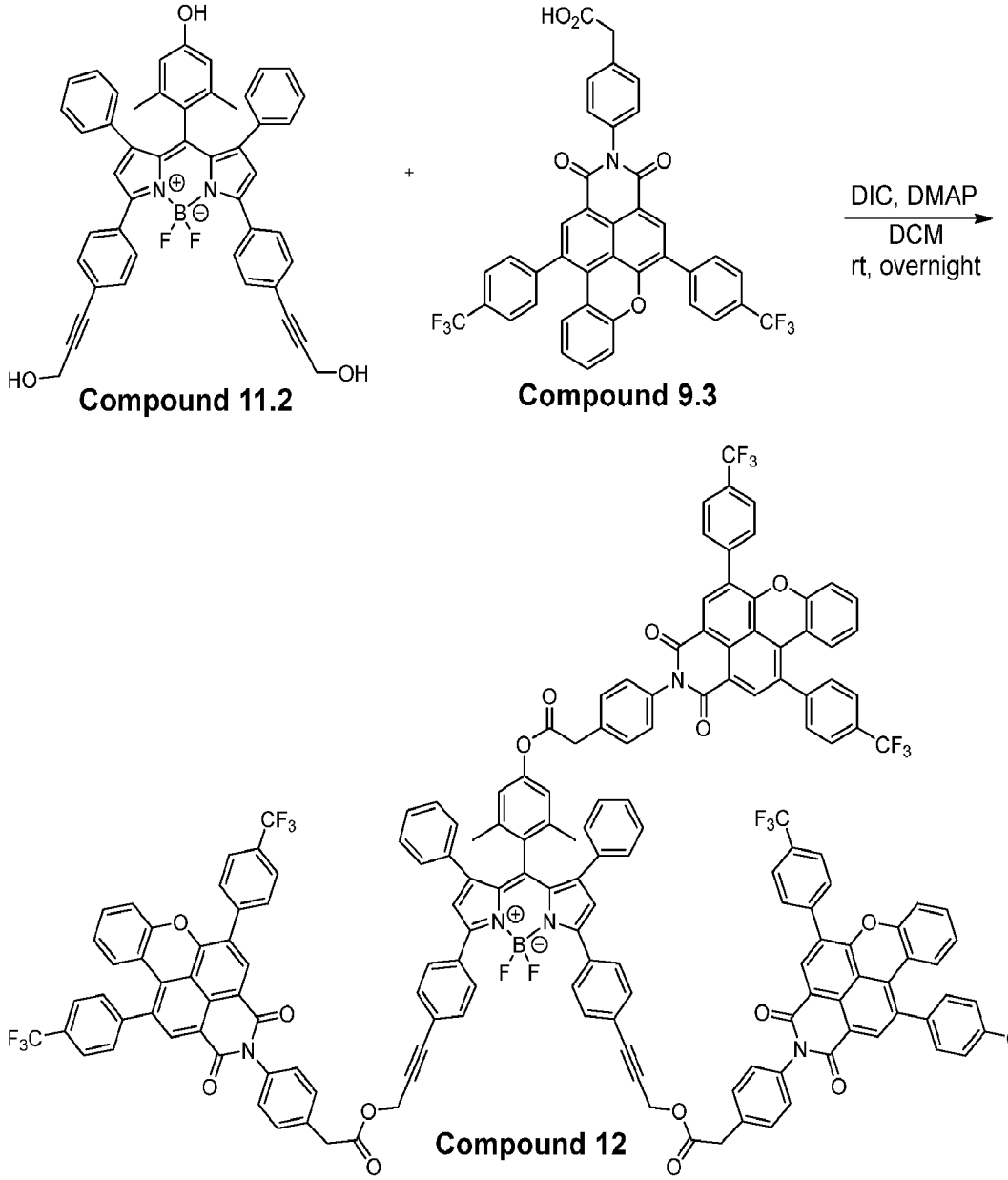
bromophenyl)-4-phenyl-1H-pyrrole (1.0 g, 3.35 mmol) and 4-hydroxyl-2,6-dimethylbenzaldehyde (251.9 mg, 1.68 mmol) were added, followed by anhydrous dichloroethane (35 ml). The reaction mixture was sparged with Ar for 30 minutes, then p-TsOH•H_2O (57.3 mg, 0.30 mmol) was added. The reaction solution was heated up to 60 °C and has been kept at this temperature overnight. Then the reaction was cooled down to room temperature and DDQ (608.4 mg, 2.68 mmol) was added. The reaction was kept at room temperature for 30 minutes. Then BF_3•OEt_2 (2.5 mL, 20.1 mmol) and Et_3N (1.9 mL, 13.4 mmol) were added at room temperature. The reaction mixture was heated up to 50 ºC and has been kept at this temperature for 2 hours. The reaction mixture was loaded with silica gel and purified by flash chromatography, using DCM in Hexane (0-100%) as an eluant to provide the pure **Compound 11.1** as a dark purple to golden solid, 560.0 mg, 43% yield. MS (APCI): calculated for Chemical Formula: $C_{41}H_{29}BBr_2F_2N_2O$ ($[M-H]^-$) = 774 found: 774. ^1H NMR (400 MHz, $CDCl_2CDCl_2$) 7.81 (m, 4H), 7.62 (m, 4H), 7.02 (m, 2H), 6.95 (m, 4H), 6.78 (m, 4H), 6.47 (s, 2H), 5.71 (s, 2H), 4.27 (s, 1H), 1.98 (s, 6H).

Compound 11.2: 3,3'-((5,5-difluoro-10-(4-hydroxy-2,6-dimethylphenyl)-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yn-1-ol): A 100 mL Schlenk tube was fitted with a stir bar. To the tube, **Compound 11.1** (155.0 mg, 0.20 mmol),CuI (7.6 mg, 0.04 mmol), $PdCl_2(PPh_3)_2$ (28.1 mg, 0.04 mmol) and prop-2-yn-1-ol (44.8 mg, 0.8 mmol) were added, followed by anhydrous Et_3N (5 ml). The reaction mixture was sparged with N_2 for 30 minutes. The reaction mixture was heated up to 80 °C and has been kept at this temperature for 8 hours. LCMS showed the completion of the reaction. DCM (50 ml) and 0.5 M HCl (100 mL) were added. The aqueous phase was further extracted with DCM (50 ml *3). The combined organic phase was concentrated under rotavapor, and the crude was purified by flash chromatography, using EtOAc in DCM (0-50%) as an eluant to provide the pure 12.2 as a dark purple solid, 111.0 mg, 77% yield. MS (APCI): calculated for Chemical Formula: $C_{47}H_{35}BF_2N_2O_3$ ($[M-H]^-$) = 724 found: 724. ^1H NMR (400 MHz, $CDCl_2CDCl_2$) 7.92 (m, 4H), 7.55 (m, 4H), 7.02 (m, 2H), 6.94 (m, 4H), 6.79 (m, 4H), 6.51 (s, 2H), 5.71 (s, 2H), 4.54 (d, J = 6.0 Hz, 4H), 4.27 (s, 1H), 1.98 (s, 6H), 1.77 (t, J = 6.0 Hz, 2H).

Compound 11: ((10-(4-(2-(4-(9-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetoxy)-2,6-dimethylphenyl)-5,5-

difluoro-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yne-3,1-diyl) bis(2-(4-(9-(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetate): A 25 mL vial was fitted with a stir bar. To the vial, **Compound 11.2** (72.4 mg, 0.10 mmol), **Compound 6.1** (379.0 mg, 0.60 mmol), DIC (176.4 mg, 1.40 mmol) and DMAP (55.0 mg, 0.45 mmol) were added, followed by anhydrous DCM (15 ml). The reaction mixture has been kept at room temperature for 5 days with another portion of DIC (25.2 mg, 0.20 mmol) addition after 24 hours. The reaction mixture was loaded with silica gel and purified by flash chromatography, using EtOAc in DCM (0-10%) as the eluant to provide **Compound 11** as a dark purple red solid. The solid was further triturated with EtOAc/MeOH (2 ml/10 ml) to deliver 12. The solid was further purified by flash chromatography using EtOAc in Hexane (0-60%) and EtOAc in DCM (0-10%) as the eluants, then triturated with DCM/EtOAc/MeOH (9:1:1), and the cycle has been repeated twice, to provide pure 11 137.0 mg, 53% yield. ^{1}H NMR (400 MHz, $CDCl_2CDCl_2$) 8.64 (m, 6H), 8.25 (m, 3H), 8.11 (m, 9H), 7.93 (m, 7H), 7.79 (m, 3H), 7.57 (m, 13H), 7.37 (m, 9H), 7.01 (m, 6H), 6.77 (m, 4H), 6.52 (s, 2H), 6.11 (s, 2H), 5.02 (s, 4H), 3.90 (s, 2H), 3.85 (s, 4H), 2.05 (s, 6H).

Synthesis of Compound 12

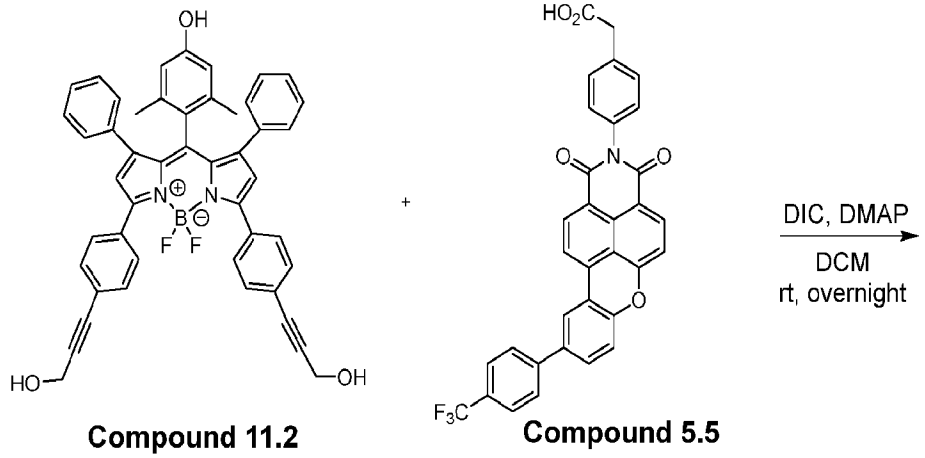


Compound 11.2 + Compound 9.3 → Compound 12

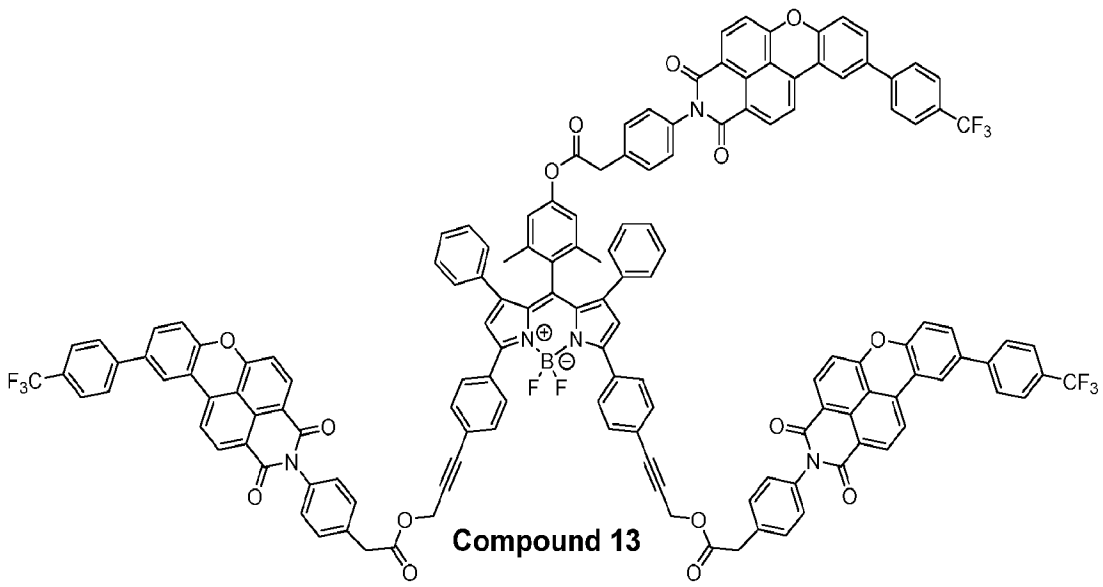
Compound 12: ((10-(4-(2-(4-(1,3-dioxo-5,11-bis(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetoxy)-2,6-dimethylphenyl)-5,5-difluoro-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yne-3,1-diyl) bis(2-(4-(1,3-dioxo-5,11-bis(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetate): A 25 mL vial was fitted with a stir bar. To the vial, **Compound 11.2** (50.0 mg, 0.07 mmol), **Compound 9.3** (261.5 mg, 0.42 mmol), DIC (123.5 mg, 0.98 mmol) and DMAP (38.0 mg, 0.32

mmol) were added, followed by anhydrous DCM (11 ml). The reaction mixture has been kept at room temperature overnight. The reaction mixture was loaded with silica gel and purified by flash chromatography, using EtOAc in DCM (0 to10%) as the eluant to provide **Compound 12** as a dark purple red solid. The solid was further triturated with EtOAc/MeOH (2 ml/10 ml) to deliver **Compound 12**. The solid was further purified by flash chromatography using EtOAc in Hexane (0 to 60%) and EtOAc in DCM (0 to 10%) as the eluants, then triturated with DCM/EtOAc/MeOH (10:1:10), and the cycle has been repeated twice, to provide pure **Compound 12**. 139.0 mg, 71% yield. ^{1}H NMR (400 MHz, $CDCl_2CDCl_2$) 8.72 (s, 1H), 8.69 (s, 2H), 8.49 (s, 1H), 8.46 (s, 2H), 7.87 (m, 22H), 7.62 (m, 16H), 7.41 (m, 5H), 7.31 (m, 7H), 7.00 (m, 12H), 6.76 (m, 4H), 6.51 (s, 2H), 6.10 (s, 2H), 5.01 (s, 4H), 3.90 (s, 2H), 3.85 (s, 4H), 2.04 (s, 6H).

Synthesis of Compound 13



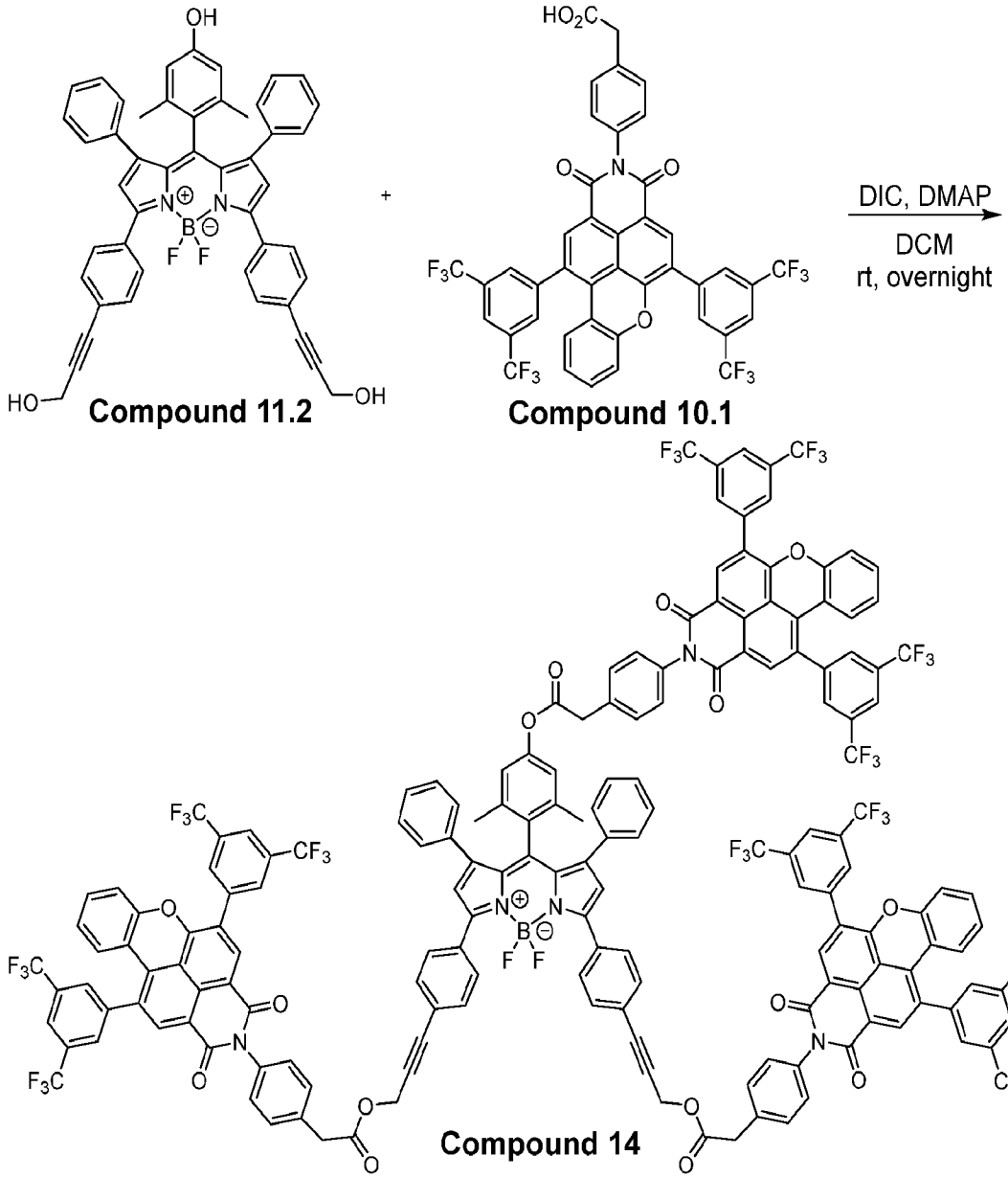
Compound 11.2 **Compound 5.5**



Compound 13

Compound 13: ((10-(4-(2-(4-(1,3-dioxo-9-(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetoxy)-2,6-dimethylphenyl)-5,5-difluoro-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yne-3,1-diyl) bis(2-(4-(1,3-dioxo-9-(4-(trifluoromethyl)phenyl)-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetate): A 25 mL vial was fitted with a stir bar. To the vial, **Compound 11.2** (50.0 mg, 0.07 mmol), **Compound 5.5** (237.5 mg, 0.42 mmol), DIC (123.5 mg, 0.98 mmol) and DMAP (38.0 mg, 0.32 mmol) were added, followed by anhydrous DCM (11 ml). The reaction mixture has been kept at room temperature overnight. The reaction mixture was loaded with silica gel and purified by flash chromatography, using EtOAc in DCM (0-10%) as the eluant to provide 14 as a dark purple red solid. The solid was further triturated with EtOAc/MeOH (2 ml/10 ml) to deliver **Compound 13**. The solid was further purified by flash chromatography using EtOAc in Hexane (0-60%) and EtOAc in DCM (0-10%) as the eluants, then triturated with DCM/EtOAc/MeOH (10:1:1), and the cycle has been repeated twice, to provide pure **Compound 13**. 100.0 mg, 60% yield. ^{1}H NMR (400 MHz, $CDCl_2CDCl_2$) 8.63 (m, 6H), 8.10 (m, 10H), 7.77 (m, 15H), 7.57 (m, 11H), 7.39 (m, 11H), 6.99 (m, 6H), 6.77 (m, 4H), 6.52 (s, 2H), 6.11 (s, 2H), 5.02 (s, 4H), 3.90 (s, 2H), 3.86 (s, 4H), 2.05 (s, 6H).

Synthesis of Compound 14



Compound 14: ((10-(4-(2-(4-(5,11-bis(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetoxy)-2,6-dimethylphenyl)-5,5-difluoro-1,9-diphenyl-5H-4l4,5l4-dipyrrolo[1,2-c:2',1'-f][1,3,2]diazaborinine-3,7-diyl)bis(4,1-phenylene))bis(prop-2-yne-3,1-diyl) bis(2-(4-(5,11-bis(3,5-bis(trifluoromethyl)phenyl)-1,3-dioxo-1H-xantheno[2,1,9-def]isoquinolin-2(3H)-yl)phenyl)acetate): A 25 mL vial was fitted with a stir bar. To the vial, **Compound 11.2** (50.0 mg, 0.07 mmol), **Compound 10.1** (355.8 mg, 0.42 mmol), DIC (123.5 mg, 0.98 mmol) and DMAP (38.0 mg, 0.32 mmol) were added, followed by anhydrous DCM (11 ml). The reaction

mixture has been kept at room temperature overnight. The reaction mixture was loaded with silica gel and purified by flash chromatography, using EtOAc in DCM (0-10%) as the eluant to provide **Compound 14** as a dark purple red solid. The solid was further triturated with EtOAc/MeOH (2 ml/10 ml) to deliver **Compound 14**. The solid was further purified by flash chromatography using EtOAc in Hexane (0-60%) and EtOAc in DCM (0-10%) as the eluants, then triturated with DCM/EtOAc/MeOH (9:1:10), and the cycle has been repeated twice, to provide pure **Compound 14**. 163.0 mg, 73% yield. ^{1}H NMR (400 MHz, $CDCl_2CDCl_2$) 8.77 (s, 1H), 8.73 (s, 2H), 8.52 (s, 1H), 8.50 (s, 2H), 8.26 (m, 6H), 8.04 (m, 12H), 7.92 (m, 4H), 7.58 (m, 10H), 7.48 (m, 3H), 7.40 (m, 2H), 7.34 (m, 4H), 7.27 (m, 3H), 6.99 (m, 12H), 6.76 (m, 4H), 6.51 (s, 2H), 6.10 (s, 2H), 5.01 (s, 4H), 3.90 (s, 2H), 3.85 (s, 4H), 2.04 (s, 6H).

Example 3 Fabrication of a Color Conversion Film

A glass substrate was prepared in substantially the following manner. A 1.1 mm thick glass substrate measuring 1-inch X 1-inch was cut to size. The glass substrate was then washed with detergent and deionized (DI) water, rinsed with fresh DI water, and sonicated for about 1 hour. The glass was then soaked in isopropanol (IPA) and sonicated for about 1 hour. The glass substrate was then soaked in acetone and sonicated for about 1 hour. The glass was then removed from the acetone bath and dried with nitrogen gas at room temperature.

A 25 wt% solution of poly(methyl methacrylate) (PMMA) (average M.W. 120,000 by GPC from MilliporeSigma, Burlington, MA, USA) polymer in Toluene was prepared. The prepared PMMA polymer in toluene was stirred overnight at 60 °C until fully dissolved. [PMMA] CAS: 9011-14-7; [Toluene] CAS: 108-88-3.

The 25% PMMA solution prepared above (3.4 mL) was added to 2 mg of the chromophore dye made as described above in a sealed container and mixed well using Vortex for 5 minutes and sonication for 30 minutes. The PMMA/chromophore solution was then spin coated onto a prepared glass substrate at 1000 RPM for 20 s. The resulting wet coating had a thickness of about 10 μm. Three samples each were prepared in this manner for absorption, emission/FWHM and quantum yield measurements. The spin coated samples were baked in an oven at 150 °C for 5 minutes to evaporate the remaining solvent. Other examples were made in a similar manner, except that a poly(butyl acrylate) solution was utilized instead of

the PMMA solution. The poly(butyl acrylate) (PBA) solution (average M.W. ~99,000 by GPC) was purchased from Sigma Aldrich, CAS: 9003-49-0.

For absorption spectra measurement, the 1-inch X 1-inch sample was inserted into a Shimadzu, UV-3600 UV-VIS- NIR spectrophotometer (Shimadzu Instruments, Inc., Columbia, MD, USA).

The fluorescence spectrum of a 1-inch X 1-inch film sample prepared as described above was determined using a Fluorolog spectrofluorometer (Horiba Scientific, Edison, NJ, USA) with the excitation wavelength set at the respective maximum absorbance wavelength. The maximum emission and FWHM are shown in Table 1.

The normalized absorption and emission spectrum for Compound 5 is shown in **FIG. 1**. The normalized absorption and emission spectrum for Compound 6 is shown in **FIG. 2**. The normalized absorption and emission spectrum for Compound 7 is shown in **FIG. 3**.

Quantum yield of a 1-inch X 1-inch sample prepared as described above were determined by Hamamatsu C11347 Absolute PL quantum yield spectrometer (Hamamatsu Inc., Campbell CA, USA). Wavelengths were scanned every 30 nm from 390 nm- 450 nm (as excitation wavelengths) for quantum yield measurement. A 0.5''x 0.5'' size film was taken out from glass for measurement. The QY results at 450 nm are reported in Table 1. The structures of the compounds in the table may be found in the description and examples above.

Table 1.

Cpd.	**Absorption (nm)**	**Emission (nm)**	**FWHM (nm)**	**QY@450nm excitation**
CE-1		512	24	<1%
CE-2		592	37	<1%
Compound -5	576	612	40	100%

Compound-6	578	612	39	90.3%
Compound-7	572	606	41	85.2%
Compound-8	581	616	40	84.6%
Compound-9	577	614	39	90.7%
Compound-10	576	611	39	89.8%
Compound-11	580	614	39	91.2%
Compound-12	580	616	39	89.7%
Compound-13	580	614	40	89.5%
Compound-14	580	615	39	90.8%

CLAIMS

1. A photoluminescent complex, comprising:

a blue light absorbing xanthenoisoquinoline derivative;

a linker complex, wherein the linker complex comprises an unsubstituted ester or substituted ester; and

a boron-dipyrromethene (BODIPY) moiety;

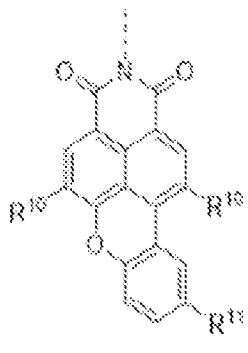
wherein the linker complex covalently links the xanthenoisoquinoline derivative and the BODIPY moiety;

wherein the xanthenoisoquinoline derivative absorbs light energy of a first excitation wavelength and transfers energy to the BODIPY moiety;

wherein the BODIPY moiety absorbs the energy from the xanthenoisoquinoline derivative and emits a light energy of a second higher wavelength; and

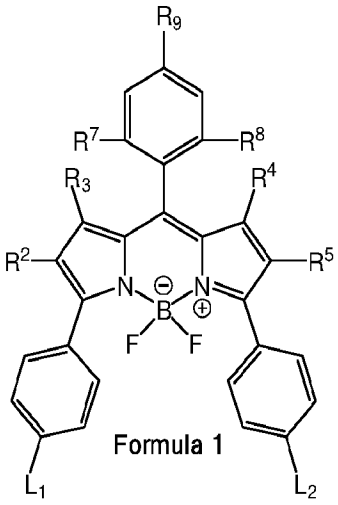
wherein the photoluminescent complex has an emission quantum yield greater than 80%.

2. The photoluminescent complex of claim 1, wherein the xanthenoisoquinoline derivative is of the general formula:



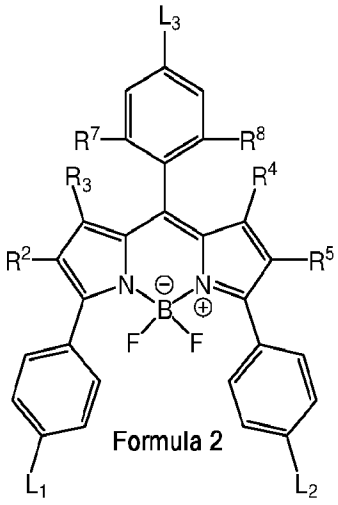
, wherein R^{10} is H, a C_1-C_4 alkyl group, or an optionally substituted aryl group; and wherein R^{11} is H or an optionally substituted aryl group.

3. The photoluminescent complex of claim 1 wherein the BODIPY moiety is of the general formula:



Formula 1

or



Formula 2

;

wherein R^2, R^3, R^4, and R^5 are independently H, a C_1-C_3 alkyl, an optionally substituted aryl group, or an ether group;

wherein R^7, R^8, and R^9 are independently H or a methyl ($-CH_3$); and

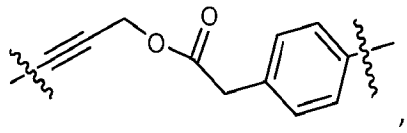
wherein L_1, L_2, and L_3 are linker complexes, wherein the linker complexes are independently an unsubstituted ester or a substituted ester.

4. The photoluminescent complex of claim 3, wherein R^3 and R^4 are an optionally substituted aryl group.

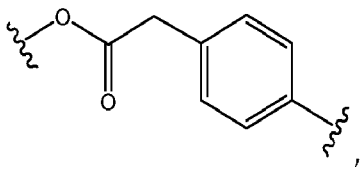
5. The photoluminescent complex of claim 4, wherein the optionally substituted aryl group comprises a 4-trifluromethylphenyl group or a 3,5-bis(trifluoromethyl)phenyl group.

6. The photoluminescent complex of claim 4, wherein the optionally substituted aryl group is a phenyl group.

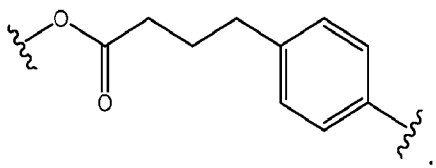
7. The photoluminescent complex of claim 1, wherein the linker complex comprises:



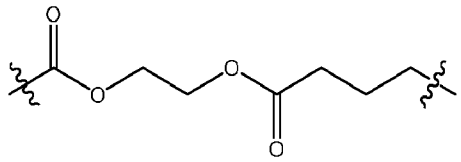
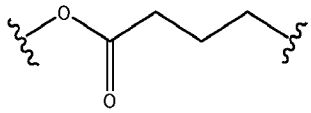
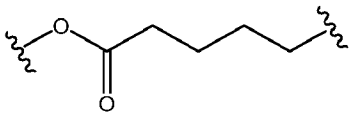
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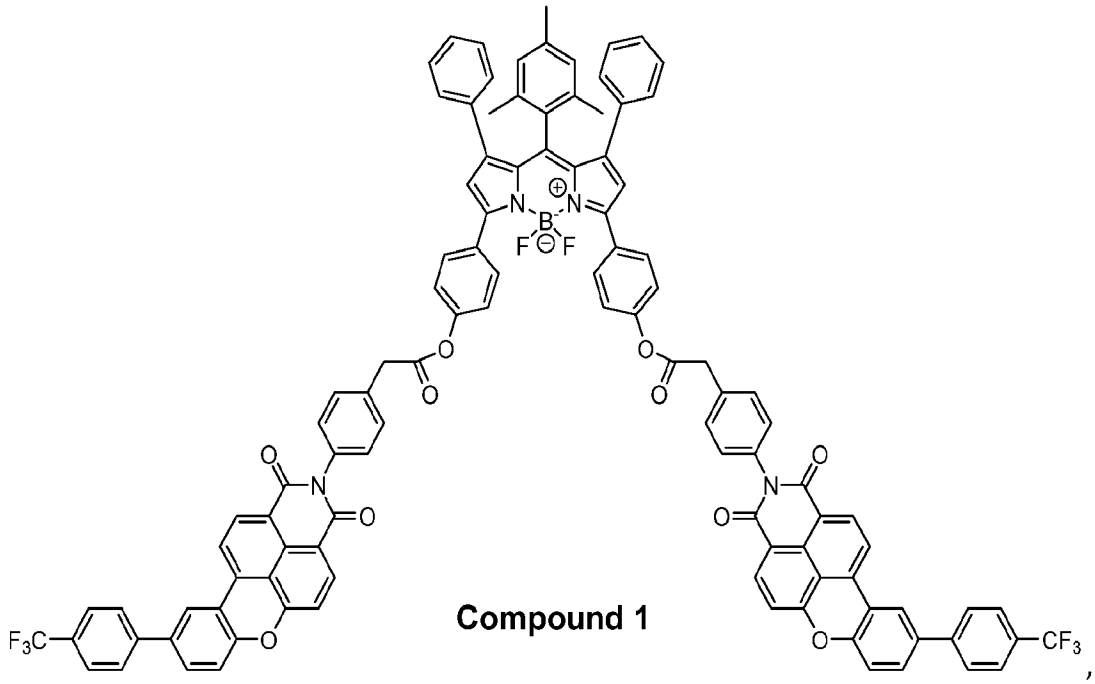
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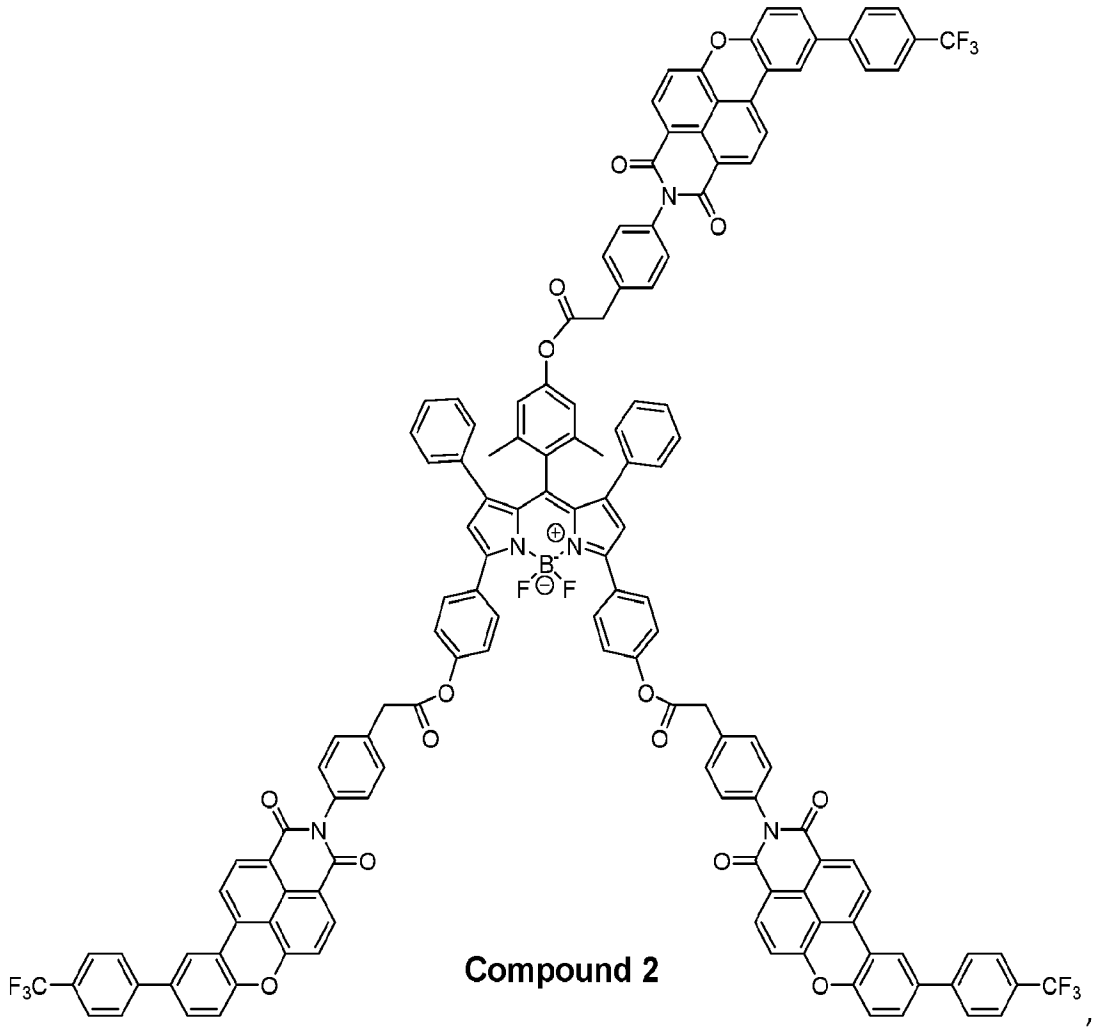
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8. The photoluminescent complex of claim 1, wherein the unsubstituted ester linker complex comprises  ,  ,  , or a combination thereof.

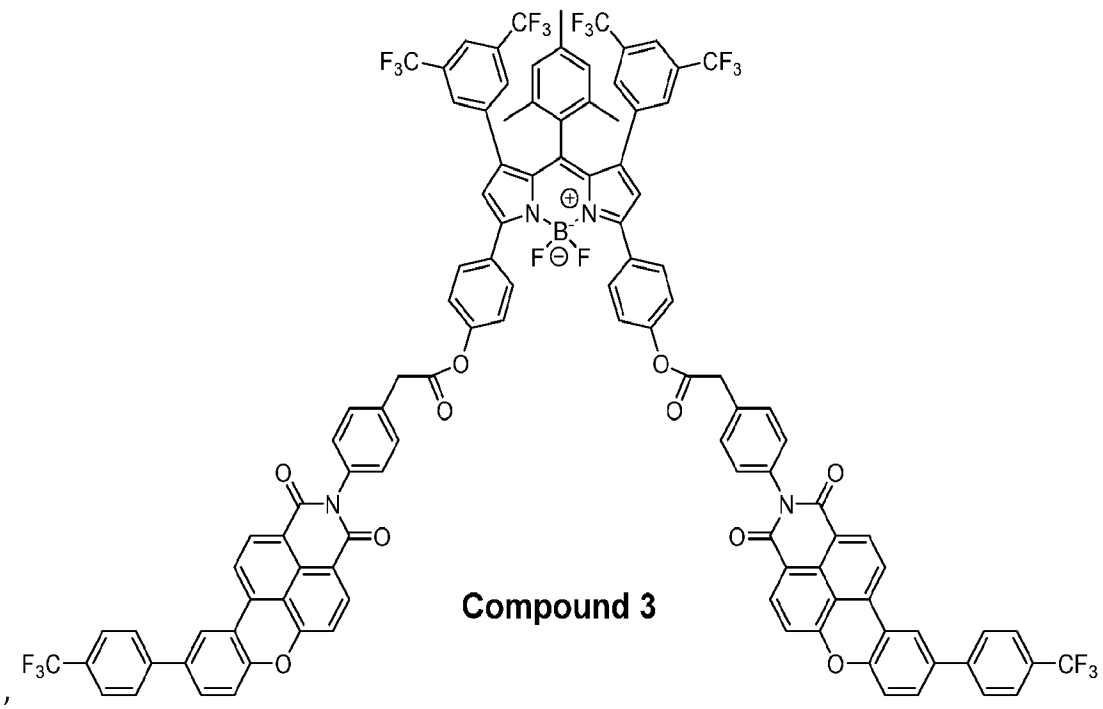
9. The photoluminescent complex of claim 1, wherein the photoluminescent complex comprises:



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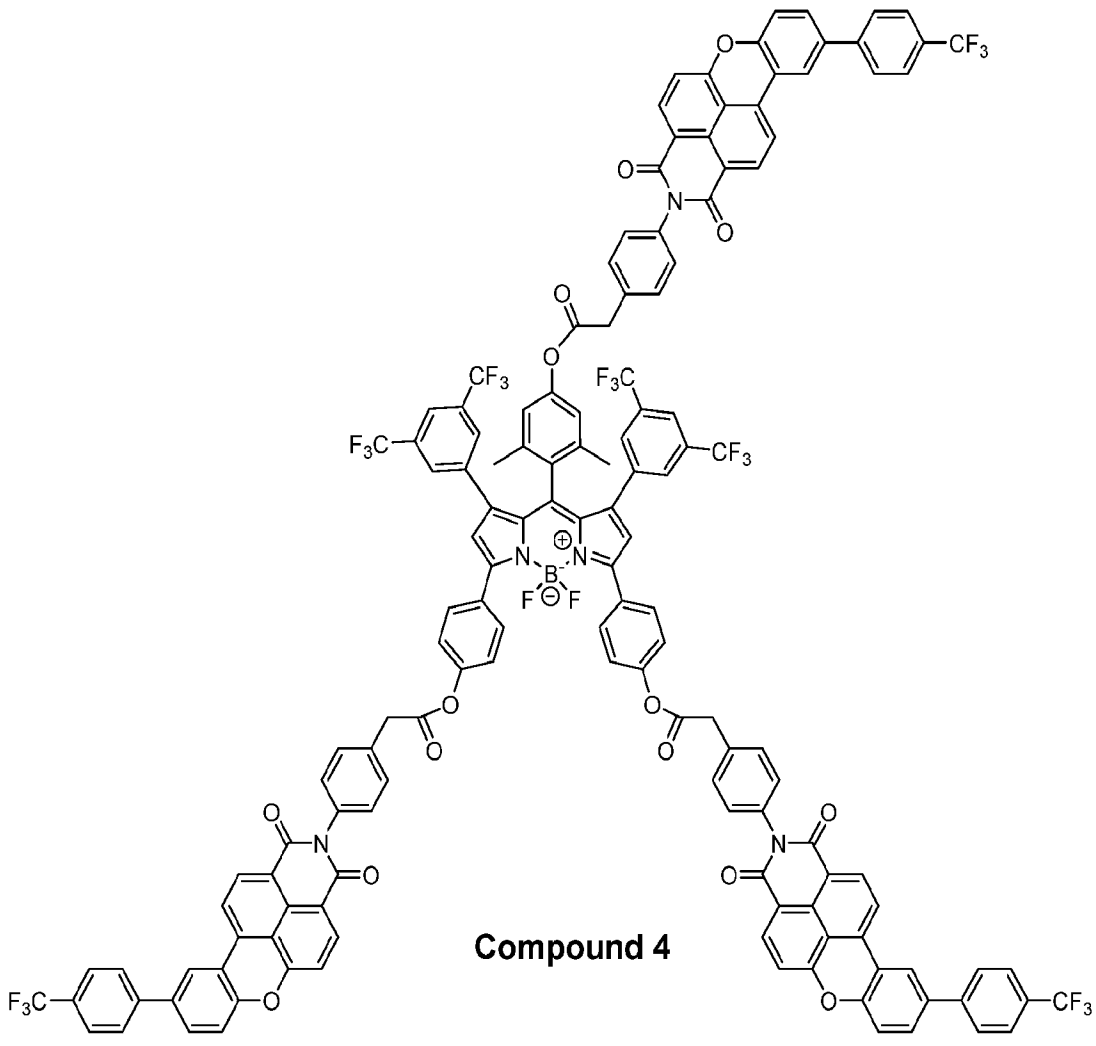


Compound 2,



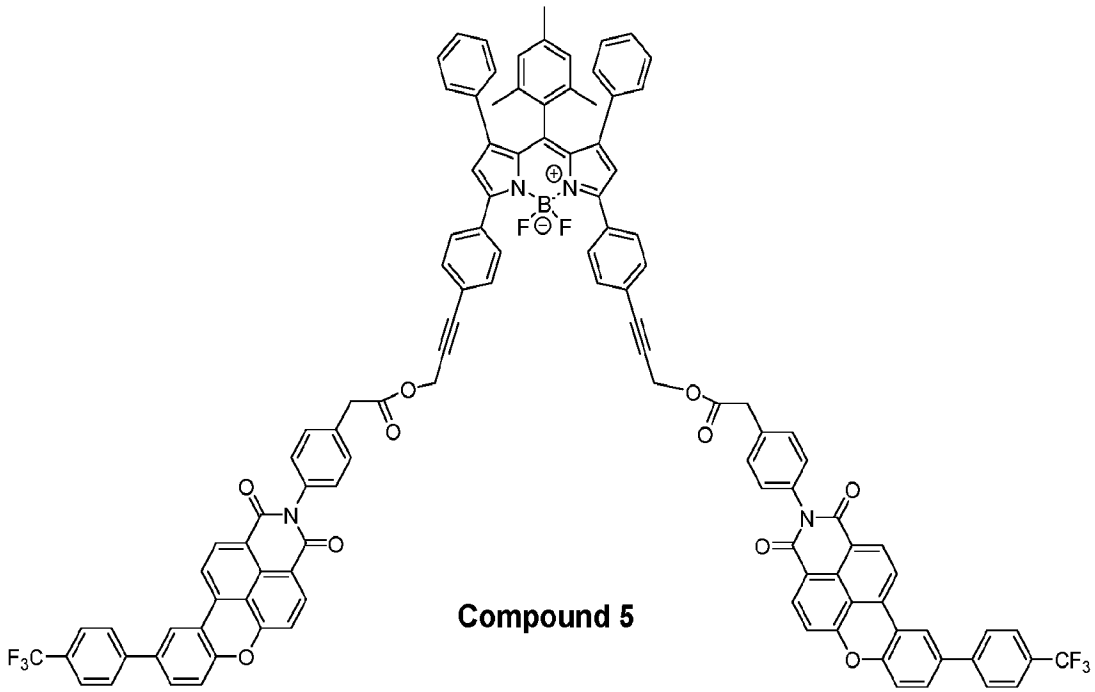
Compound 3

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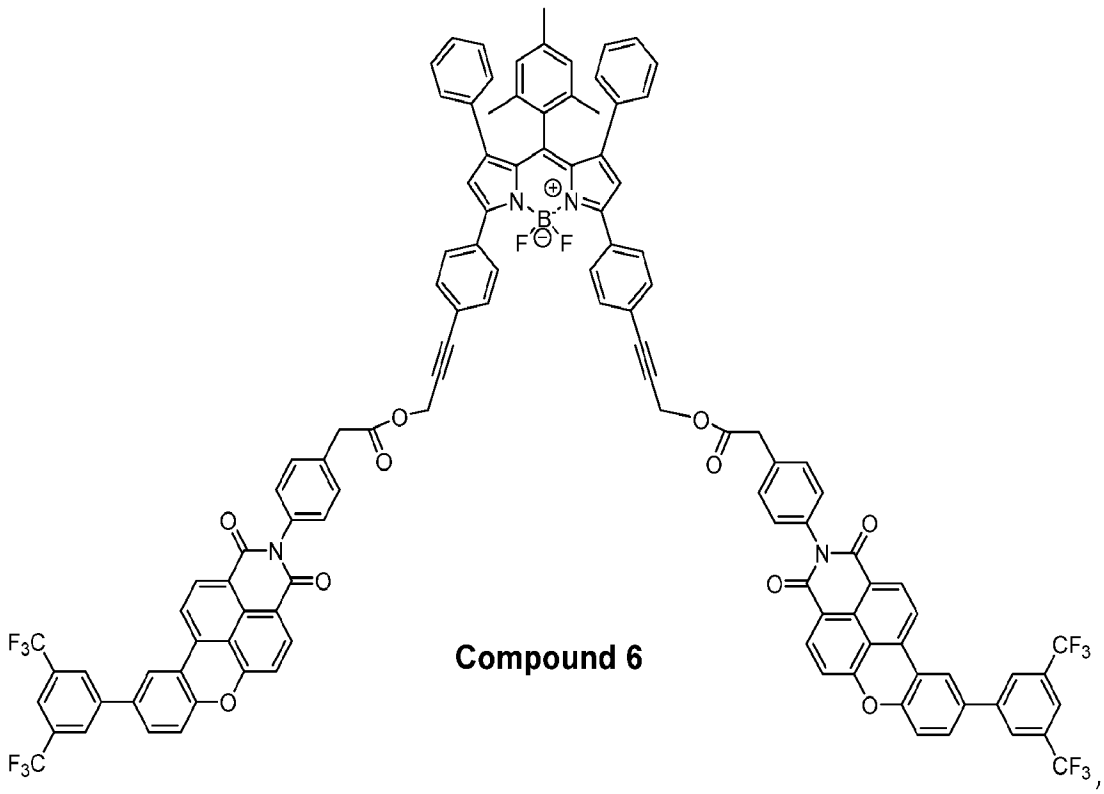


Compound 4

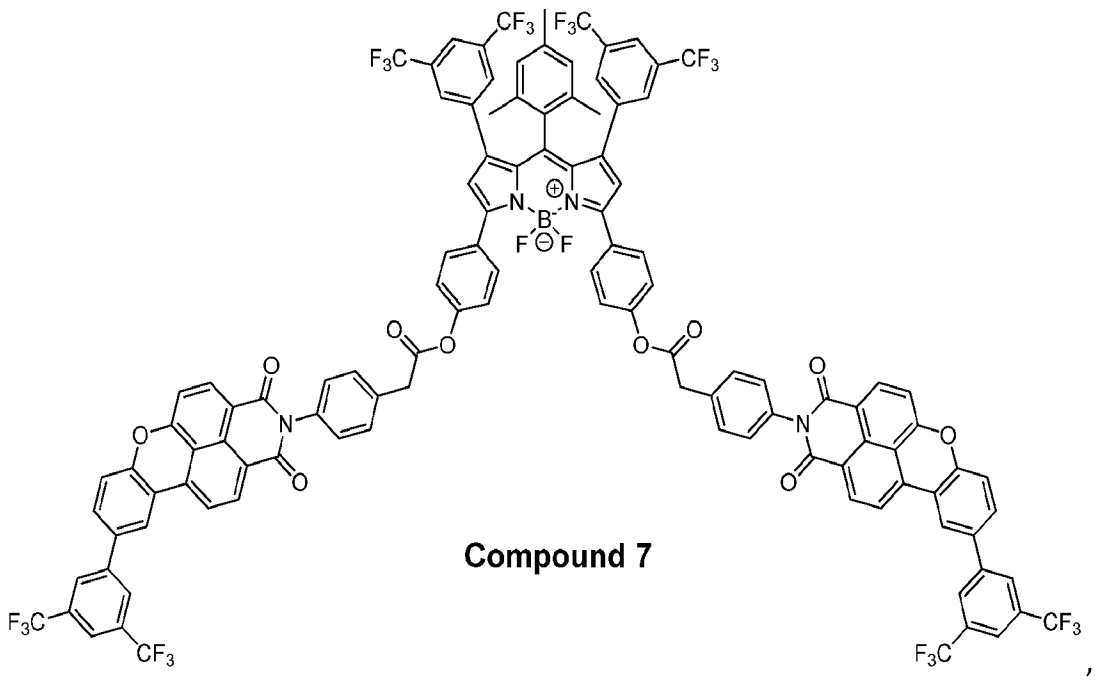
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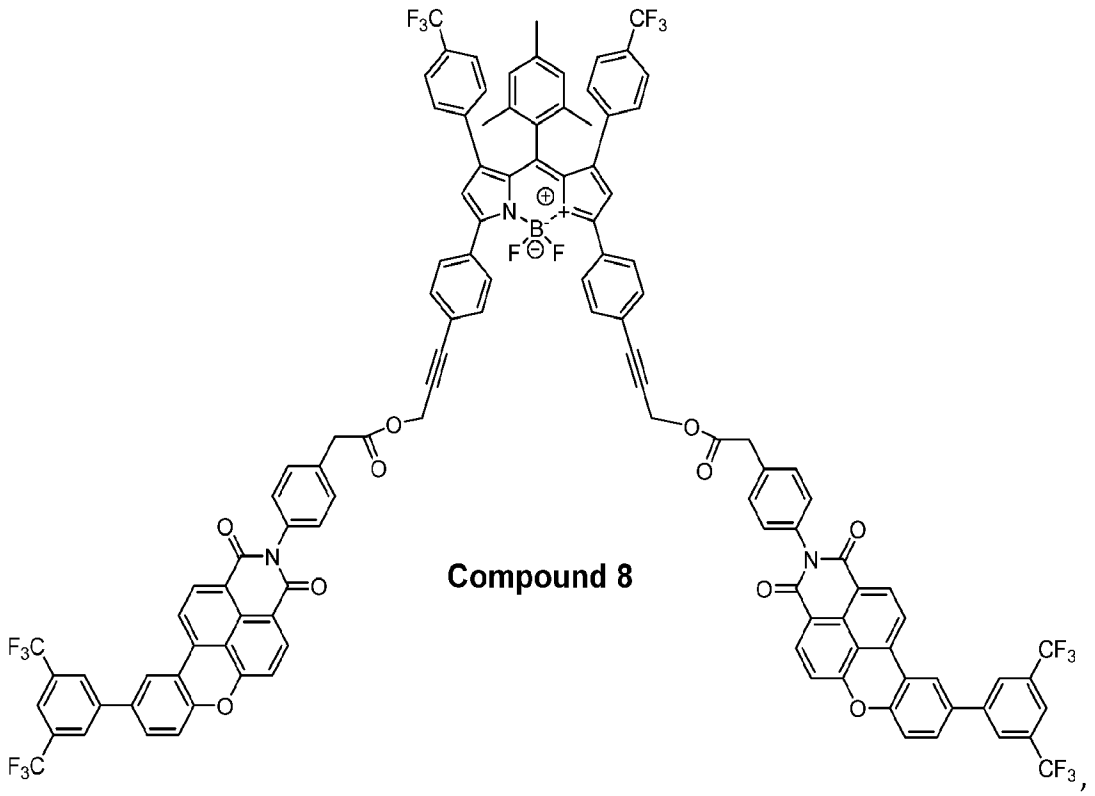
Compound 5



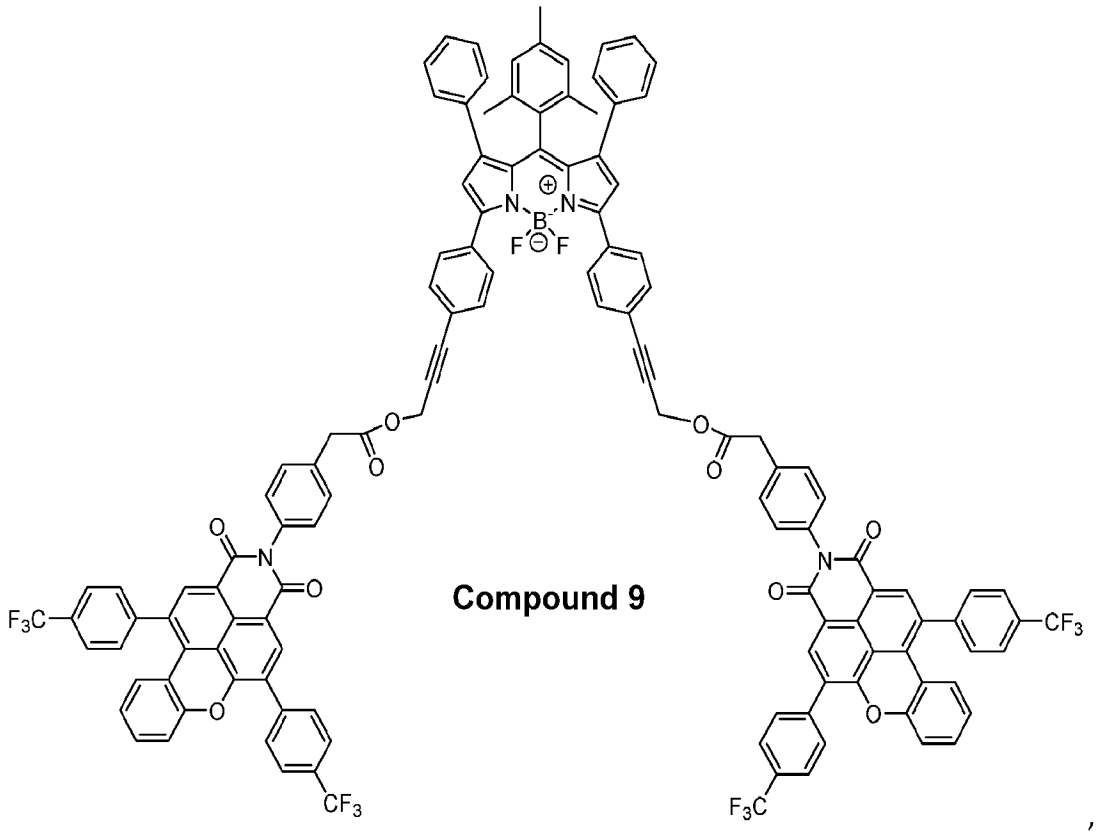
Compound 6



Compound 7,

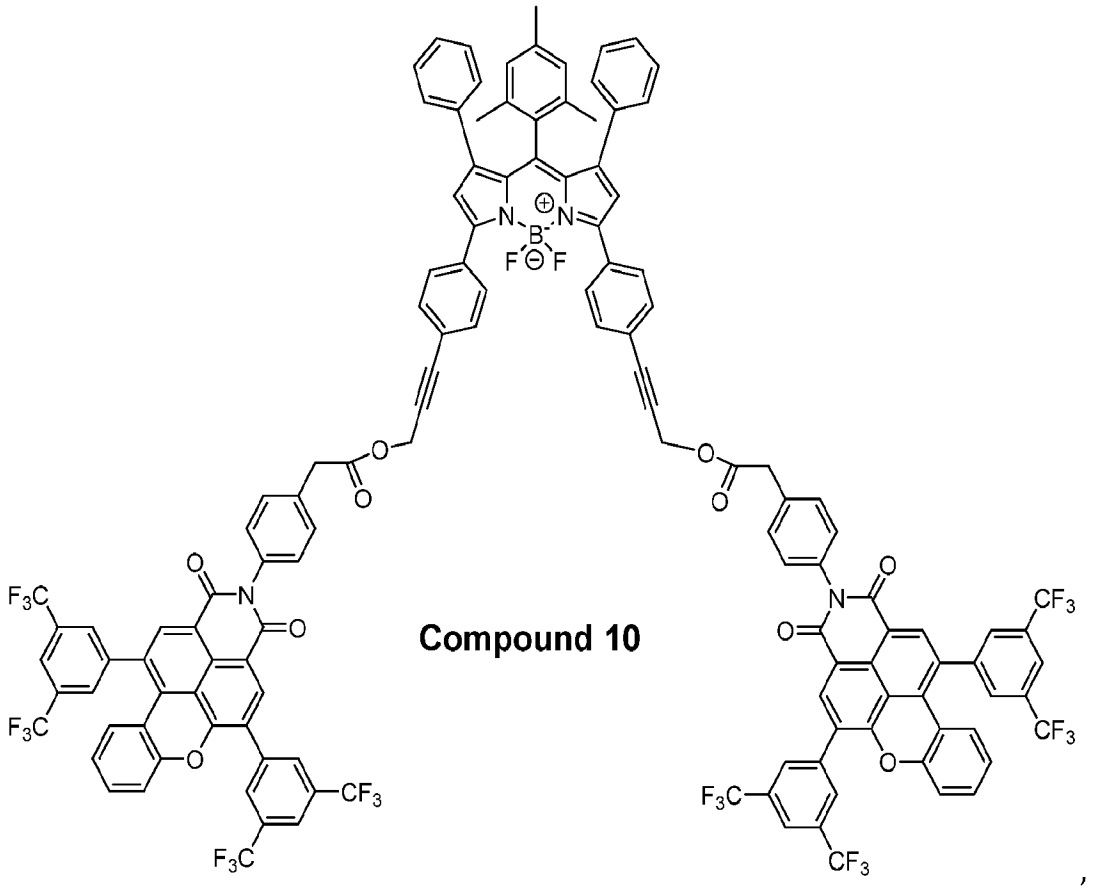


Compound 8,



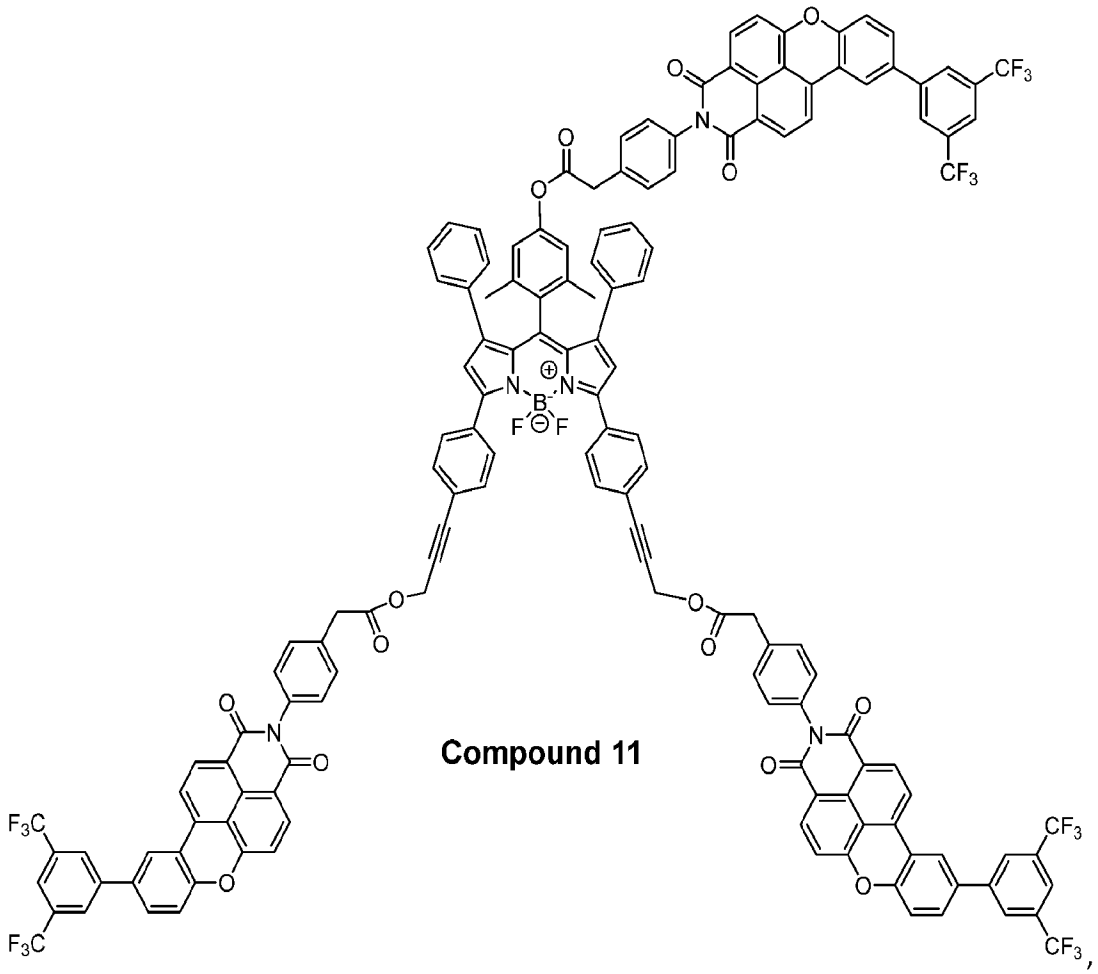
Compound 9

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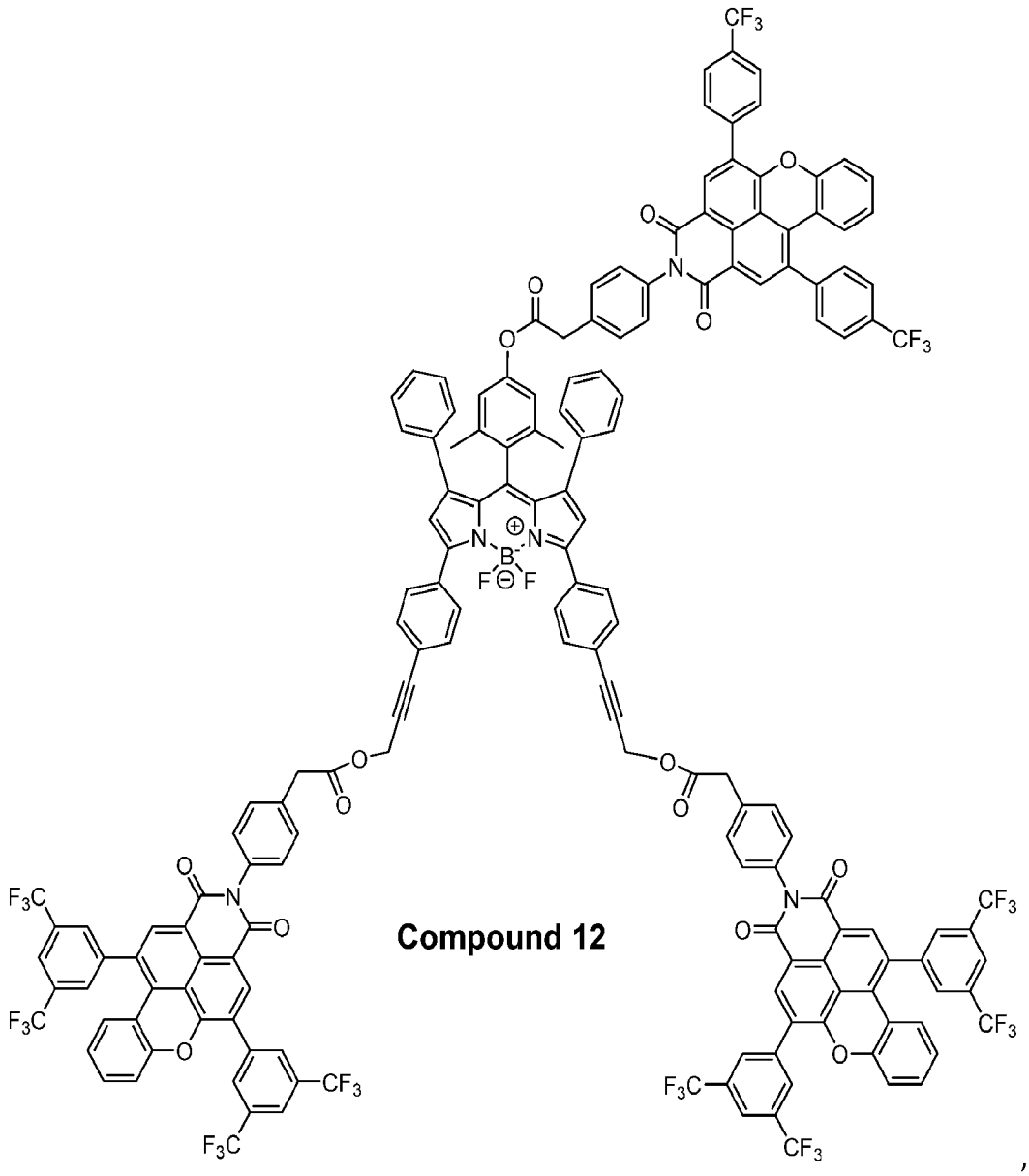


Compound 10

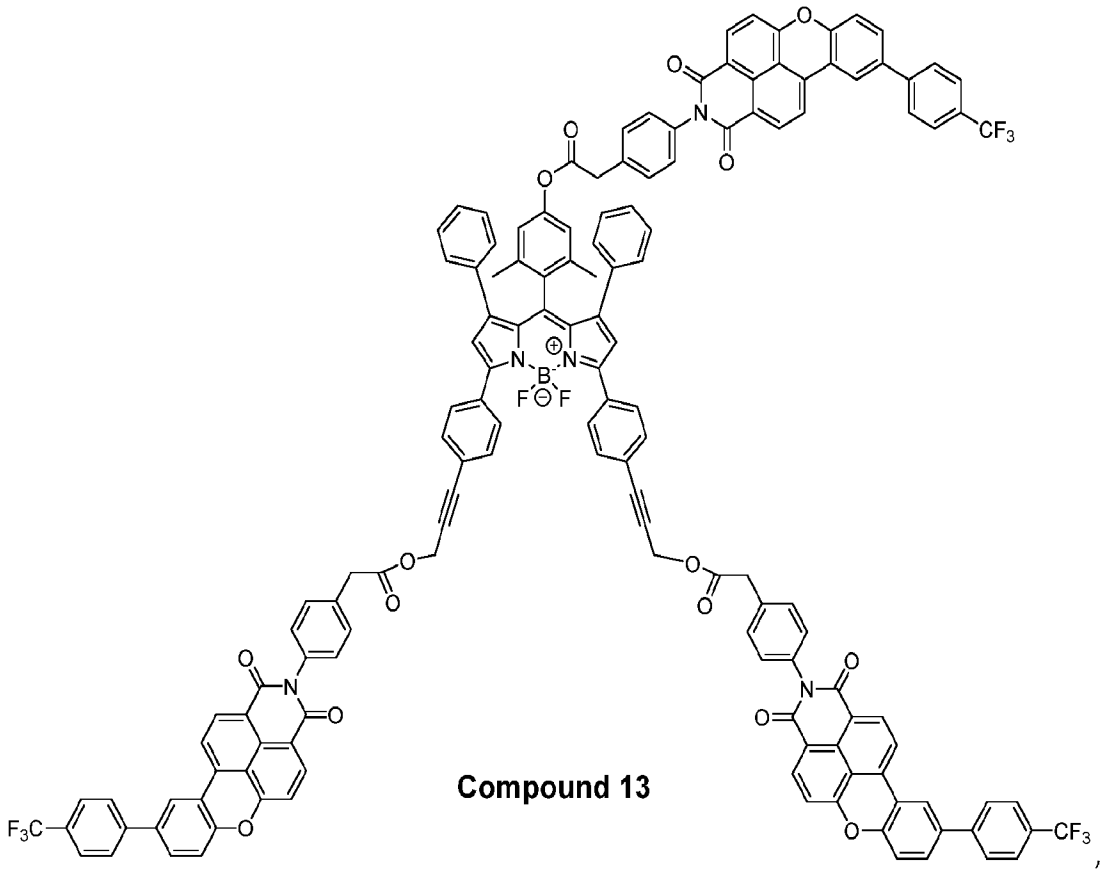
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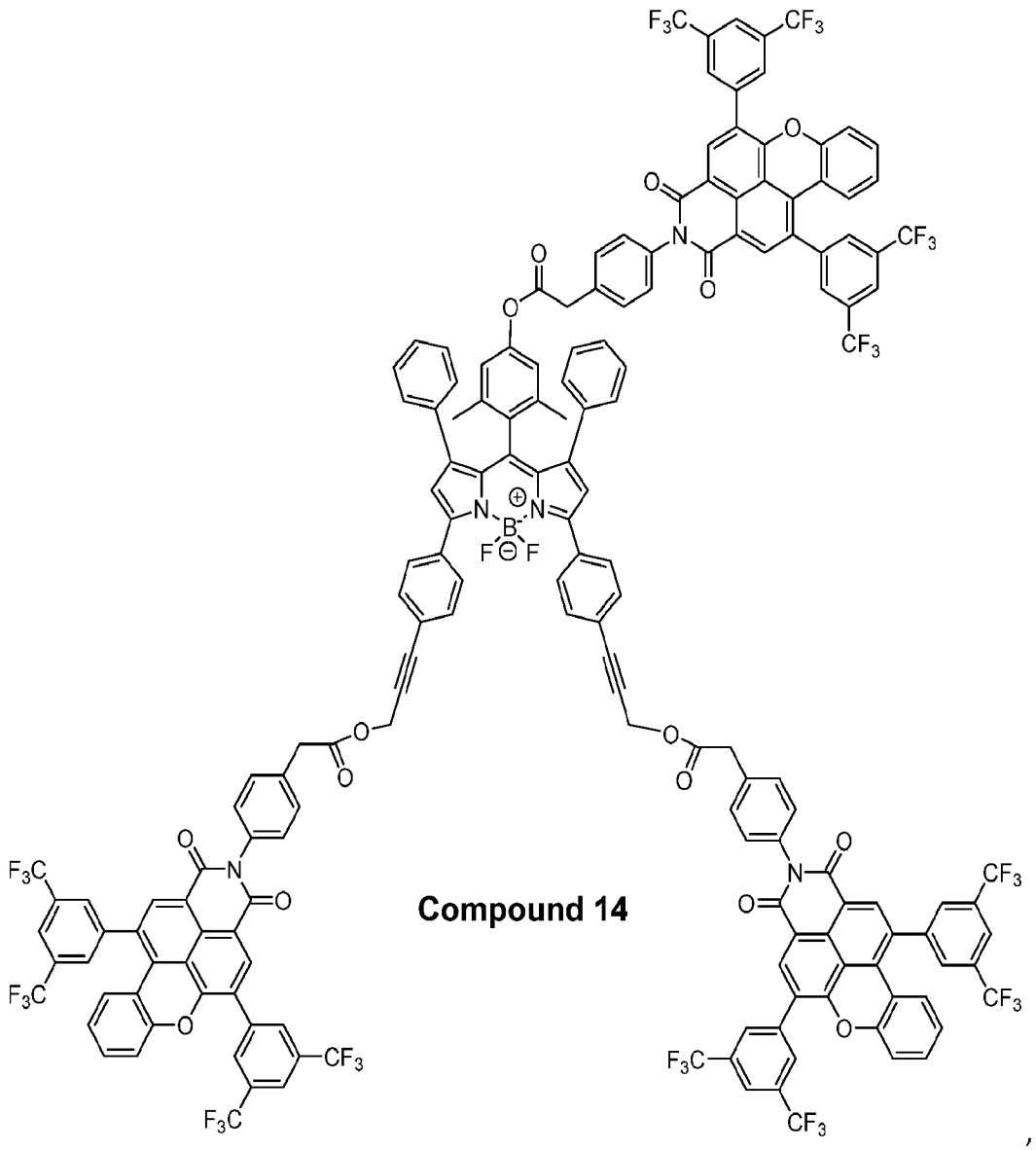
Compound 11



Compound 12



Compound 13



Compound 14

or a combination thereof.

10. A color conversion film, comprising:

a transparent substrate layer;

a color conversion layer, wherein the color conversion layer includes a resin matrix; and

a photoluminescent complex, comprising the photoluminescent compound of claim 1, 2, 3, 4, 5, 6, 7, 8, or 9, dispersed within the resin matrix.

11. The color conversion film of claim 10, wherein the resin matrix comprises poly(methyl methacrylate).

12. The color conversion film of claim 10, wherein the resin matrix comprises poly(butyl acrylate).

13. The color conversion film of claim 10, wherein the film has a thickness of about 10 μm to about 200 μm.

14. The color conversion film of claim 10, 11, 12, or 13, further comprising a singlet oxygen quencher or a radical scavenger.

15. The color conversion film of claim 10, 11, 12, 13, or 14, wherein the film absorbs light of about 400 nm to about 590 nm wavelength and emits light of about 600 nm to about 620 nm wavelength.

16. A method for preparing a color conversion film, the method comprising:

dissolving the photoluminescent complex of claim 1, 2, 3, 4, 5, 6, 7, 8, or 9 and a binder resin within a solvent; and

applying the mixture to one of the transparent substrates opposing surfaces.

17. The method of claim 16, wherein the resin matrix comprises poly(methyl methacrylate).

18. The method of claim 16, wherein the resin matrix comprises poly(butyl acrylate).

19. A backlight unit, comprising the color conversion film of claim 10, 11, 12, 13, 14, or 15.

20. A display device, comprising the backlight unit of claim 19.

FIGURES

1/3

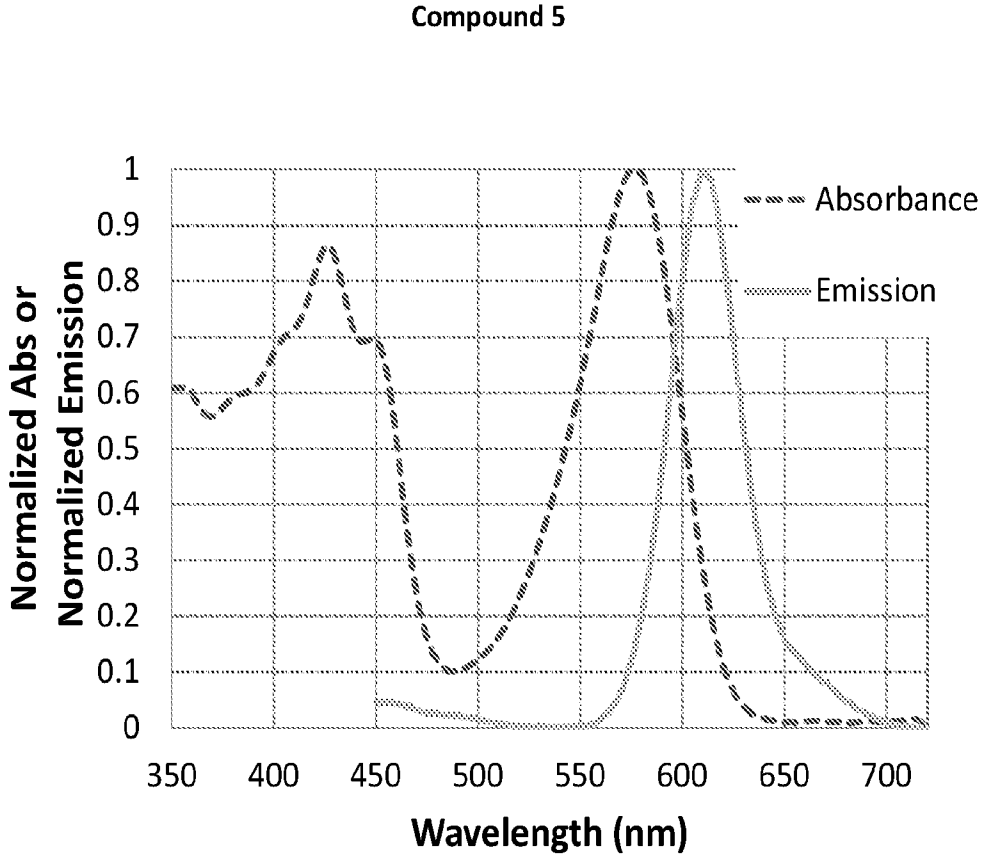


FIG. 1

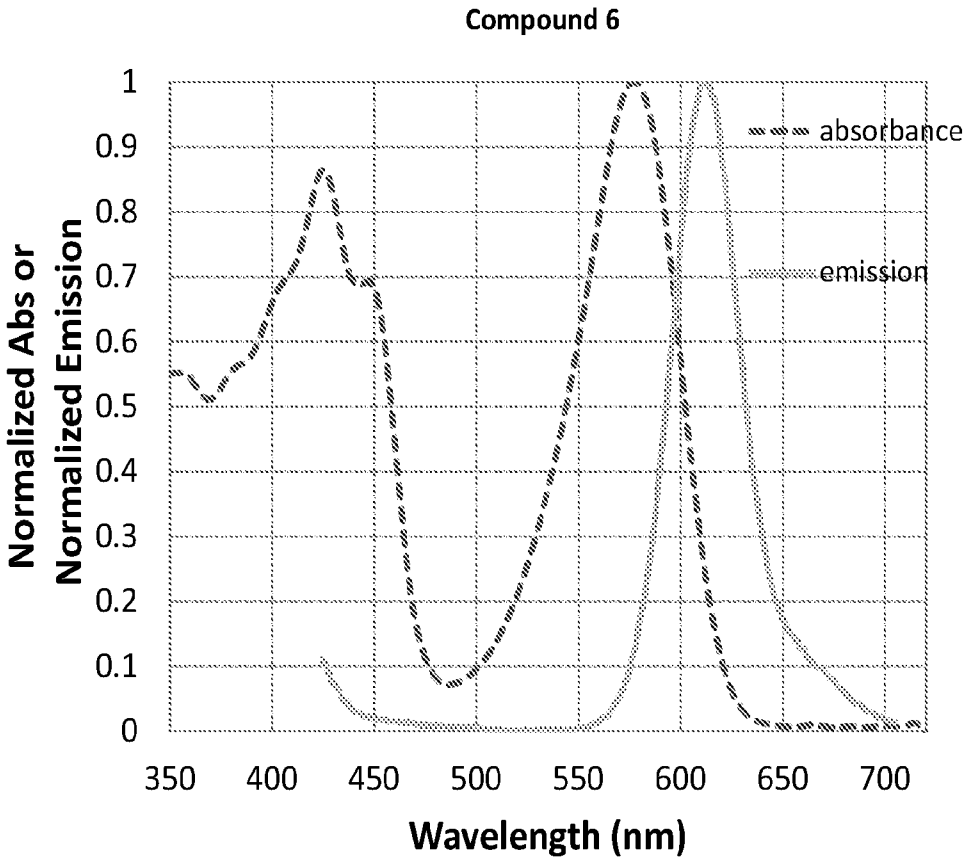

Compound 6
Normalized Abs or Normalized Emission
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
350
400
450
500
550
600
650
700
Wavelength (nm)
absorbance
emission

FIG. 2

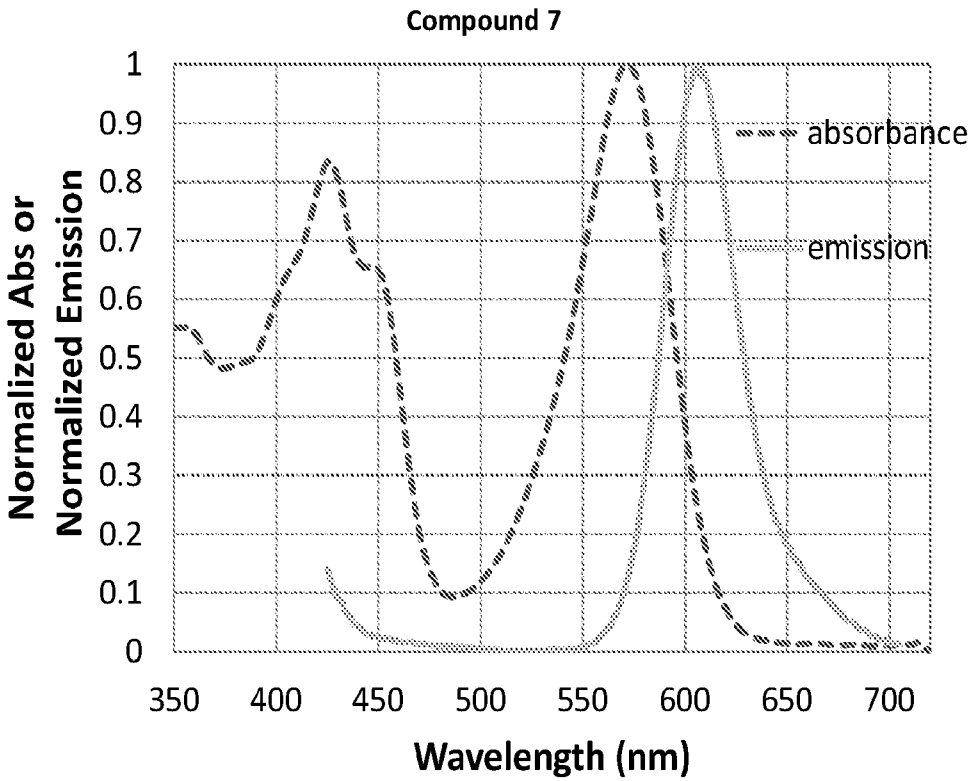

Compound 7
Normalized Abs or Normalized Emission
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
350
400
450
500
550
600
650
700
Wavelength (nm)
absorbance
emission

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/062465

A. CLASSIFICATION OF SUBJECT MATTER
INV. C09K11/06 H10K50/11 H01L33/50
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C09K H10K H01L

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 3 505 592 A1 (FUJIFILM CORP [JP]) 3 July 2019 (2019-07-03) paragraph [0104]; example 1; table 1 the whole document	1-20
A	WO 2020/053124 A1 (BASF SE [DE]) 19 March 2020 (2020-03-19) page 90; compounds dye 26, dye 27 the whole document	1-20
A	WO 2016/151068 A1 (BASF SE [DE]) 29 September 2016 (2016-09-29) example 1 the whole document	1-20
A	US 2019/300782 A1 (KANAZAWA YOSHINORI [JP] ET AL) 3 October 2019 (2019-10-03) paragraph [0158] the whole document	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 May 2023	13/06/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ziegler, Jan

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2023/062465

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3505592 A1	03-07-2019	CN 109642154 A	16-04-2019
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		JP 6756839 B2	16-09-2020
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