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**Xia et al.**

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(54) **ORGANIC ELECTROLUMINESCENT MATERIALS AND DEVICES**

- (71) Applicant: **Universal Display Corporation**, Ewing, NJ (US)
- (72) Inventors: **Chuanjun Xia**, Lawrenceville, NJ (US); **Chun Lin**, Yardley, PA (US)
- (73) Assignee: **UNIVERSAL DISPLAY CORPORATION**, Ewing, NJ (US)
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**H01L 51/00** (2006.01)  
**C07F 15/00** (2006.01)  
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(52) **U.S. Cl.**  
CPC ..... **H01L 51/0085** (2013.01); **C07F 15/0033** (2013.01); **C09K 11/06** (2013.01); **C09K 2211/185** (2013.01); **H01L 51/5016** (2013.01)

(58) **Field of Classification Search**  
CPC ..... C07D 221/04  
See application file for complete search history.

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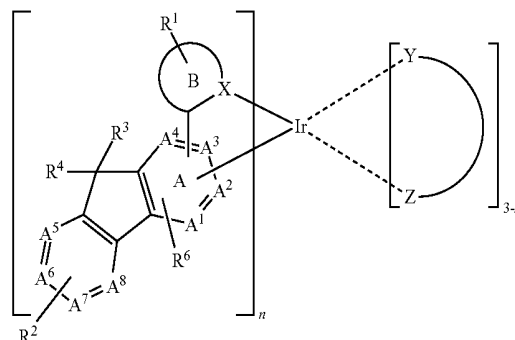
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Primary Examiner — Paul V Ward

(74) Attorney, Agent, or Firm — Duane Morris LLP

(57) **ABSTRACT**

A compound having the structure of formula I:



is described. In formula I, A<sup>1</sup>, A<sup>2</sup>, A<sup>3</sup>, A<sup>4</sup>, A<sup>5</sup>, A<sup>6</sup>, A<sup>7</sup>, and A<sup>8</sup> can be carbon or nitrogen; at least one of A<sup>1</sup>, A<sup>2</sup>, A<sup>3</sup>, A<sup>4</sup>, A<sup>5</sup>, A<sup>6</sup>, A<sup>7</sup>, and A<sup>8</sup> being nitrogen; X is a neutral donor;



is a monoanionic bidentate ligand; n is an integer from 1 to 3; ring B is bonded to ring A through a C—C bond; and ring A is bonded to the iridium through a Ir—C bond. In addition, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, and R<sup>6</sup> are independently selected from hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrite, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof. Also described are formulations and devices, such as an OLEDs, that include the compound of formula I.

**18 Claims, 3 Drawing Sheets**

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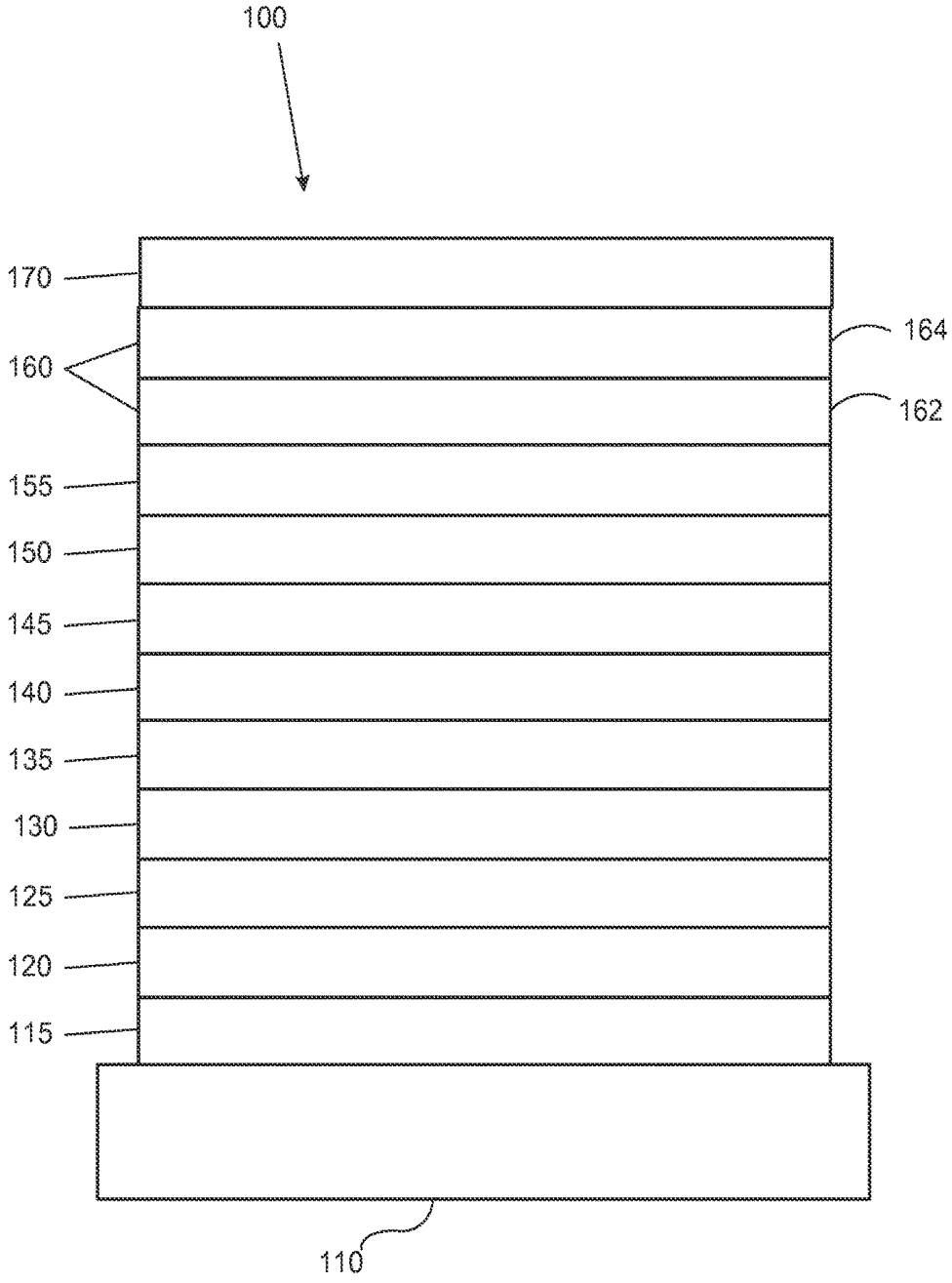


FIGURE 1

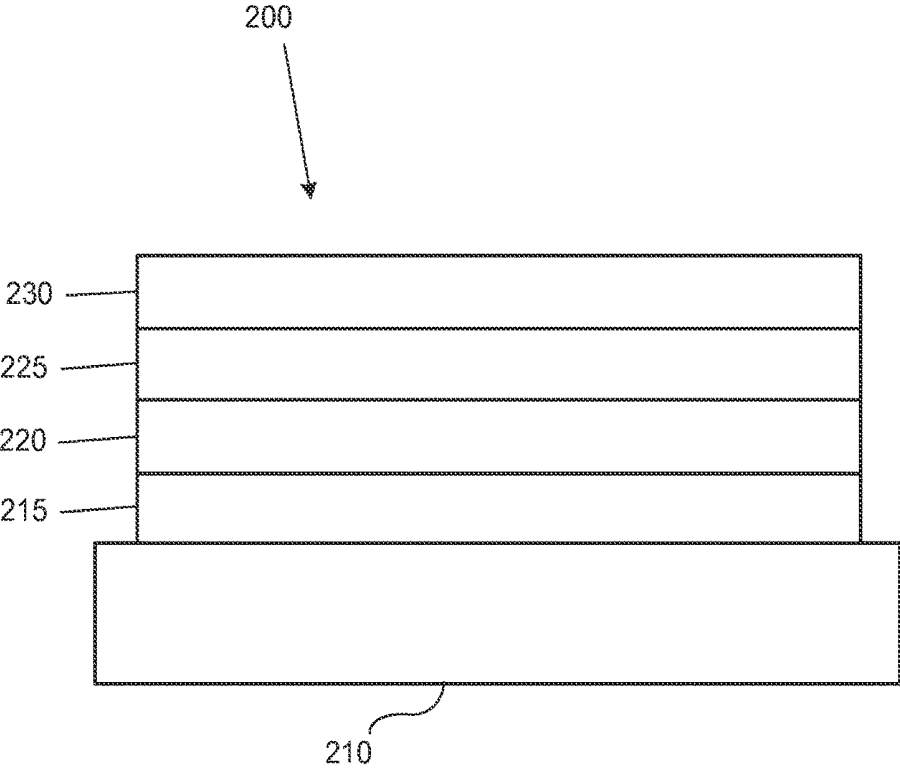


FIGURE 2

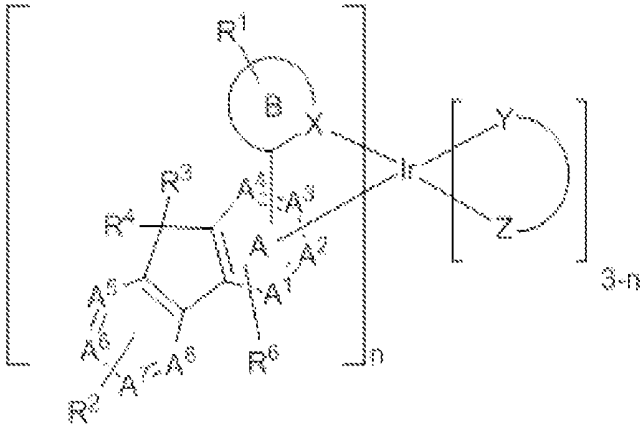


FIGURE 3

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ORGANIC ELECTROLUMINESCENT  
MATERIALS AND DEVICESCROSS-REFERENCE TO RELATED  
APPLICATIONS

This application claims priority to U.S. Provisional Patent Application Ser. No. 61/884,213, filed Sep. 30, 2013, the entire contents of which is incorporated herein by reference.

PARTIES TO A JOINT RESEARCH  
AGREEMENT

The claimed invention was made by, on behalf of, and/or in connection with one or more of the following parties to a joint university corporation research agreement: Regents of the University of Michigan, Princeton University, University of Southern California, and the Universal Display Corporation. The agreement was in effect on and before the date the claimed invention was made, and the claimed invention was made as a result of activities undertaken within the scope of the agreement.

## FIELD OF THE INVENTION

The present invention relates to compounds for use as emitters and devices, such as organic light emitting diodes, including the same.

## BACKGROUND

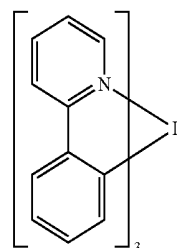
Opto-electronic devices that make use of organic materials are becoming increasingly desirable for a number of reasons. Many of the materials used to make such devices are relatively inexpensive, so organic opto-electronic devices have the potential for cost advantages over inorganic devices. In addition, the inherent properties of organic materials, such as their flexibility, may make them well suited for particular applications such as fabrication on a flexible substrate. Examples of organic opto-electronic devices include organic light emitting devices (OLEDs), organic phototransistors, organic photovoltaic cells, and organic photodetectors. For OLEDs, the organic materials may have performance advantages over conventional materials. For example, the wavelength at which an organic emissive layer emits light may generally be readily tuned with appropriate dopants.

OLEDs make use of thin organic films that emit light when voltage is applied across the device. OLEDs are becoming an increasingly interesting technology for use in applications such as flat panel displays, illumination, and backlighting. Several OLED materials and configurations are described in U.S. Pat. Nos. 5,844,363, 6,303,238, and 5,707,745, which are incorporated herein by reference in their entirety.

One application for phosphorescent emissive molecules is a full color display. Industry standards for such a display call for pixels adapted to emit particular colors, referred to as "saturated" colors. In particular, these standards call for saturated red, green, and blue pixels. Color may be measured using CIE coordinates, which are well known to the art.

One example of a green emissive molecule is tris(2-phenylpyridine) iridium, denoted Ir(ppy)<sub>3</sub>, which has the following structure:

2



In this, and later figures herein, we depict the dative bond from nitrogen to metal (here, Ir) as a straight line.

As used herein, the term "organic" includes polymeric materials as well as small molecule organic materials that may be used to fabricate organic opto-electronic devices. "Small molecule" refers to any organic material that is not a polymer, and "small molecules" may actually be quite large. Small molecules may include repeat units in some circumstances. For example, using a long chain alkyl group as a substituent does not remove a molecule from the "small molecule" class. Small molecules may also be incorporated into polymers, for example as a pendent group on a polymer backbone or as a part of the backbone. Small molecules may also serve as the core moiety of a dendrimer, which consists of a series of chemical shells built on the core moiety. The core moiety of a dendrimer may be a fluorescent or phosphorescent small molecule emitter. A dendrimer may be a "small molecule," and it is believed that all dendrimers currently used in the field of OLEDs are small molecules.

As used herein, "top" means furthest away from the substrate, while "bottom" means closest to the substrate. Where a first layer is described as "disposed over" a second layer, the first layer is disposed further away from substrate. There may be other layers between the first and second layer, unless it is specified that the first layer is "in contact with" the second layer. For example, a cathode may be described as "disposed over" an anode, even though there are various organic layers in between.

As used herein, "solution processible" means capable of being dissolved, dispersed, or transported in and/or deposited from a liquid medium, either in solution or suspension form.

A ligand may be referred to as "photoactive" when it is believed that the ligand directly contributes to the photoactive properties of an emissive material. A ligand may be referred to as "ancillary" when it is believed that the ligand does not contribute to the photoactive properties of an emissive material, although an ancillary ligand may alter the properties of a photoactive ligand.

As used herein, and as would be generally understood by one skilled in the art, a first "Highest Occupied Molecular Orbital" (HOMO) or "Lowest Unoccupied Molecular Orbital" (LUMO) energy level is "greater than" or "higher than" a second HOMO or LUMO energy level if the first energy level is closer to the vacuum energy level. Since ionization potentials (IP) are measured as a negative energy relative to a vacuum level, a higher HOMO energy level corresponds to an IP having a smaller absolute value (an IP that is less negative). Similarly, a higher LUMO energy level corresponds to an electron affinity (EA) having a smaller absolute value (an EA that is less negative). On a conventional energy level diagram, with the vacuum level at the top, the LUMO energy level of a material is higher than the HOMO energy level of the same material. A "higher"

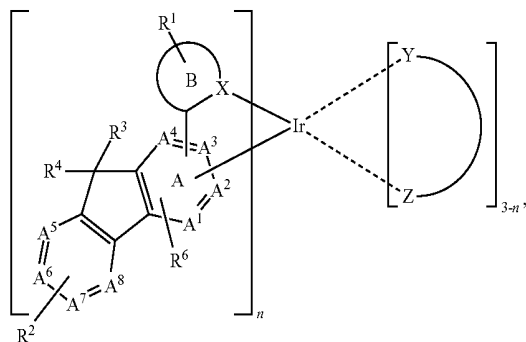
HOMO or LUMO energy level appears closer to the top of such a diagram than a “lower” HOMO or LUMO energy level.

As used herein, and as would be generally understood by one skilled in the art, a first work function is “greater than” or “higher than” a second work function if the first work function has a higher absolute value. Because work functions are generally measured as negative numbers relative to vacuum level, this means that a “higher” work function is more negative. On a conventional energy level diagram, with the vacuum level at the top, a “higher” work function is illustrated as further away from the vacuum level in the downward direction. Thus, the definitions of HOMO and LUMO energy levels follow a different convention than work functions.

More details on OLEDs, and the definitions described above, can be found in U.S. Pat. No. 7,279,704, which is incorporated herein by reference in its entirety.

### SUMMARY OF THE INVENTION

According to an embodiment, a compound having the formula  $\text{Ir}(\text{L}_A)_n(\text{L}_B)_{3-n}$ , having the structure of Formula I:



Formula I, is provided.

In the compound of Formula I:

$A^1, A^2, A^3, A^4, A^5, A^6, A^7,$  and  $A^8$  comprise carbon or nitrogen;

at least one of  $A^1, A^2, A^3, A^4, A^5, A^6, A^7,$  and  $A^8$  is nitrogen;

ring B is bonded to ring A through a CC bond;

the iridium is bonded to ring A through a Ir—C bond;

$R^1, R^2,$  and  $R^6$  independently represent from mono-substitution to the possible maximum number of substitution, or no substitution;

any adjacent substitutions in  $R^1, R^2, R^3,$  and  $R^4$  are optionally linked together to form a ring;

X is a neutral donor;



is a monoanionic bidentate ligand;

$R^1, R^2, R^3, R^4,$  and  $R^6$  are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl,

heteroaryl, acyl, carbonyl, carboxylic acids, ester, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and n is an integer from 1 to 3.

According to another embodiment, a first device comprising a first organic light emitting device is also provided. The first organic light emitting device can include an anode, a cathode, and an organic layer, disposed between the anode and the cathode. The organic layer can include a compound of formula I. The first device can be a consumer product, an organic light-emitting device, and/or a lighting panel.

Formulations containing a compound of formula I are also provided.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an organic light emitting device.

FIG. 2 shows an inverted organic light emitting device that does not have a separate electron transport layer.

FIG. 3 shows Formula I as disclosed herein.

### DETAILED DESCRIPTION

Generally, an OLED comprises at least one organic layer disposed between and electrically connected to an anode and a cathode. When a current is applied, the anode injects holes and the cathode injects electrons into the organic layer(s). The injected holes and electrons each migrate toward the oppositely charged electrode. When an electron and hole localize on the same molecule, an “exciton,” which is a localized electron-hole pair having an excited energy state, is formed. Light is emitted when the exciton relaxes via a photoemissive mechanism. In some cases, the exciton may be localized on an excimer or an exciplex. Non-radiative mechanisms, such as thermal relaxation, may also occur, but are generally considered undesirable.

The initial OLEDs used emissive molecules that emitted light from their singlet states (“fluorescence”) as disclosed, for example, in U.S. Pat. No. 4,769,292, which is incorporated by reference in its entirety. Fluorescent emission generally occurs in a time frame of less than 10 nanoseconds.

More recently, OLEDs having emissive materials that emit light from triplet states (“phosphorescence”) have been demonstrated. Baldo et al., “Highly Efficient Phosphorescent Emission from Organic Electroluminescent Devices,” *Nature*, vol. 395, 151-154, 1998; (“Baldo-I”) and Baldo et al., “Very high-efficiency green organic light-emitting devices based on electrophosphorescence,” *Appl. Phys. Lett.*, vol. 75, No. 3, 4-6 (1999) (“Baldo-II”), which are incorporated by reference in their entireties. Phosphorescence is described in more detail in U.S. Pat. No. 7,279,704 at cols. 5-6, which are incorporated by reference.

FIG. 1 shows an organic light emitting device 100. The figures are not necessarily drawn to scale. Device 100 may include a substrate 110, an anode 115, a hole injection layer 120, a hole transport layer 125, an electron blocking layer 130, an emissive layer 135, a hole blocking layer 140, an electron transport layer 145, an electron injection layer 150, a protective layer 155, a cathode 160, and a barrier layer 170. Cathode 160 is a compound cathode having a first conductive layer 162 and a second conductive layer 164. Device 100 may be fabricated by depositing the layers described, in order. The properties and functions of these various layers, as well as example materials, are described in more detail in U.S. Pat. No. 7,279,704 at cols. 6-10, which are incorporated by reference.

More examples for each of these layers are available. For example, a flexible and transparent substrate-anode combination is disclosed in U.S. Pat. No. 5,844,363, which is incorporated by reference in its entirety. An example of a p-doped hole transport layer is m-MTDATA doped with F<sub>4</sub>-TCNQ at a molar ratio of 50:1, as disclosed in U.S. Patent Application Publication No. 2003/0230980, which is incorporated by reference in its entirety. Examples of emissive and host materials are disclosed in U.S. Pat. No. 6,303,238 to Thompson et al., which is incorporated by reference in its entirety. An example of an n-doped electron transport layer is BPhen doped with Li at a molar ratio of 1:1, as disclosed in U.S. Patent Application Publication No. 2003/0230980, which is incorporated by reference in its entirety. U.S. Pat. Nos. 5,703,436 and 5,707,745, which are incorporated by reference in their entireties, disclose examples of cathodes including compound cathodes having a thin layer of metal such as Mg:Ag with an overlying transparent, electrically-conductive, sputter-deposited ITO layer. The theory and use of blocking layers is described in more detail in U.S. Pat. No. 6,097,147 and U.S. Patent Application Publication No. 2003/0230980, which are incorporated by reference in their entireties. Examples of injection layers are provided in U.S. Patent Application Publication No. 2004/0174116, which is incorporated by reference in its entirety. A description of protective layers may be found in U.S. Patent Application Publication No. 2004/0174116, which is incorporated by reference in its entirety.

FIG. 2 shows an inverted OLED 200. The device includes a substrate 210, a cathode 215, an emissive layer 220, a hole transport layer 225, and an anode 230. Device 200 may be fabricated by depositing the layers described, in order. Because the most common OLED configuration has a cathode disposed over the anode, and device 200 has cathode 215 disposed under anode 230, device 200 may be referred to as an "inverted" OLED. Materials similar to those described with respect to device 100 may be used in the corresponding layers of device 200. FIG. 2 provides one example of how some layers may be omitted from the structure of device 100.

The simple layered structure illustrated in FIGS. 1 and 2 is provided by way of non-limiting example, and it is understood that embodiments of the invention may be used in connection with a wide variety of other structures. The specific materials and structures described are exemplary in nature, and other materials and structures may be used. Functional OLEDs may be achieved by combining the various layers described in different ways, or layers may be omitted entirely, based on design, performance, and cost factors. Other layers not specifically described may also be included. Materials other than those specifically described may be used. Although many of the examples provided herein describe various layers as comprising a single material, it is understood that combinations of materials, such as a mixture of host and dopant, or more generally a mixture, may be used. Also, the layers may have various sublayers. The names given to the various layers herein are not intended to be strictly limiting. For example, in device 200, hole transport layer 225 transports holes and injects holes into emissive layer 220, and may be described as a hole transport layer or a hole injection layer. In one embodiment, an OLED may be described as having an "organic layer" disposed between a cathode and an anode. This organic layer may comprise a single layer, or may further comprise multiple layers of different organic materials as described, for example, with respect to FIGS. 1 and 2.

Structures and materials not specifically described may also be used, such as OLEDs comprised of polymeric materials (PLEDs) such as disclosed in U.S. Pat. No. 5,247,190 to Friend et al., which is incorporated by reference in its entirety. By way of further example, OLEDs having a single organic layer may be used. OLEDs may be stacked, for example as described in U.S. Pat. No. 5,707,745 to Forrest et al, which is incorporated by reference in its entirety. The OLED structure may deviate from the simple layered structure illustrated in FIGS. 1 and 2. For example, the substrate may include an angled reflective surface to improve out-coupling, such as a mesa structure as described in U.S. Pat. No. 6,091,195 to Forrest et al., and/or a pit structure as described in U.S. Pat. No. 5,834,893 to Bulovic et al., which are incorporated by reference in their entireties.

Unless otherwise specified, any of the layers of the various embodiments may be deposited by any suitable method. For the organic layers, preferred methods include thermal evaporation, ink-jet, such as described in U.S. Pat. Nos. 6,013,982 and 6,087,196, which are incorporated by reference in their entireties, organic vapor phase deposition (OVPD), such as described in U.S. Pat. No. 6,337,102 to Forrest et al., which is incorporated by reference in its entirety, and deposition by organic vapor jet printing (OVJP), such as described in U.S. Pat. No. 7,431,968, which is incorporated by reference in its entirety. Other suitable deposition methods include spin coating and other solution based processes. Solution based processes are preferably carried out in nitrogen or an inert atmosphere. For the other layers, preferred methods include thermal evaporation. Preferred patterning methods include deposition through a mask, cold welding such as described in U.S. Pat. Nos. 6,294,398 and 6,468,819, which are incorporated by reference in their entireties, and patterning associated with some of the deposition methods such as ink-jet and OVJD. Other methods may also be used. The materials to be deposited may be modified to make them compatible with a particular deposition method. For example, substituents such as alkyl and aryl groups, branched or unbranched, and preferably containing at least 3 carbons, may be used in small molecules to enhance their ability to undergo solution processing. Substituents having 20 carbons or more may be used, and 3-20 carbons is a preferred range. Materials with asymmetric structures may have better solution processibility than those having symmetric structures, because asymmetric materials may have a lower tendency to recrystallize. Dendrimer substituents may be used to enhance the ability of small molecules to undergo solution processing.

Devices fabricated in accordance with embodiments of the present invention may further optionally comprise a barrier layer. One purpose of the barrier layer is to protect the electrodes and organic layers from damaging exposure to harmful species in the environment including moisture, vapor and/or gases, etc. The barrier layer may be deposited over, under or next to a substrate, an electrode, or over any other parts of a device including an edge. The barrier layer may comprise a single layer, or multiple layers. The barrier layer may be formed by various known chemical vapor deposition techniques and may include compositions having a single phase as well as compositions having multiple phases. Any suitable material or combination of materials may be used for the barrier layer. The barrier layer may incorporate an inorganic or an organic compound or both. The preferred barrier layer comprises a mixture of a polymeric material and a non-polymeric material as described in U.S. Pat. No. 7,968,146, PCT Pat. Application Nos. PCT/US2007/023098 and PCT/US2009/042829, which are

herein incorporated by reference in their entireties. To be considered a “mixture”, the aforesaid polymeric and non-polymeric materials comprising the barrier layer should be deposited under the same reaction conditions and/or at the same time. The weight ratio of polymeric to non-polymeric material may be in the range of 95:5 to 5:95. The polymeric material and the non-polymeric material may be created from the same precursor material. In one example, the mixture of a polymeric material and a non-polymeric material consists essentially of polymeric silicon and inorganic silicon.

Devices fabricated in accordance with embodiments of the invention may be incorporated into a wide variety of consumer products, including flat panel displays, computer monitors, medical monitors, televisions, billboards, lights for interior or exterior illumination and/or signaling, heads up displays, fully transparent displays, flexible displays, laser printers, telephones, cell phones, personal digital assistants (PDAs), laptop computers, digital cameras, camcorders, viewfinders, micro-displays, 3-D displays, vehicles, a large area wall, theater or stadium screen, or a sign. Various control mechanisms may be used to control devices fabricated in accordance with the present invention, including passive matrix and active matrix. Many of the devices are intended for use in a temperature range comfortable to humans, such as 18 degrees C. to 30 degrees C., and more preferably at room temperature (20-25 degrees C.), but could be used outside this temperature range, for example, from -40 degree C. to +80 degree C.

The materials and structures described herein may have applications in devices other than OLEDs. For example, other optoelectronic devices such as organic solar cells and organic photodetectors may employ the materials and structures. More generally, organic devices, such as organic transistors, may employ the materials and structures.

The term “halo” or “halogen” as used herein includes fluorine, chlorine, bromine, and iodine.

The term “alkyl” as used herein contemplates both straight and branched chain alkyl radicals. Preferred alkyl groups are those containing from one to fifteen carbon atoms and includes methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tert-butyl, and the like. Additionally, the alkyl group may be optionally substituted.

The term “cycloalkyl” as used herein contemplates cyclic alkyl radicals. Preferred cycloalkyl groups are those containing 3 to 7 carbon atoms and includes cyclopropyl, cyclopentyl, cyclohexyl, and the like. Additionally, the cycloalkyl group may be optionally substituted.

The term “alkenyl” as used herein contemplates both straight and branched chain alkene radicals. Preferred alkenyl groups are those containing two to fifteen carbon atoms. Additionally, the alkenyl group may be optionally substituted.

The term “alkynyl” as used herein contemplates both straight and branched chain alkyne radicals. Preferred alkynyl groups are those containing two to fifteen carbon atoms. Additionally, the alkynyl group may be optionally substituted.

The terms “aralkyl” or “arylalkyl” as used herein are used interchangeably and contemplate an alkyl group that has as a substituent an aromatic group. Additionally, the aralkyl group may be optionally substituted.

The term “heterocyclic group” as used herein contemplates aromatic and non-aromatic cyclic radicals. Heteroaromatic cyclic radicals also means heteroaryl. Preferred

hetero-non-aromatic cyclic groups are those containing 3 or 7 ring atoms which includes at least one hetero atom, and includes cyclic amines such as morpholino, piperidino, pyrrolidino, and the like, and cyclic ethers, such as tetrahydrofuran, tetrahydropyran, and the like. Additionally, the heterocyclic group may be optionally substituted.

The term “aryl” or “aromatic group” as used herein contemplates single-ring groups and polycyclic ring systems. The polycyclic rings may have two or more rings in which two carbons are common to two adjoining rings (the rings are “fused”) wherein at least one of the rings is aromatic, e.g., the other rings can be cycloalkyls, cycloalkenyls, aryl, heterocycles, and/or heteroaryls. Additionally, the aryl group may be optionally substituted.

The term “heteroaryl” as used herein contemplates single-ring hetero-aromatic groups that may include from one to three heteroatoms, for example, pyrrole, furan, thiophene, imidazole, oxazole, thiazole, triazole, pyrazole, pyridine, pyrazine and pyrimidine, and the like. The term heteroaryl also includes polycyclic hetero-aromatic systems having two or more rings in which two atoms are common to two adjoining rings (the rings are “fused”) wherein at least one of the rings is a heteroaryl, e.g., the other rings can be cycloalkyls, cycloalkenyls, aryl, heterocycles, and/or heteroaryls. Additionally, the heteroaryl group may be optionally substituted.

The alkyl, cycloalkyl, alkenyl, alkynyl, aralkyl, heterocyclic group, aryl, and heteroaryl may be optionally substituted with one or more substituents selected from the group consisting of hydrogen, deuterium, halogen, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, cyclic amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acid, ether, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

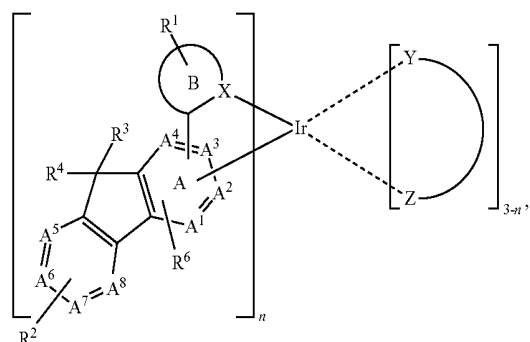
As used herein, “substituted” indicates that a substituent other than H is bonded to the relevant position, such as carbon. Thus, for example, where R<sup>1</sup> is mono-substituted, then one R<sup>1</sup> must be other than H. Similarly, where R<sup>1</sup> is di-substituted, then two of R<sup>1</sup> must be other than H. Similarly, where R<sup>1</sup> is unsubstituted, R<sup>1</sup> is hydrogen for all available positions.

The “aza” designation in the fragments described herein, i.e. aza-dibenzofuran, aza-dibenzothiophene, etc. means that one or more of the C—H groups in the respective fragment can be replaced by a nitrogen atom, for example, and without any limitation, azatriphenylene encompasses both dibenzo[f,h]quinoxaline and dibenzo[f,h]quinoline. One of ordinary skill in the art can readily envision other nitrogen analogs of the aza-derivatives described above, and all such analogs are intended to be encompassed by the terms as set forth herein.

It is to be understood that when a molecular fragment is described as being a substituent or otherwise attached to another moiety, its name may be written as if it were a fragment (e.g. phenyl, phenylene, naphthyl, dibenzofuryl) or as if it were the whole molecule (e.g. benzene, naphthalene, dibenzofuran). As used herein, these different ways of designating a substituent or attached fragment are considered to be equivalent.

According to one embodiment, a compound having the formula Ir(L<sub>A</sub>)<sub>n</sub>(L<sub>B</sub>)<sub>3-n</sub>, having the structure of Formula I:

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Formula I, is disclosed.

In the compound of Formula I:

$A^1, A^2, A^3, A^4, A^5, A^6, A^7,$  and  $A^8$  comprise carbon or nitrogen;

at least one of  $A^1, A^2, A^3, A^4, A^5, A^6, A^7,$  and  $A^8$  is nitrogen;

ring B is bonded to ring A through a C—C bond;

the iridium is bonded to ring A through a Ir—C bond;

$R^1, R^2,$  and  $R^6$  independently represent from mono-substitution to the possible maximum number of substitution, or no substitution;

any adjacent substitutions in  $R^1, R^2, R^3,$  and  $R^4$  are optionally linked together to form a ring;

X is a neutral donor;



is a monoanionic bidentate ligand;

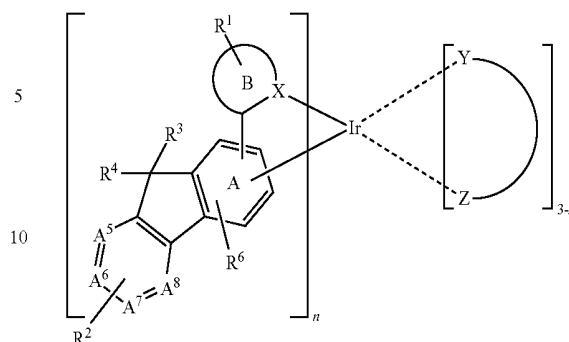
$R^1, R^2, R^3, R^4,$  and  $R^6$  are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrite, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and

n is an integer from 1 to 3.

In some embodiments, ring B is selected from the group consisting of pyridine, imidazole, pyrazole, oxazole, pyrazine, pyrimidine, pyridazine. In some embodiments, X is an atom selected from the group consisting of a carbene carbon, an anionic carbon, and nitrogen. In some embodiments, no adjacent  $R^6$  substituents are bonded to form a fused ring. In some embodiments, n is 1.

In some embodiment, the compound has the structure of Formula II:

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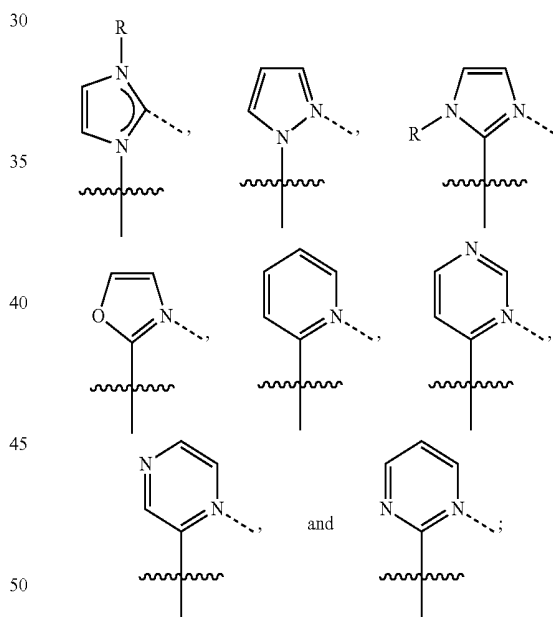


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In some embodiments, X is selected from the group consisting of N, P, and C. In some embodiments, X is selected from the group consisting of a carbene carbon, an anionic carbon, and nitrogen.

In some embodiments, only one of  $A^1$  to  $A^8$  is nitrogen. In some embodiments,  $A^1$  to  $A^4$  are carbon, and only one of  $A^5$  to  $A^8$  is nitrogen. In some embodiments,  $A^1$  to  $A^4$  are carbon, and only two of  $A^5$  to  $A^8$  is nitrogen. In some embodiments,  $A^1$  to  $A^4$  are carbon, and exactly three of  $A^5$  to  $A^8$  is nitrogen.

In some embodiments, ring B is selected from the group consisting of:



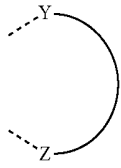
wherein the wave line indicates the bond to ring A, and the dashed line represents the bond to Ir; and wherein R is selected from the group consisting of hydrogen, deuterium, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, and combinations thereof.

In some embodiments,  $R^3$  and  $R^4$  are alkyl. In some embodiments,  $R^3,$  and  $R^4$  are linked together to form a ring.

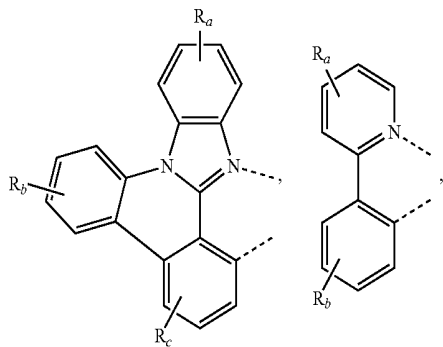
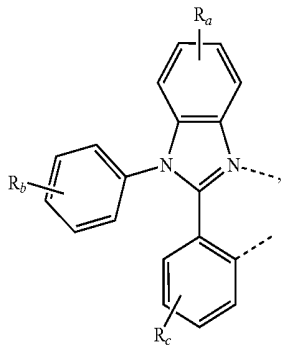
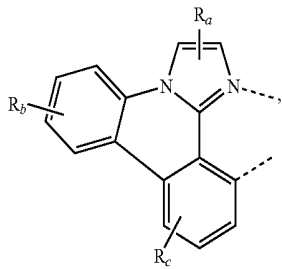
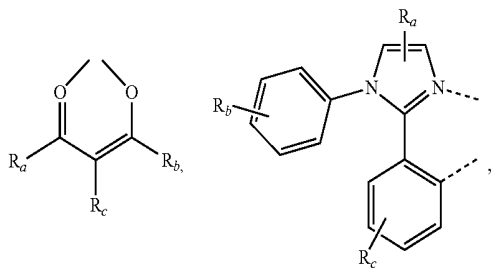
In some embodiments,  $R^2$  is selected from the group consisting of hydrogen, deuterium, cycloalkyl, and combinations thereof. In some embodiments, at least one  $R^1$  is selected from the group consisting of alkyl, cycloalkyl, and combinations thereof.

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In some embodiments,

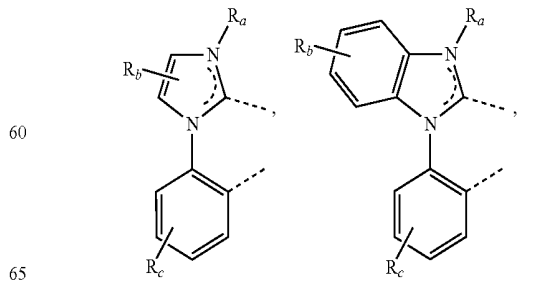
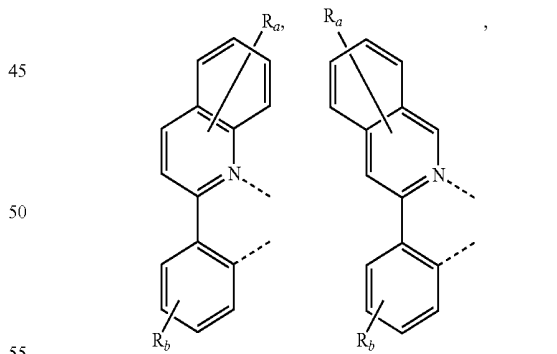
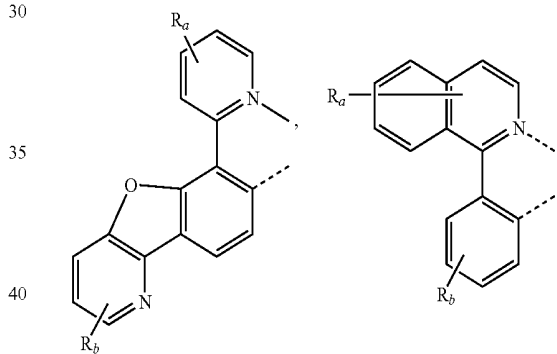
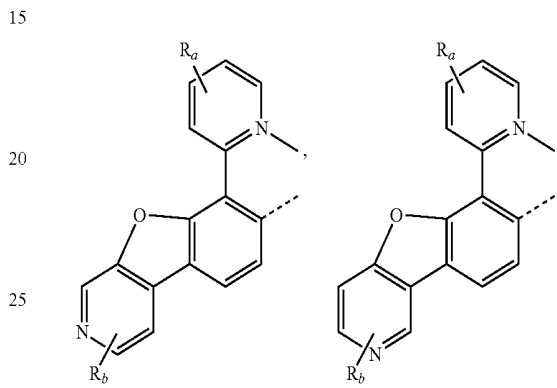
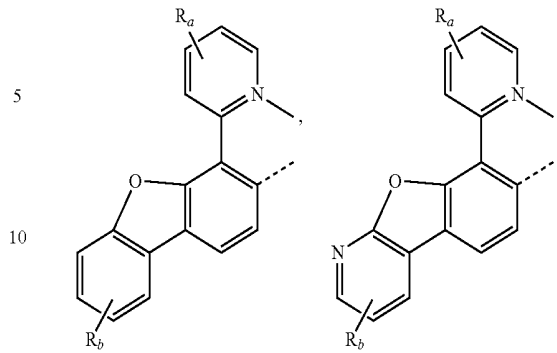


is selected from the group consisting of:



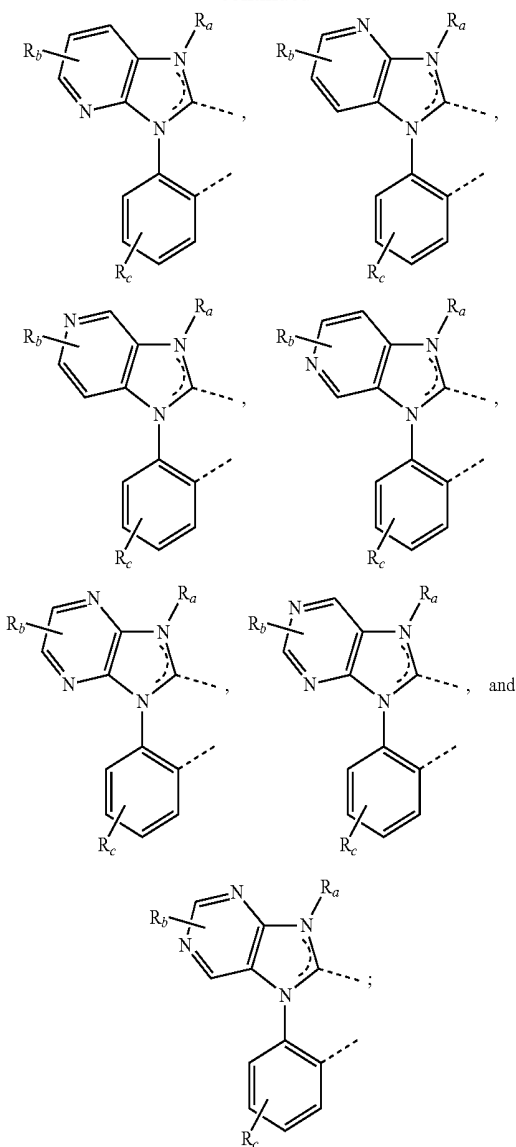
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wherein  $R_a$ ,  $R_b$ , and  $R_c$ , may represent mono, di, tri, or tetra substitution, or no substitution;

wherein  $R_a$ ,  $R_b$ , and  $R_c$  are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and

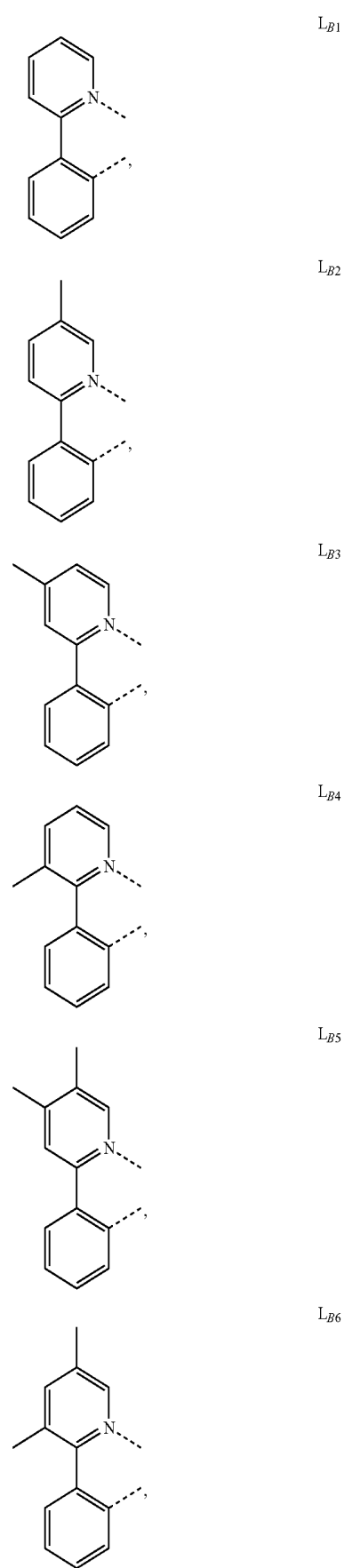
wherein two adjacent substituents of  $R_a$ ,  $R_b$ , and  $R_c$  are optionally joined to form a fused ring or form a multidentate ligand.

In some embodiments,



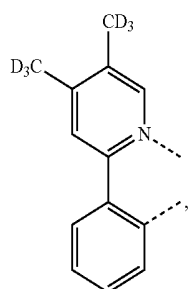
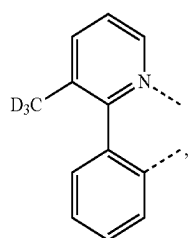
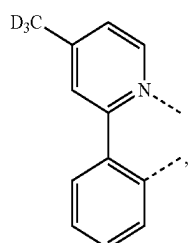
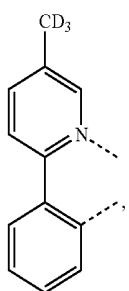
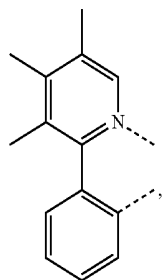
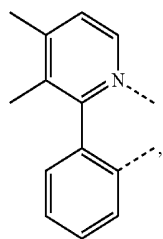
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is selected from the group consisting of:



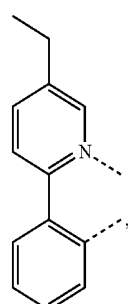
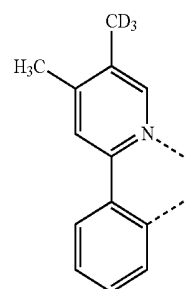
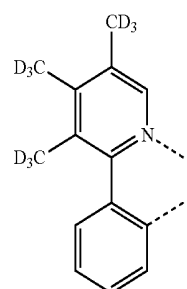
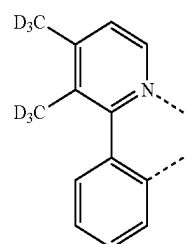
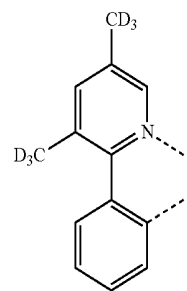
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**16**

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L<sub>B7</sub>

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L<sub>B8</sub>

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L<sub>B9</sub>

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L<sub>B10</sub>

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L<sub>B11</sub>

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L<sub>B12</sub>

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L<sub>B13</sub>

L<sub>B14</sub>

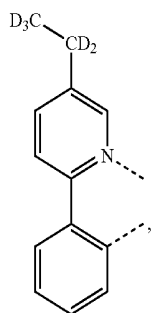
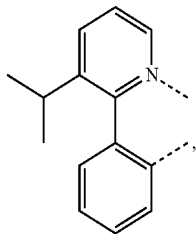
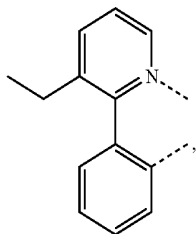
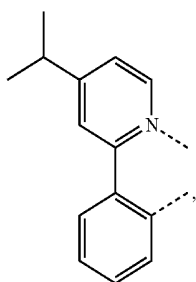
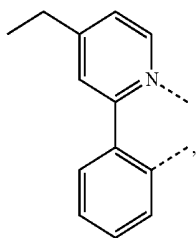
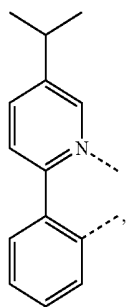
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L<sub>B16</sub>

L<sub>B17</sub>

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L<sub>B18</sub>

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L<sub>B19</sub>

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L<sub>B20</sub>

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L<sub>B21</sub>

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L<sub>B22</sub>

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L<sub>B23</sub>

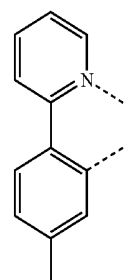
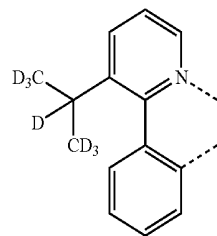
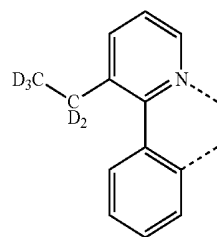
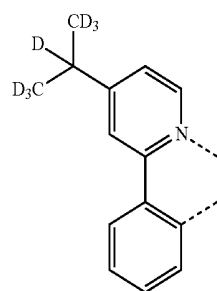
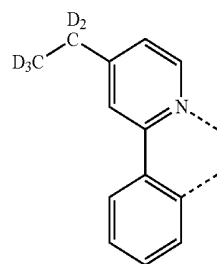
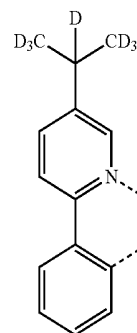
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L<sub>B24</sub>

L<sub>B25</sub>

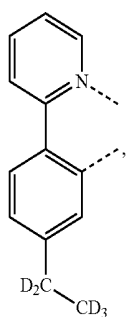
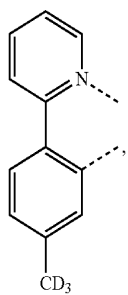
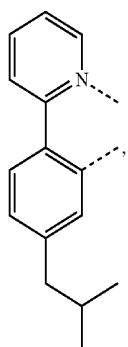
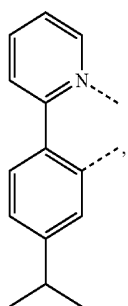
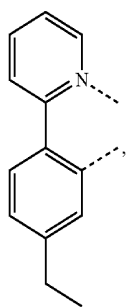
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L<sub>B27</sub>

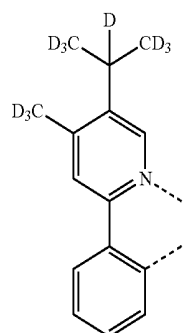
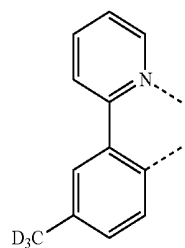
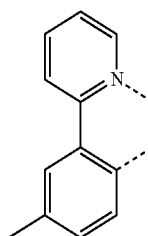
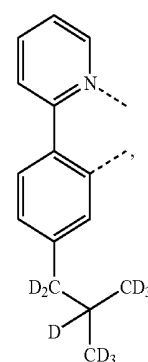
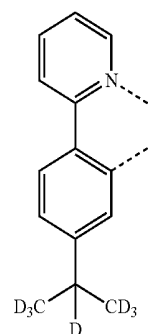
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L<sub>B30</sub>

**19**  
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**20**  
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L<sub>B31</sub>

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L<sub>B32</sub>

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L<sub>B33</sub>

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L<sub>B34</sub>

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L<sub>B35</sub>

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L<sub>B36</sub>

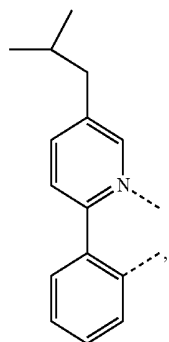
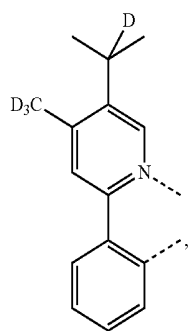
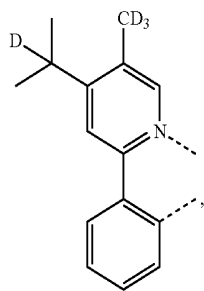
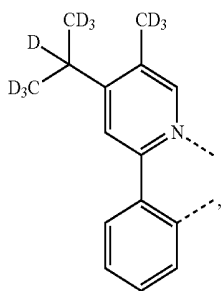
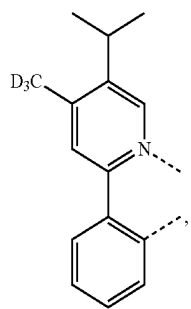
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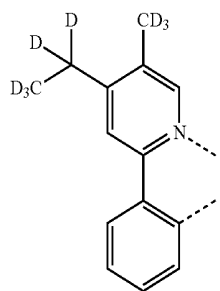
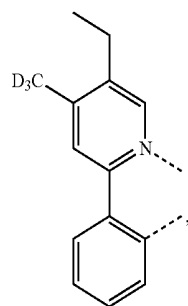
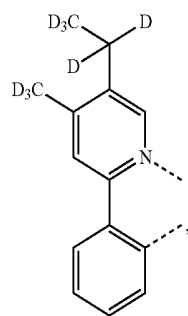
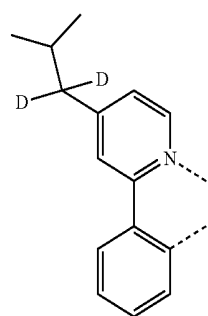
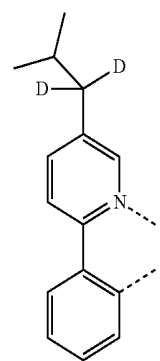
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L<sub>B40</sub>

**21**  
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**22**  
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L<sub>B41</sub>

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L<sub>B42</sub>

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L<sub>B43</sub>

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L<sub>B44</sub>

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L<sub>B47</sub>

L<sub>B48</sub>

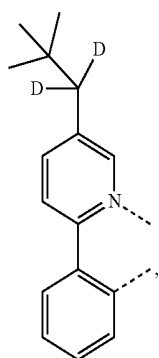
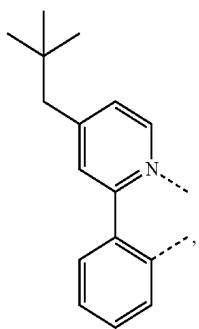
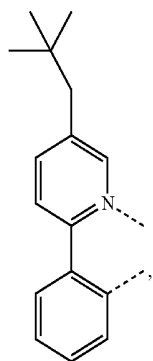
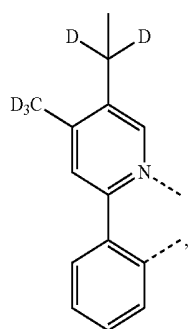
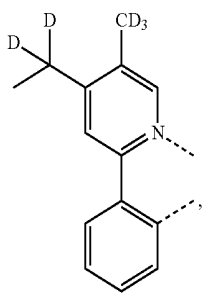
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L<sub>B51</sub>

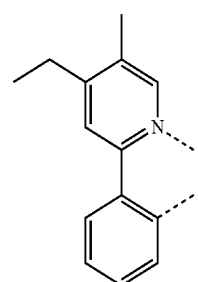
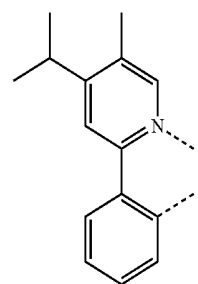
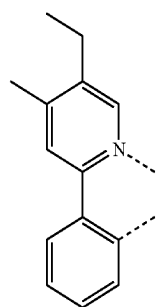
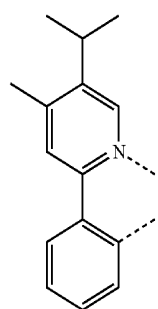
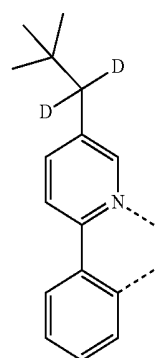
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**24**

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L<sub>B52</sub>

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L<sub>B53</sub>

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L<sub>B54</sub>

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L<sub>B56</sub>

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L<sub>B57</sub>

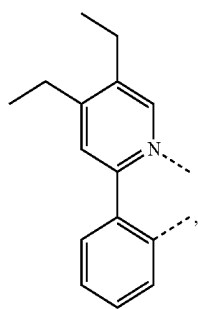
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L<sub>B59</sub>

L<sub>B60</sub>

L<sub>B61</sub>

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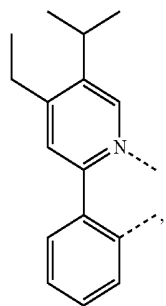
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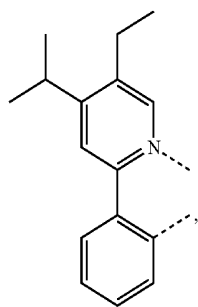
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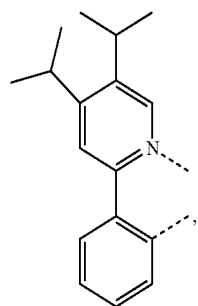
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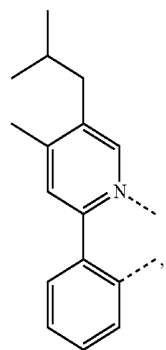
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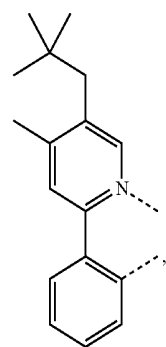


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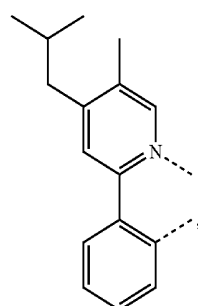
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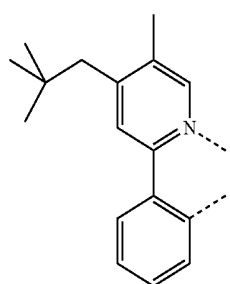
**26**  
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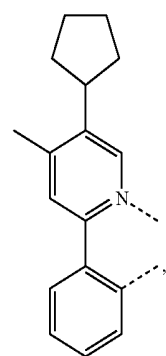
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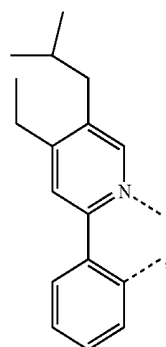
L<sub>B68</sub>



L<sub>B69</sub>



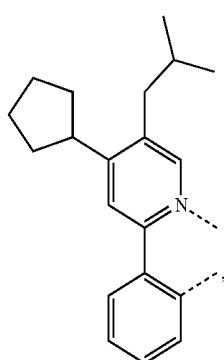
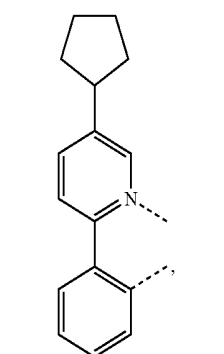
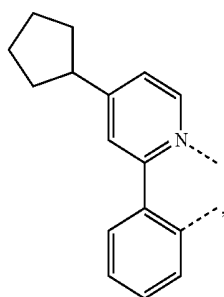
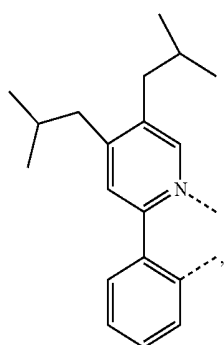
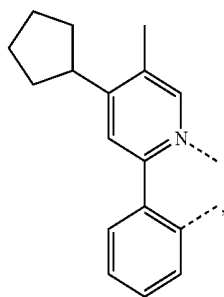
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L<sub>B71</sub>

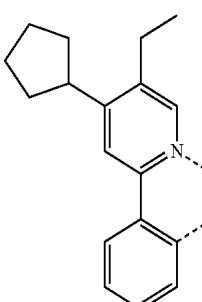
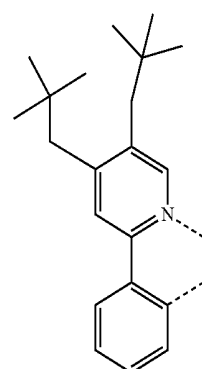
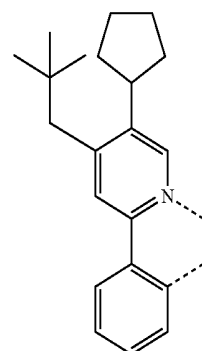
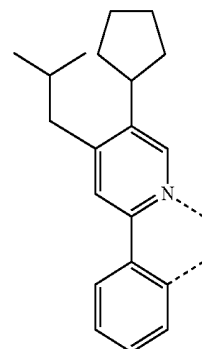
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L<sub>B72</sub>

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L<sub>B73</sub>

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L<sub>B74</sub>

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L<sub>B76</sub>

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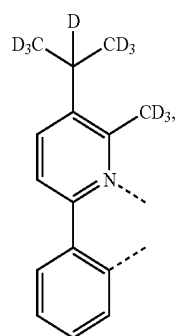
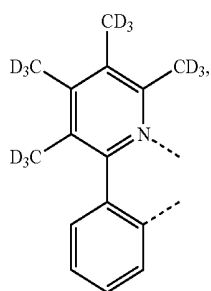
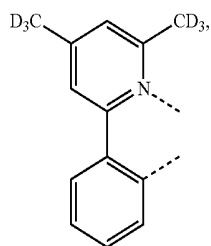
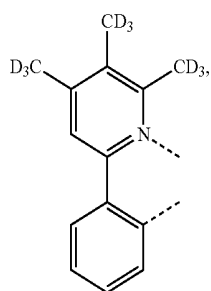
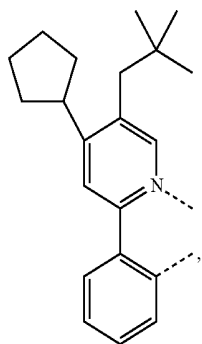
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L<sub>B78</sub>

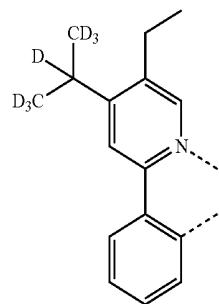
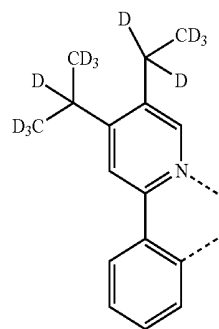
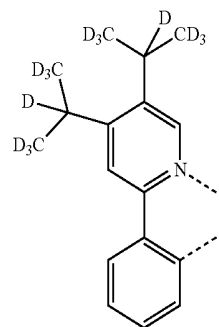
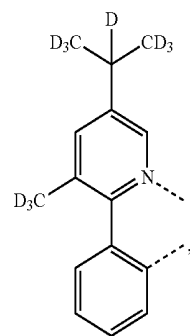
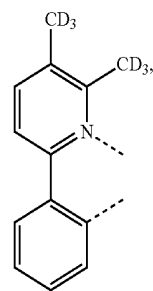
L<sub>B79</sub>

L<sub>B80</sub>

**29**  
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**30**  
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L<sub>B81</sub>

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L<sub>B82</sub>

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L<sub>B83</sub>

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L<sub>B84</sub>

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L<sub>B86</sub>

L<sub>B87</sub>

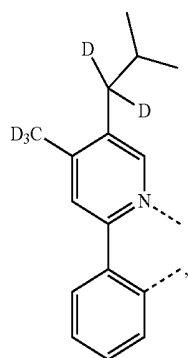
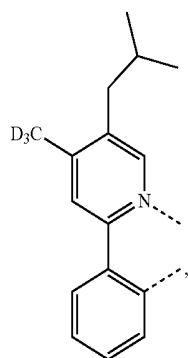
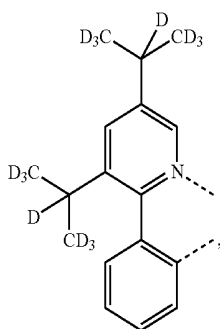
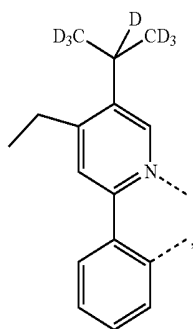
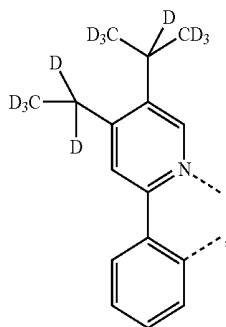
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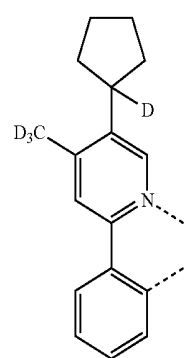
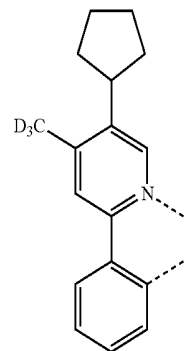
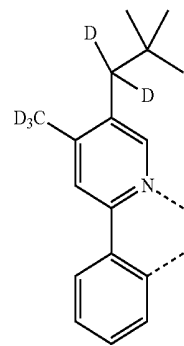
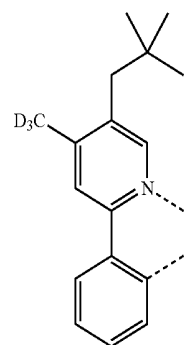
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**32**

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L<sub>B91</sub>

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L<sub>B92</sub>

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L<sub>B93</sub>

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L<sub>B95</sub>

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L<sub>B96</sub>

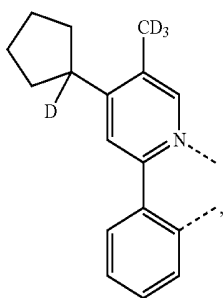
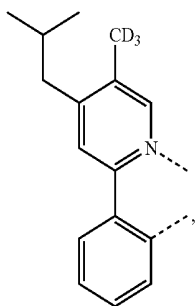
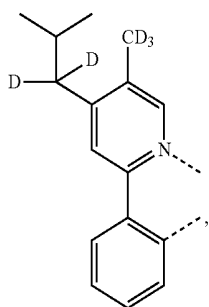
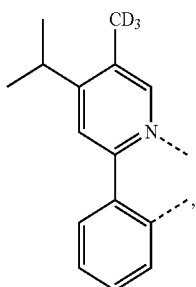
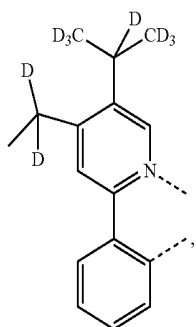
L<sub>B97</sub>

L<sub>B98</sub>

L<sub>B99</sub>

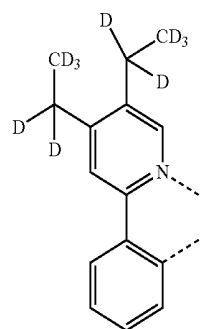
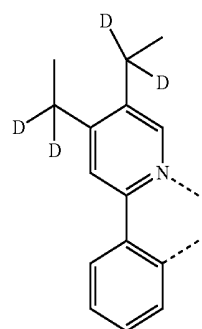
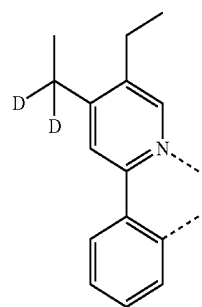
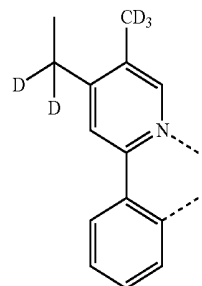
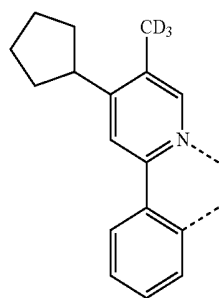
**33**

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**34**

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L<sub>B100</sub>

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L<sub>B101</sub>

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L<sub>B102</sub>

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L<sub>B103</sub>

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L<sub>B104</sub>

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L<sub>B105</sub>

L<sub>B106</sub>

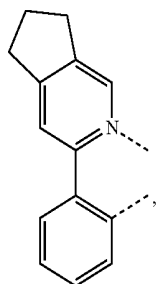
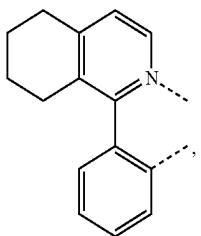
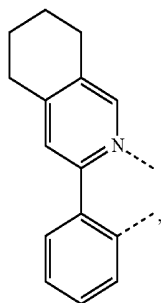
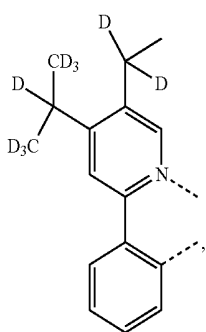
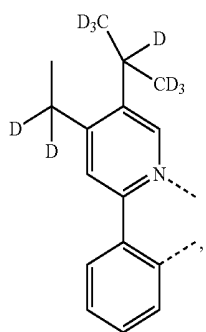
L<sub>B107</sub>

L<sub>B108</sub>

L<sub>B109</sub>

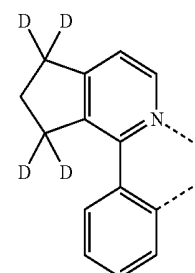
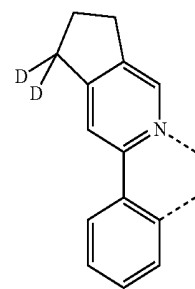
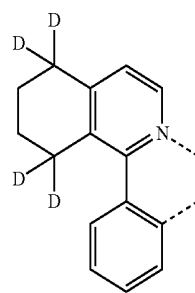
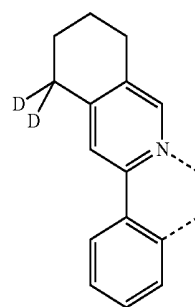
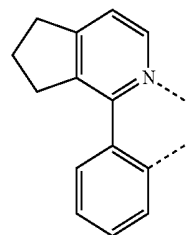
**35**

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**36**

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L<sub>B110</sub>

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L<sub>B111</sub>

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L<sub>B112</sub>

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L<sub>B113</sub>

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L<sub>B114</sub>

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L<sub>B115</sub>

L<sub>B116</sub>

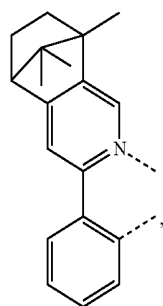
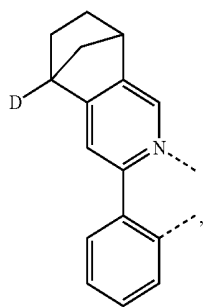
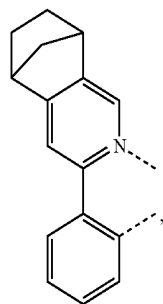
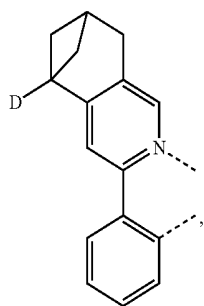
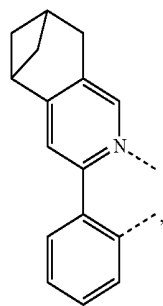
L<sub>B117</sub>

L<sub>B118</sub>

L<sub>B119</sub>

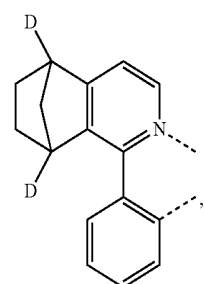
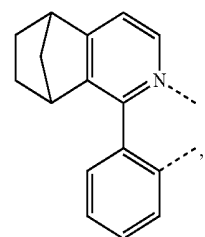
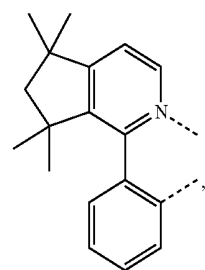
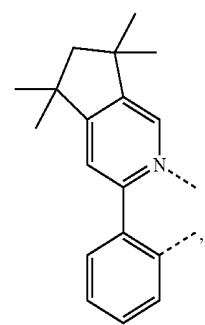
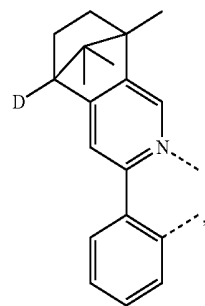
37

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L<sub>B120</sub>

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L<sub>B121</sub>

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L<sub>B122</sub>

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L<sub>B123</sub>

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L<sub>B124</sub>

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L<sub>B125</sub>

L<sub>B126</sub>

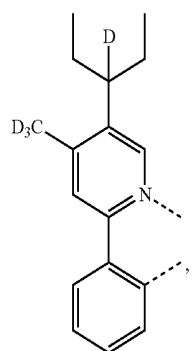
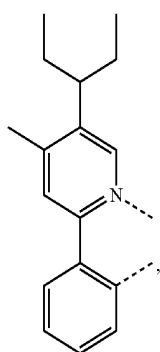
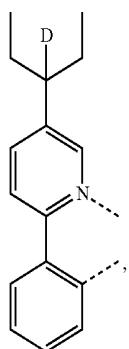
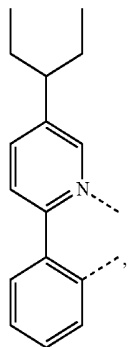
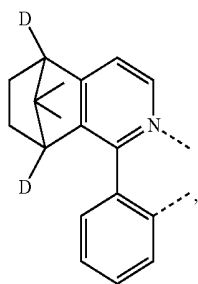
L<sub>B127</sub>

L<sub>B128</sub>

L<sub>B129</sub>

**39**

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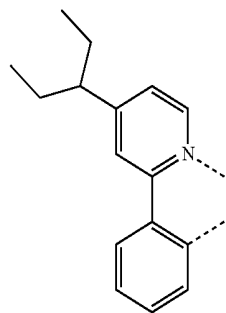


**40**

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L<sub>B130</sub>

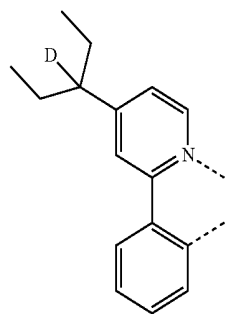
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L<sub>B135</sub>

L<sub>B132</sub>

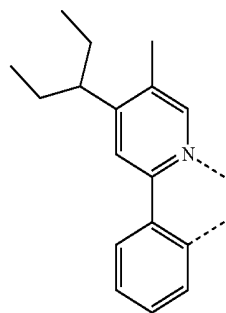
15



L<sub>B136</sub>

L<sub>B132</sub>

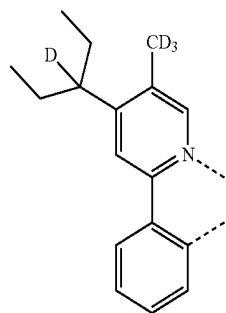
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L<sub>B137</sub>

L<sub>B133</sub>

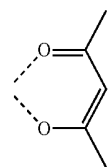
35



L<sub>B138</sub>

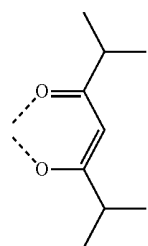
L<sub>B134</sub>

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L<sub>B139</sub>

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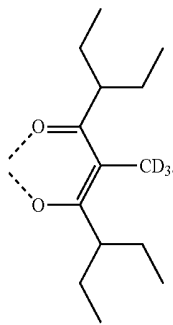
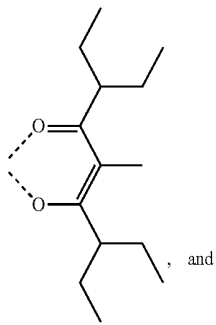
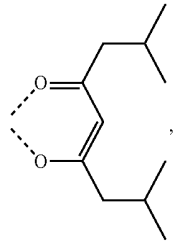
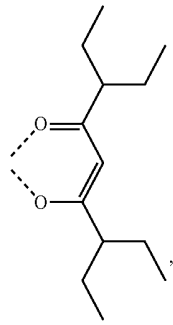
L<sub>B140</sub>

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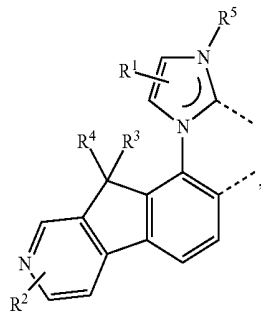
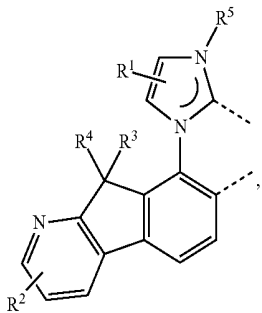
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41

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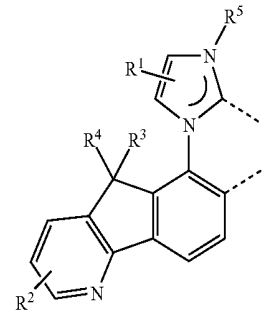
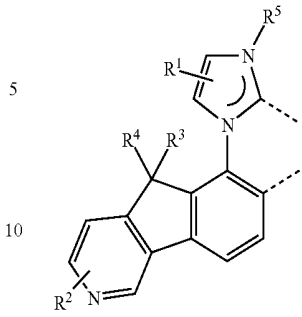
In some embodiments,  $L_A$  is selected from the group consisting of:



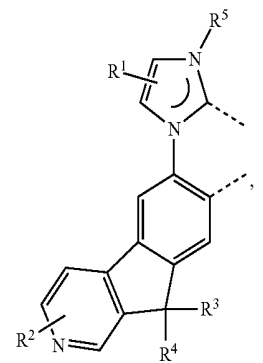
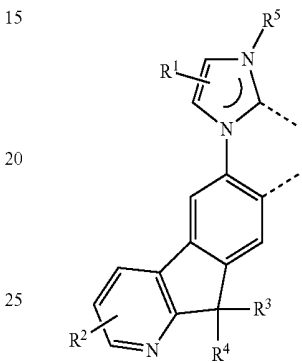
42

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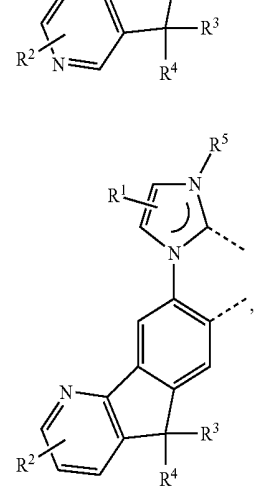
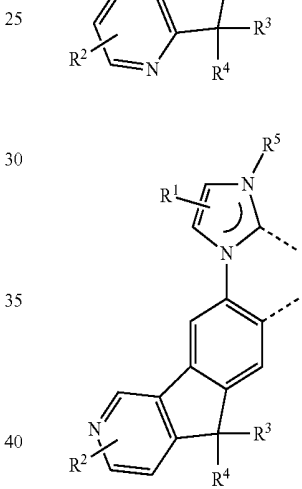
$L_{B141}$



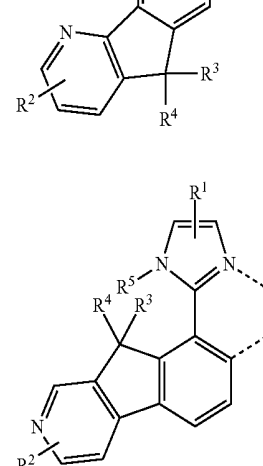
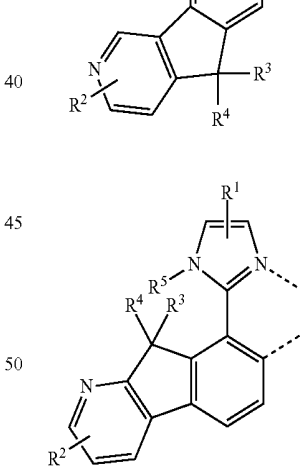
$L_{B142}$



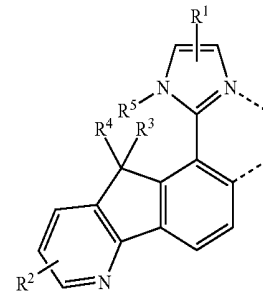
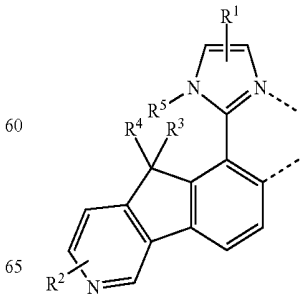
$L_{B143}$



$L_{B144}$

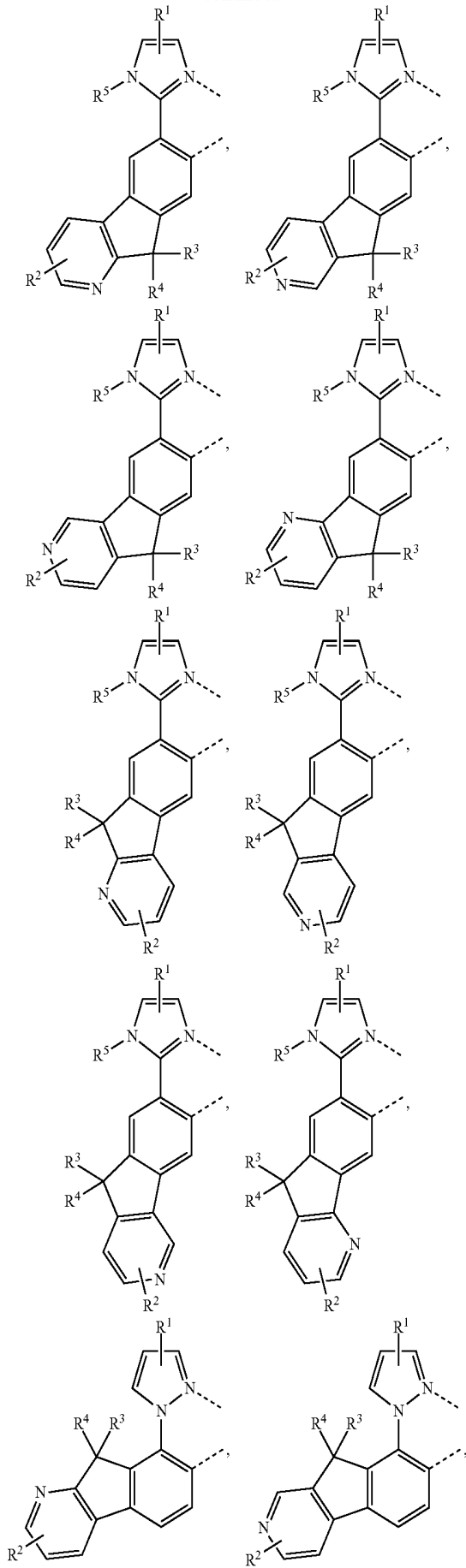


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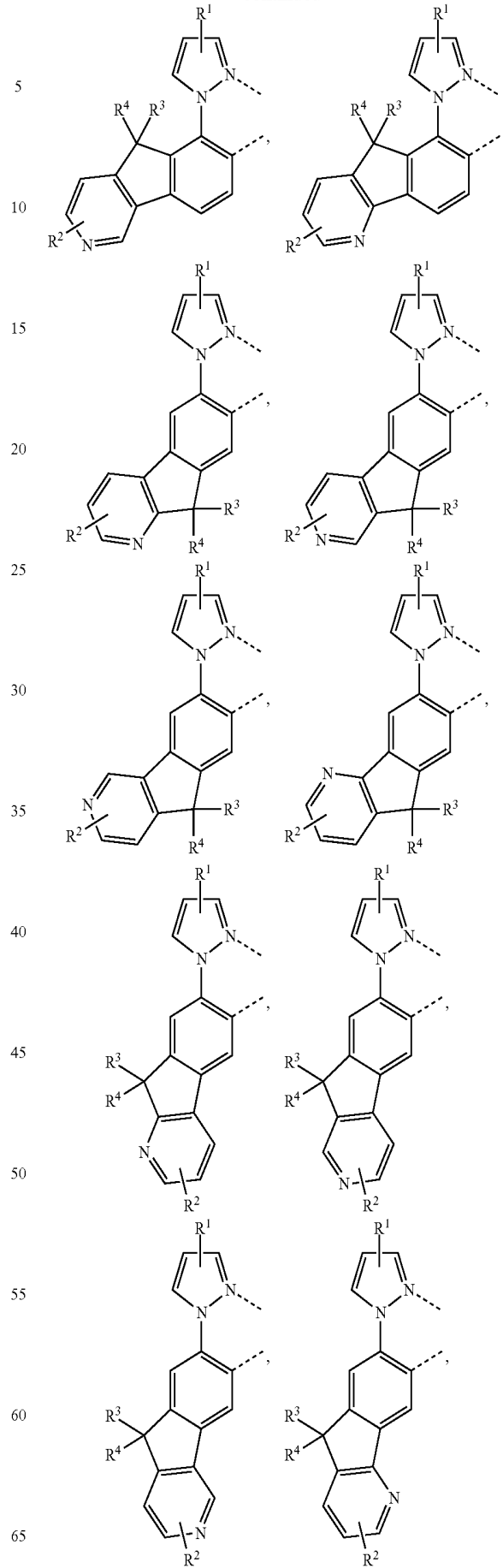
43

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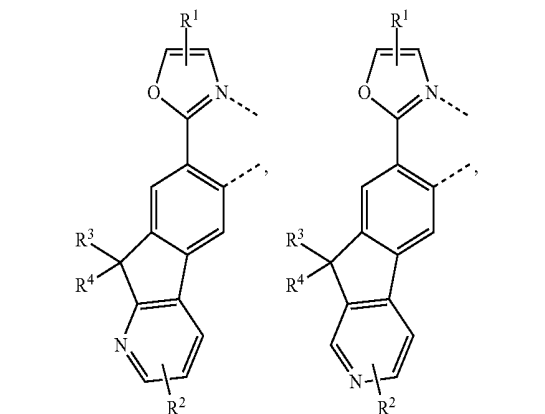
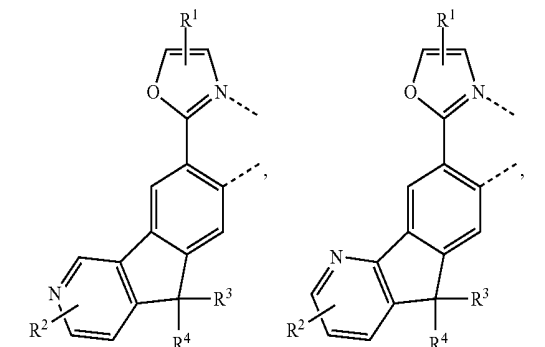
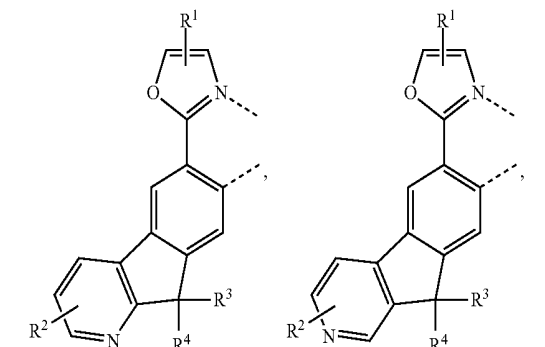
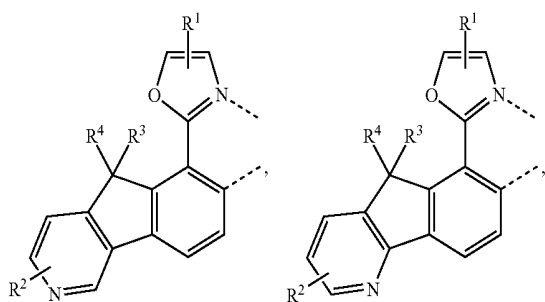
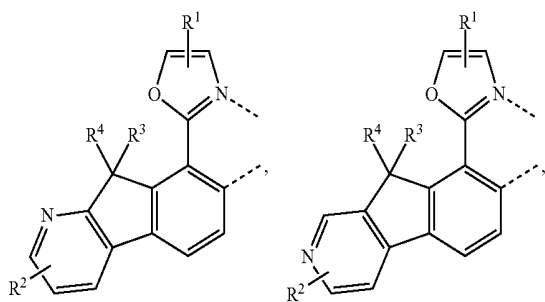
44

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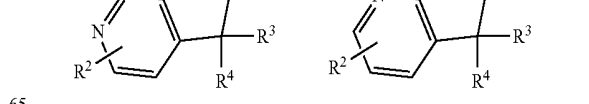
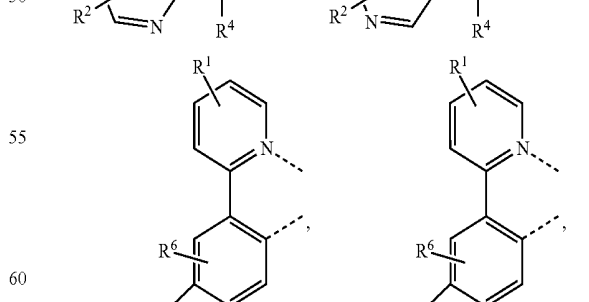
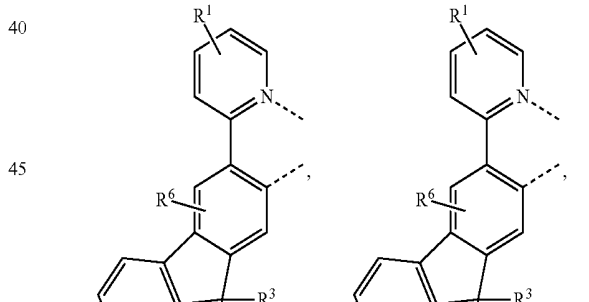
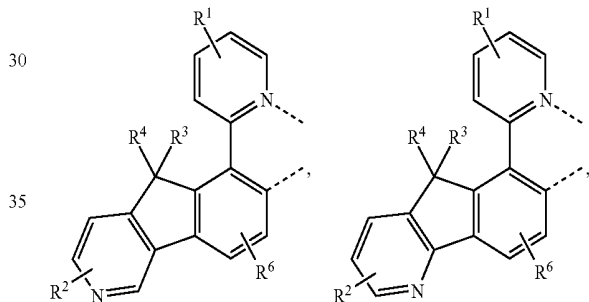
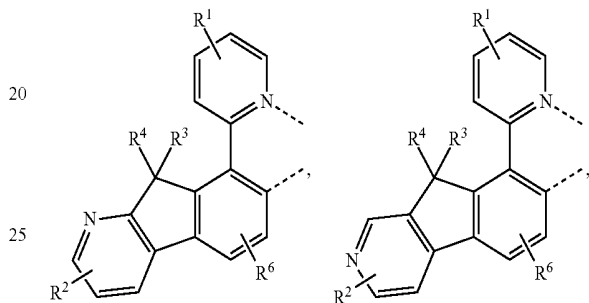
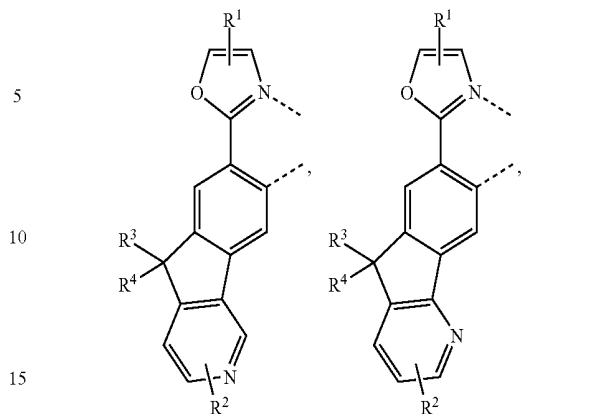
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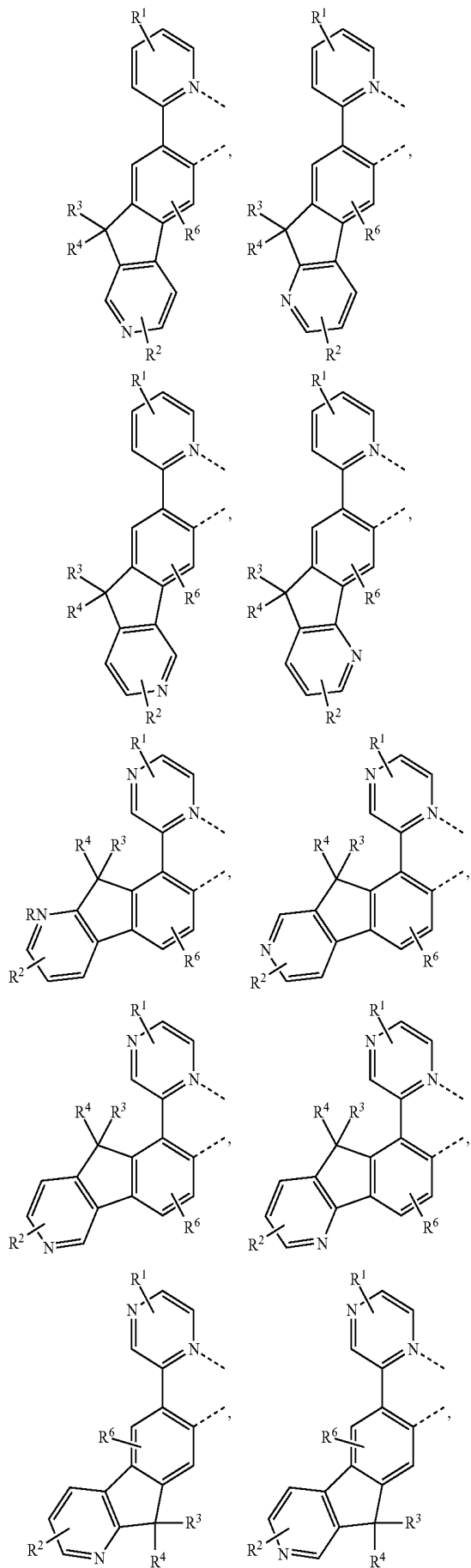
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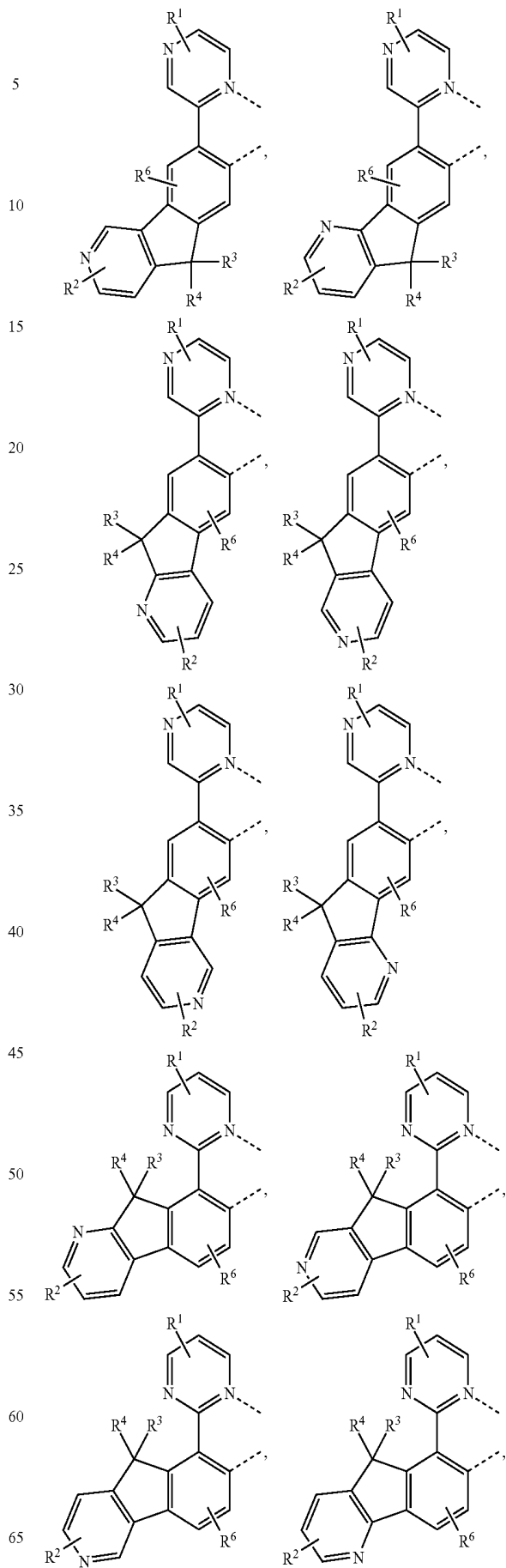
47

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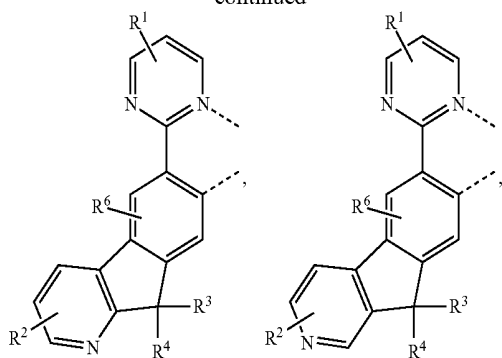
48

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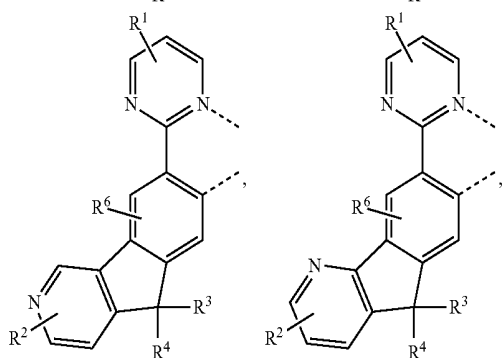
49

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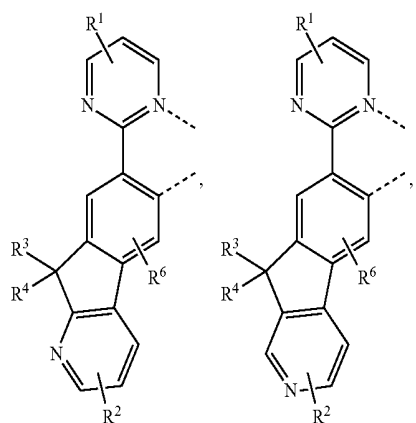
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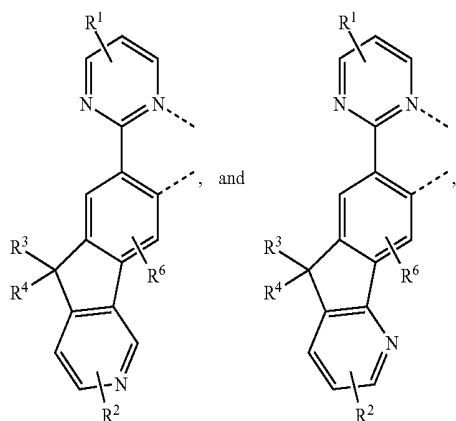
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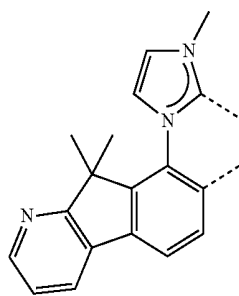
and

wherein R<sup>5</sup> is selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfonyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In some embodiments, L<sub>A</sub> is selected from the group consisting of:

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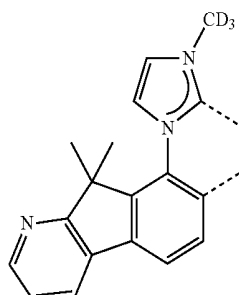
L<sub>A1</sub>



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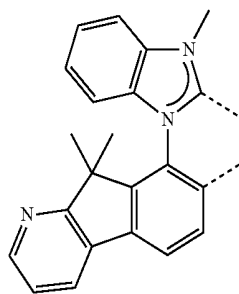
L<sub>A2</sub>



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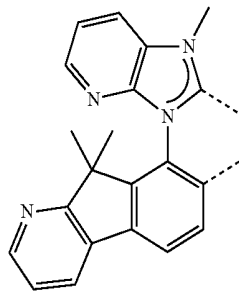


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L<sub>A3</sub>

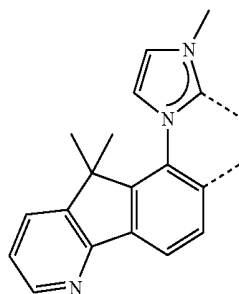


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L<sub>A4</sub>



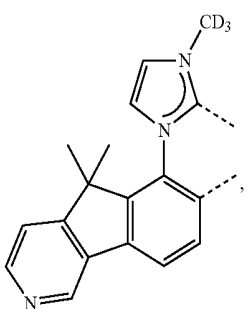
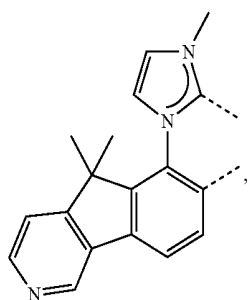
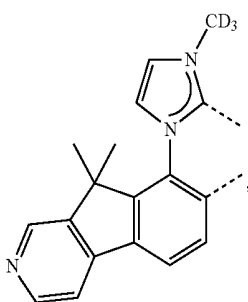
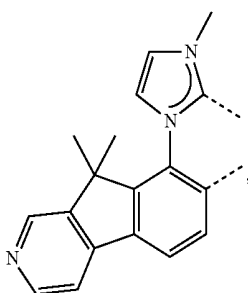
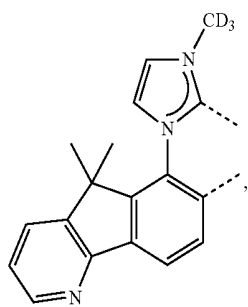
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**51**

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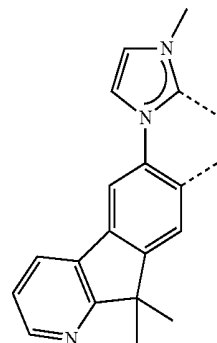
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L<sub>46</sub>

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L<sub>411</sub>

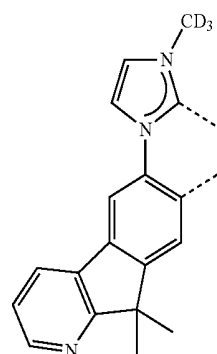


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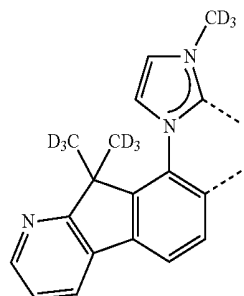


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L<sub>413</sub>



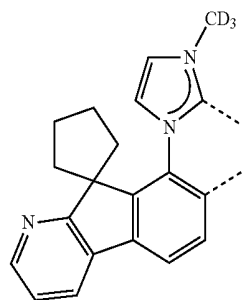
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L<sub>49</sub>

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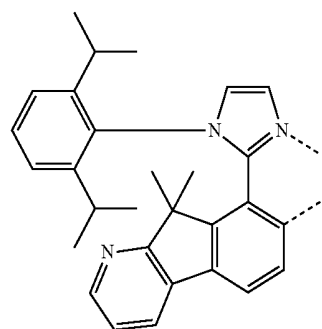


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L<sub>410</sub>

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L<sub>415</sub>

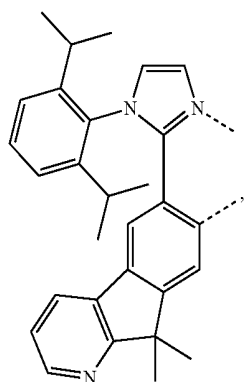
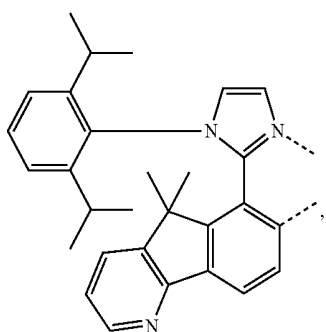
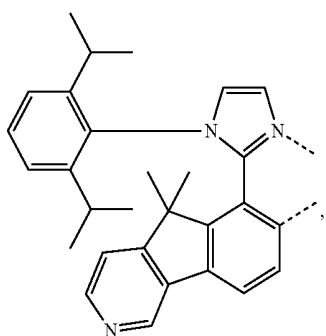
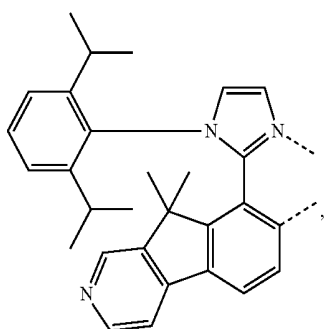
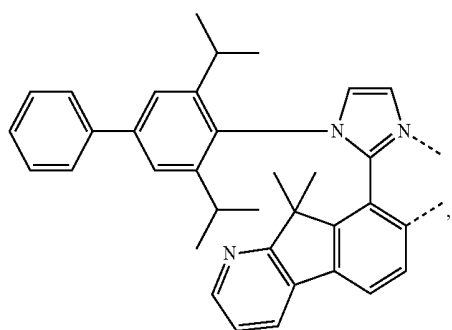


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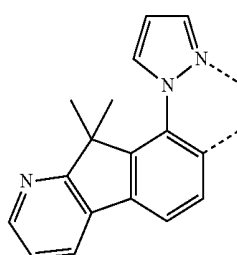
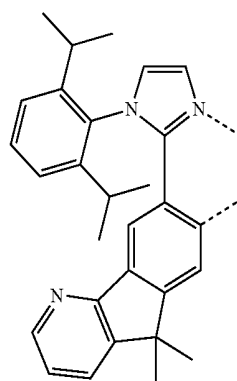
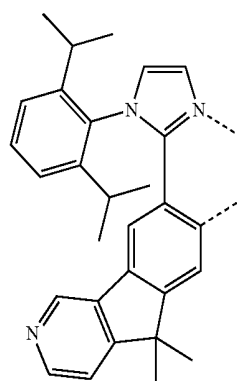
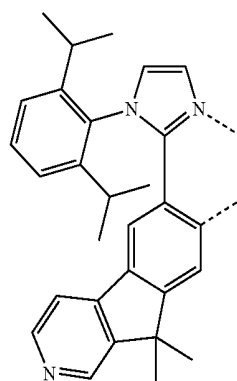
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**54**

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L<sub>417</sub>

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L<sub>418</sub>

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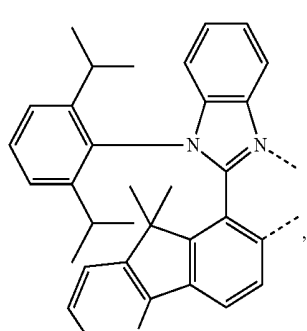
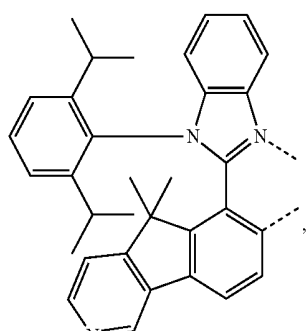
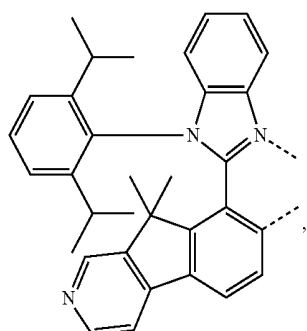
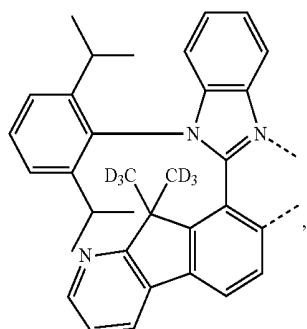
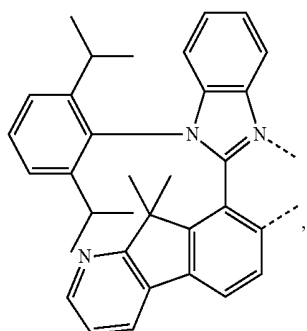
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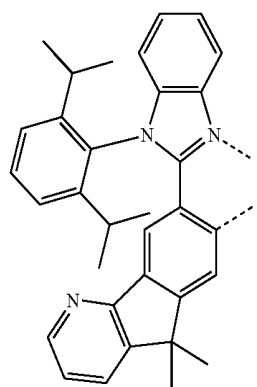
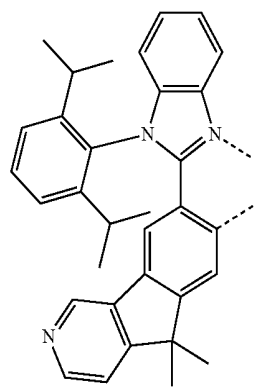
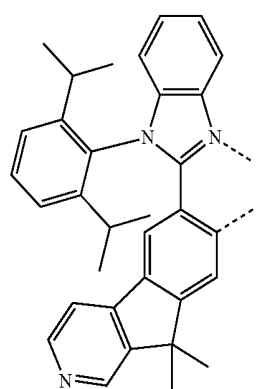
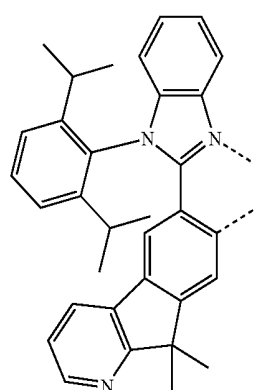
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**56**

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L<sub>A26</sub>

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L<sub>A27</sub>

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L<sub>A29</sub>

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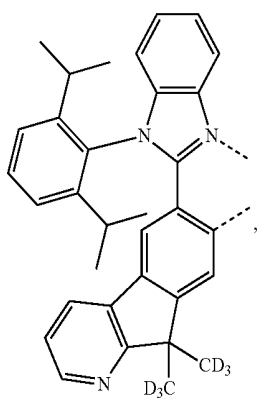
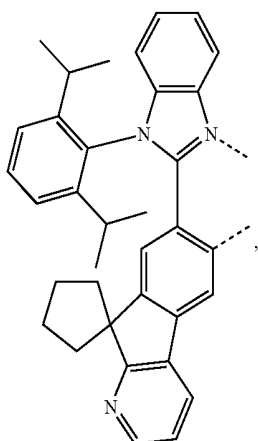
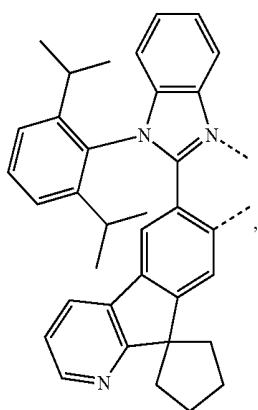
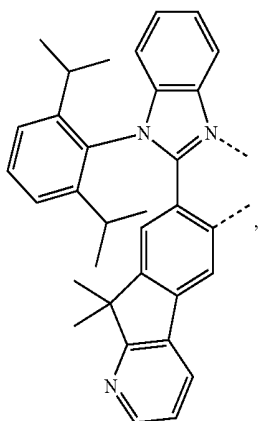
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L<sub>A32</sub>

L<sub>A33</sub>

**57**  
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**58**  
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L<sub>434</sub>

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L<sub>435</sub>

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L<sub>436</sub>

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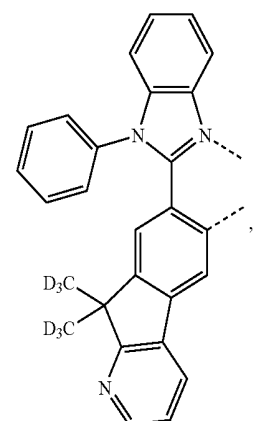
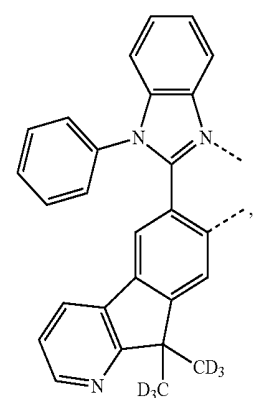
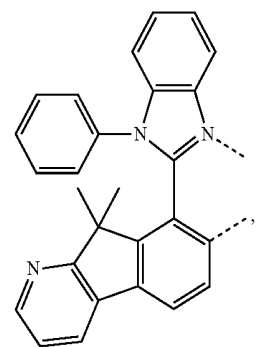
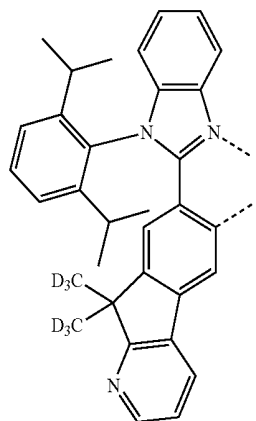
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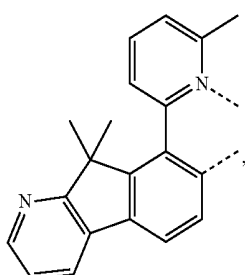
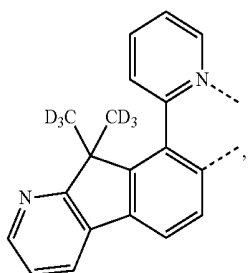
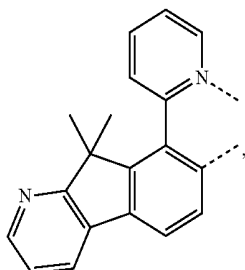
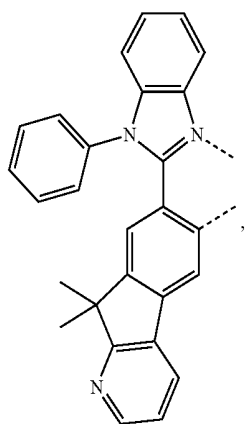
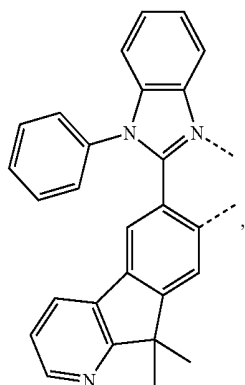


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L<sub>441</sub>

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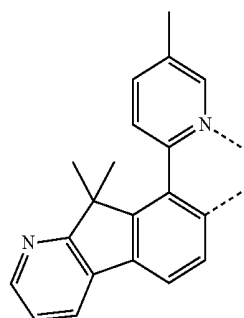


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L<sub>447</sub>



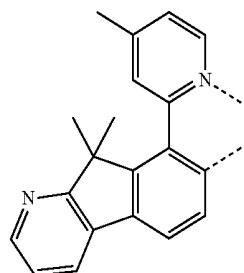
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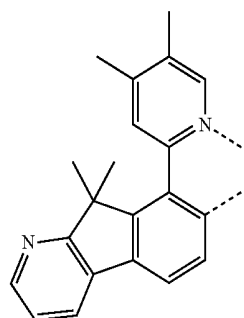
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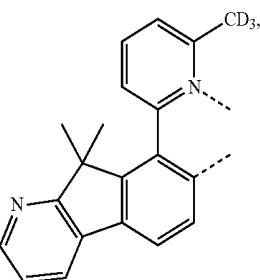
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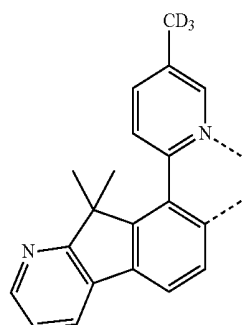


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L<sub>451</sub>

L<sub>446</sub>

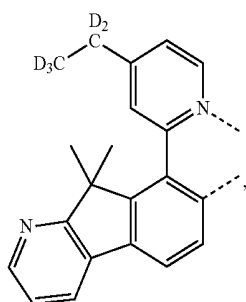
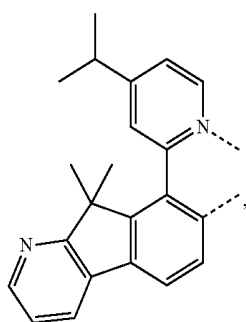
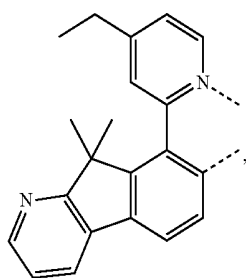
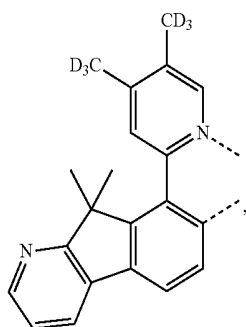
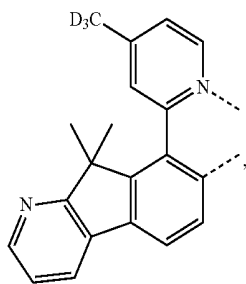
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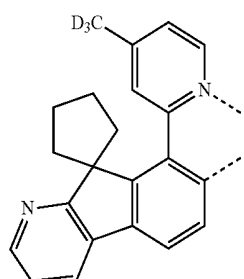
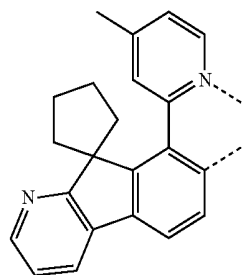
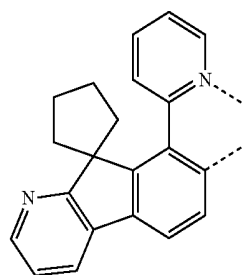
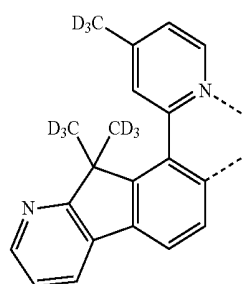
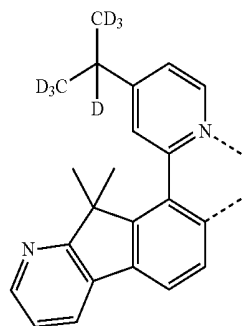
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**62**

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L<sub>452</sub>

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L<sub>457</sub>

L<sub>458</sub>

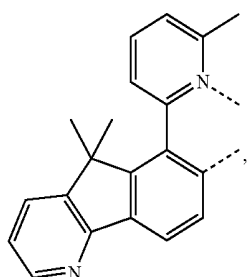
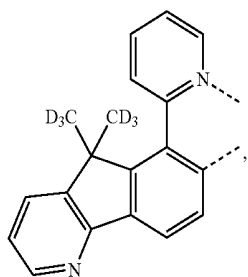
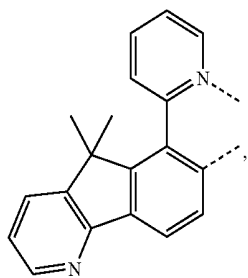
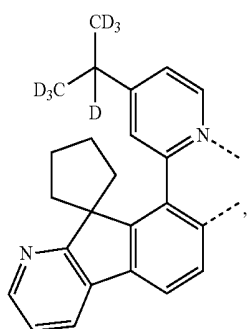
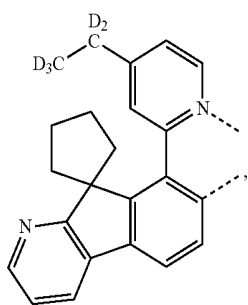
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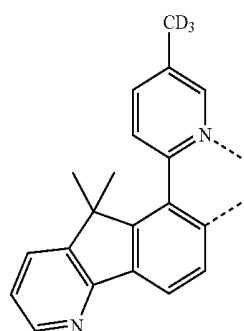
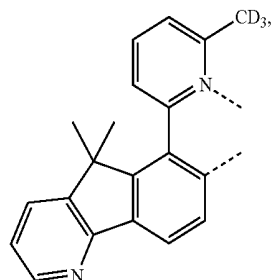
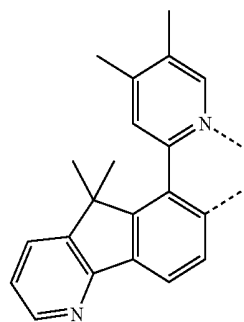
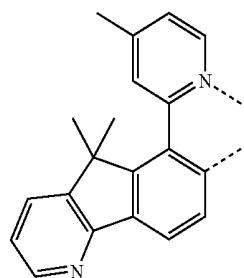
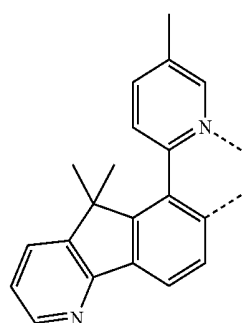
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**64**

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L<sub>462</sub>

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L<sub>463</sub>

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L<sub>464</sub>

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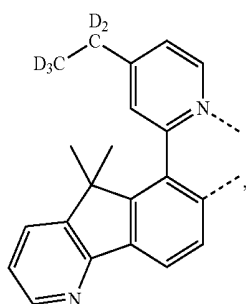
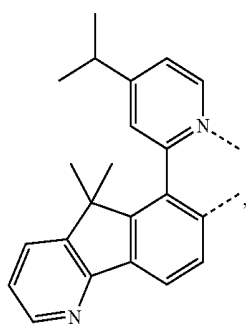
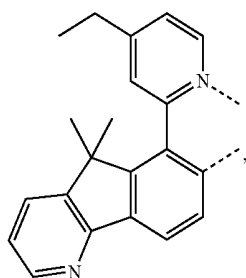
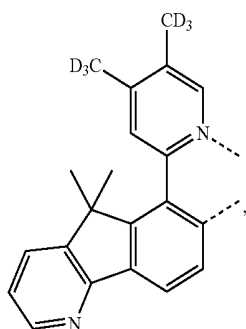
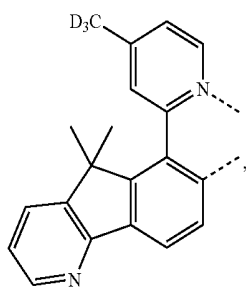
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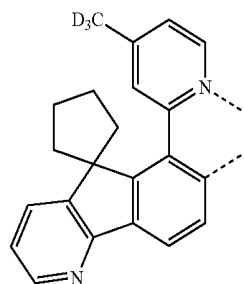
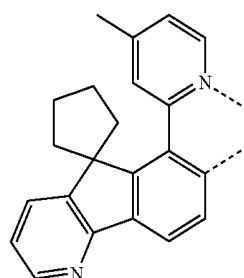
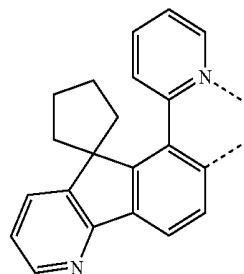
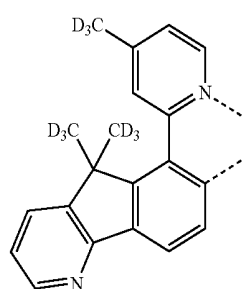
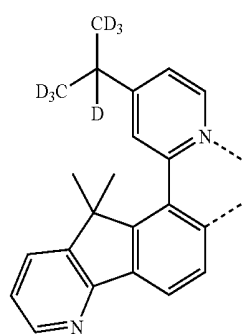
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**66**

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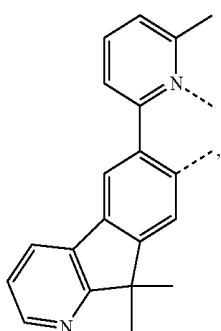
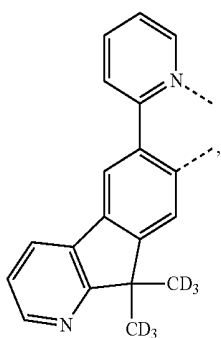
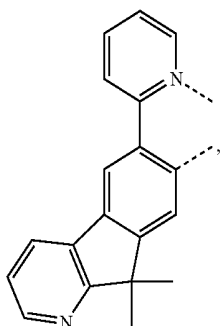
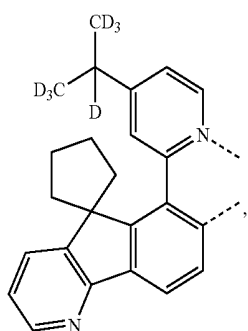
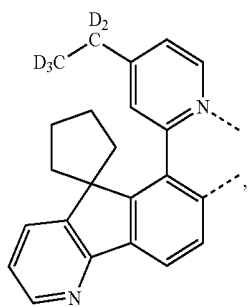
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L<sub>480</sub>

L<sub>481</sub>

**67**

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**68**

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L<sub>482</sub>

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L<sub>483</sub>

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L<sub>484</sub>

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L<sub>485</sub>

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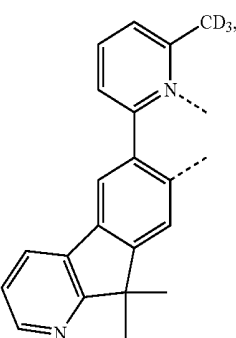
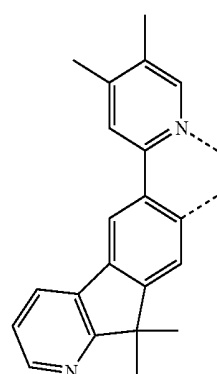
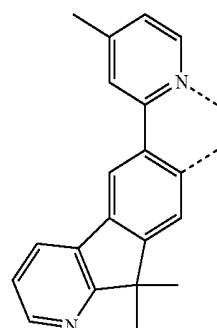
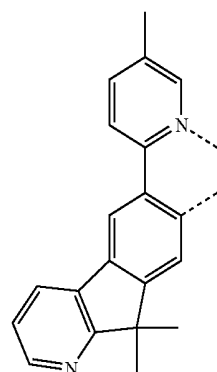
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L<sub>487</sub>

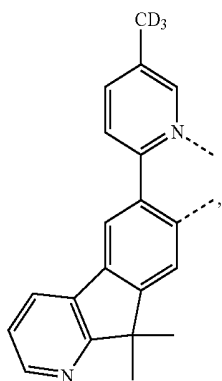


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L<sub>490</sub>

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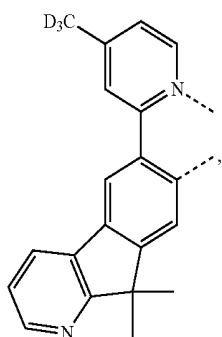


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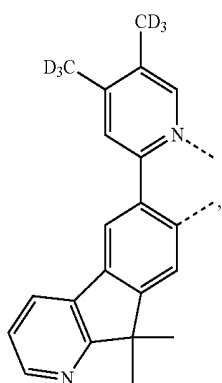


L<sub>492</sub>

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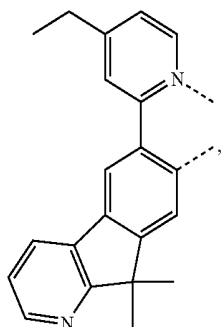
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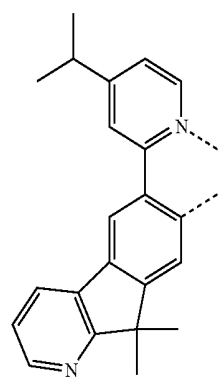
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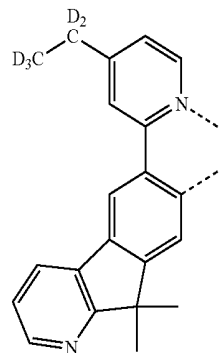
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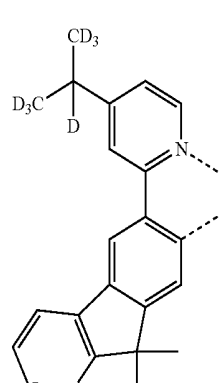
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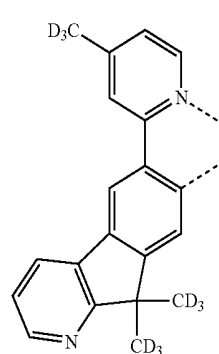
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L<sub>496</sub>

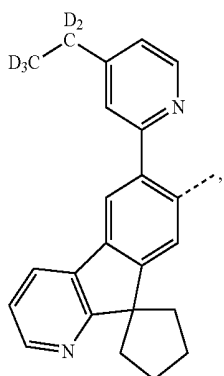
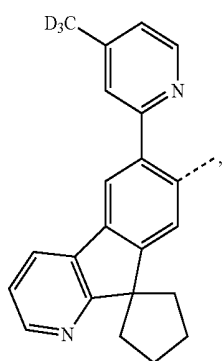
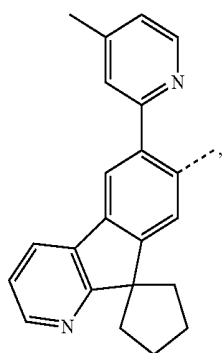
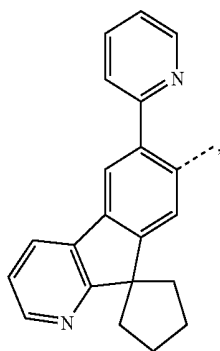


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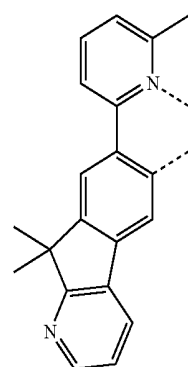
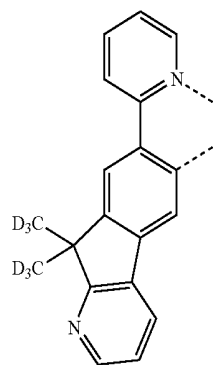
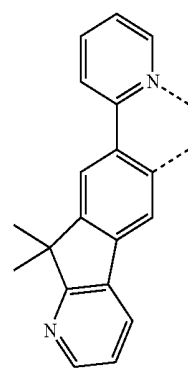
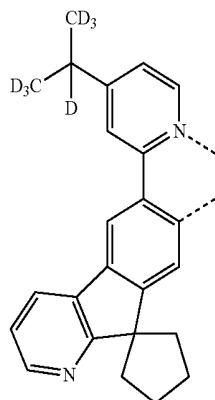


L<sub>498</sub>

**71**  
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**72**  
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L<sub>A99</sub>

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L<sub>A100</sub>

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L<sub>A101</sub>

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L<sub>A102</sub>

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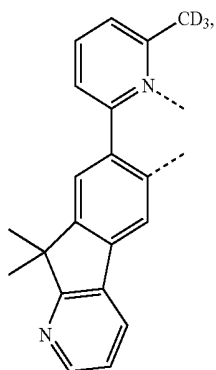
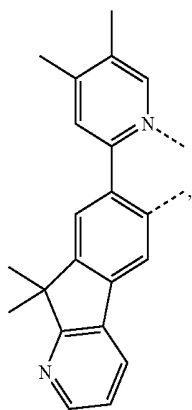
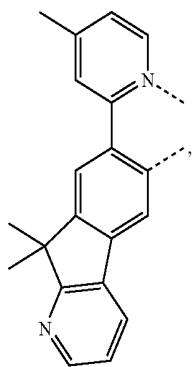
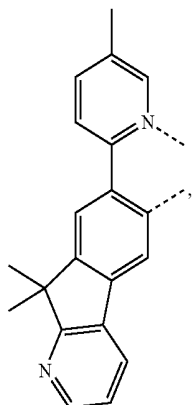
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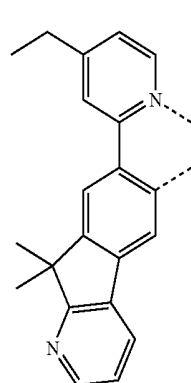
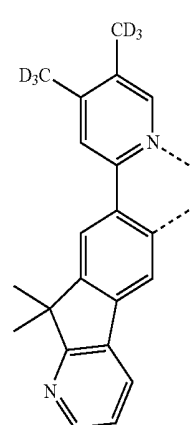
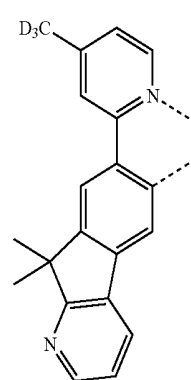
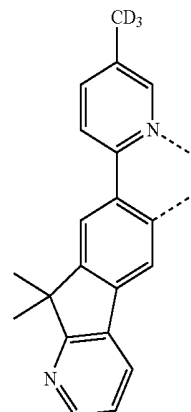
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L<sub>A106</sub>

**73**  
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**74**  
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L<sub>A107</sub>

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L<sub>A108</sub>

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L<sub>A109</sub>

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L<sub>A110</sub>

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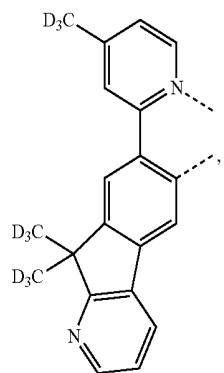
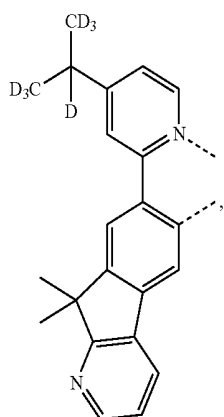
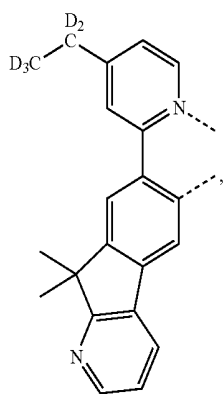
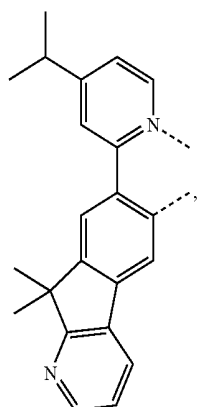
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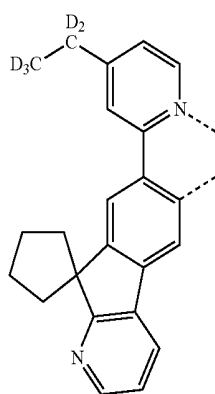
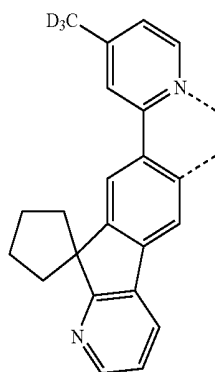
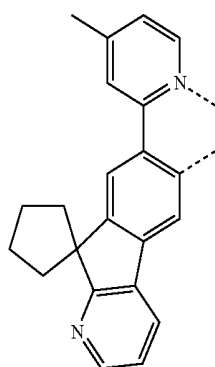
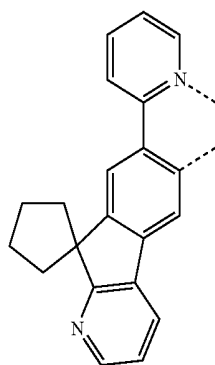
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L<sub>A114</sub>

**75**  
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**76**  
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L<sub>A115</sub>

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L<sub>A116</sub>

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L<sub>A117</sub>

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L<sub>A118</sub>

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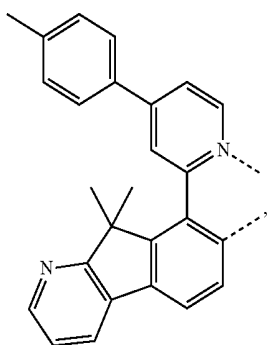
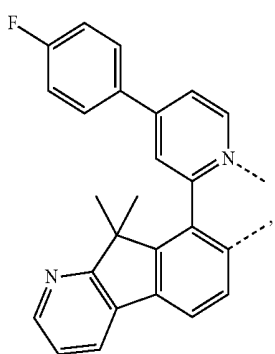
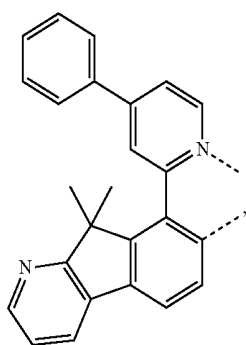
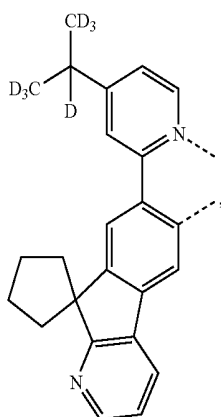
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L<sub>A122</sub>

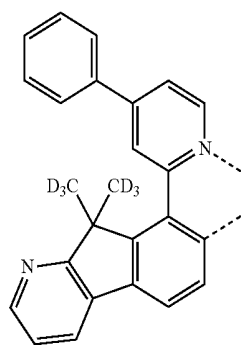
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**78**  
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L<sub>A127</sub>

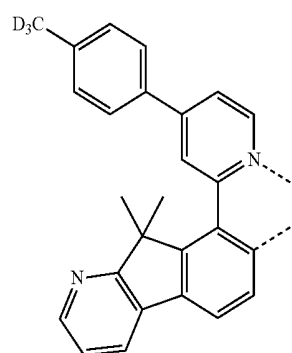
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L<sub>A124</sub>

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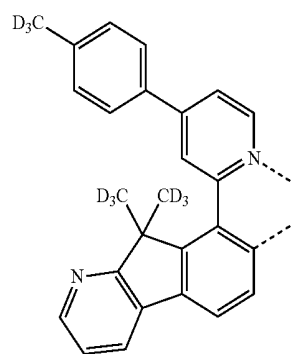
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L<sub>A125</sub>

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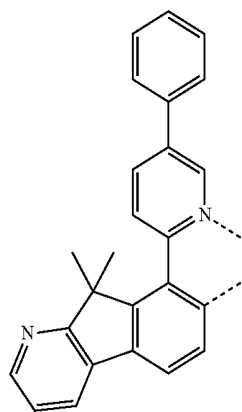
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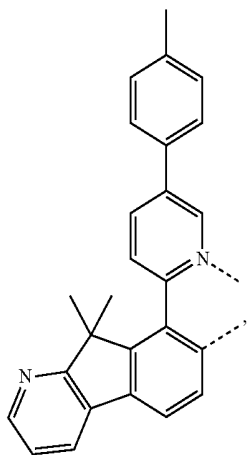
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L<sub>A130</sub>

**79**  
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L<sub>A131</sub>

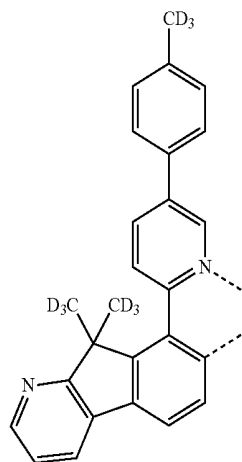
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**80**  
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L<sub>A134</sub>

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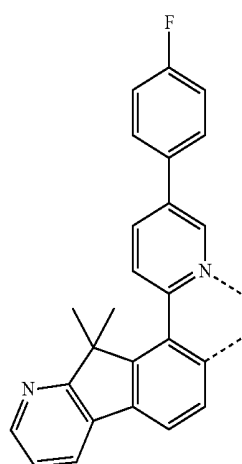
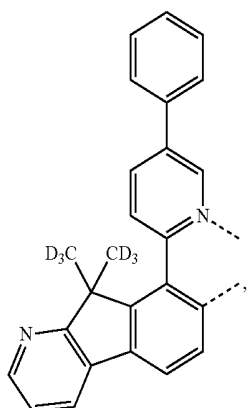
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L<sub>A135</sub>

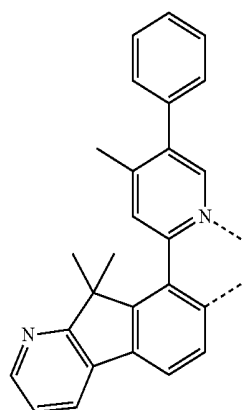
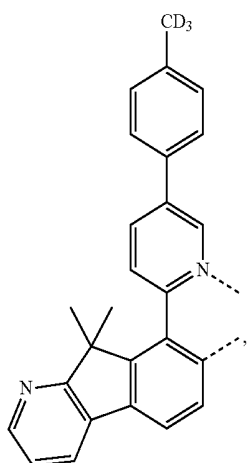
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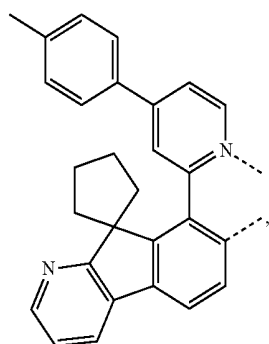
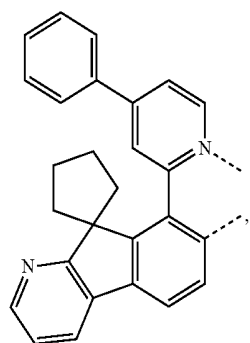
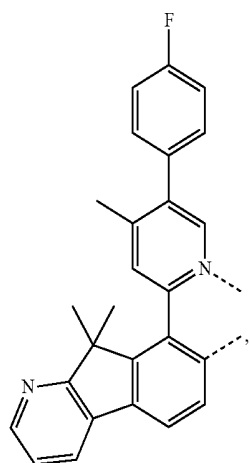
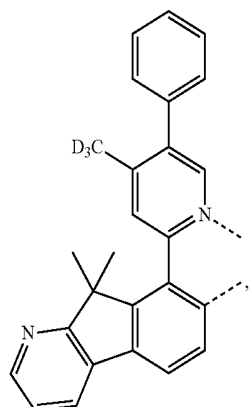
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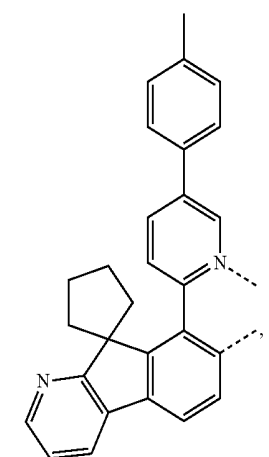
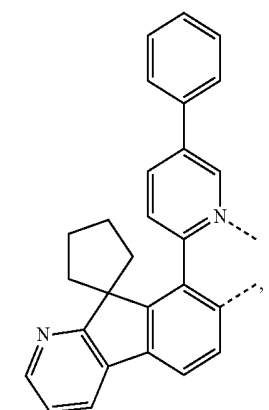
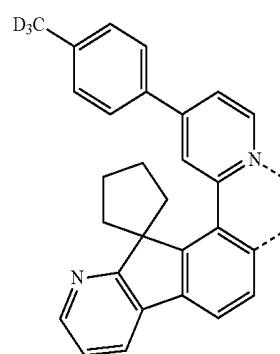
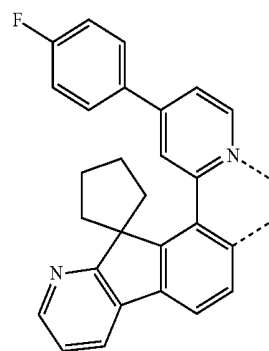
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**82**

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L<sub>A137</sub>

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L<sub>A138</sub>

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L<sub>A140</sub>

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L<sub>A141</sub>

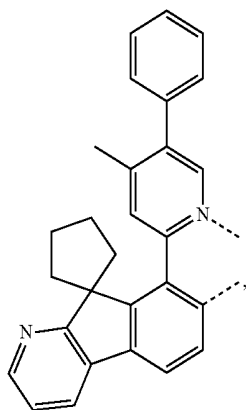
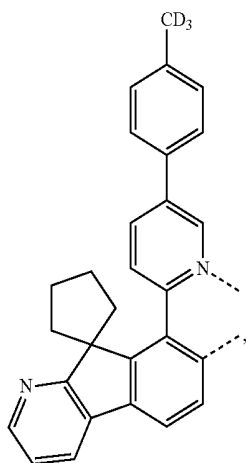
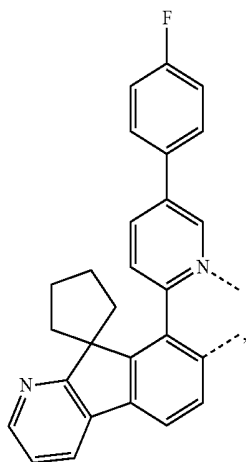
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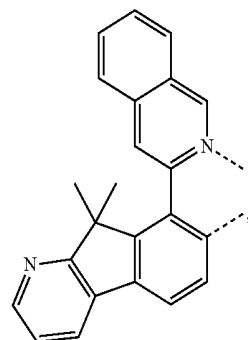
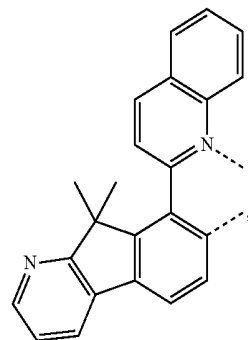
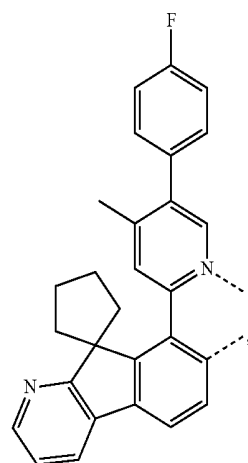
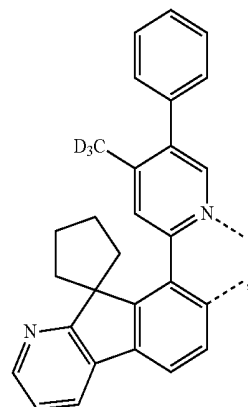
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L<sub>A145</sub>

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L<sub>A146</sub>

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L<sub>A147</sub>

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L<sub>A148</sub>

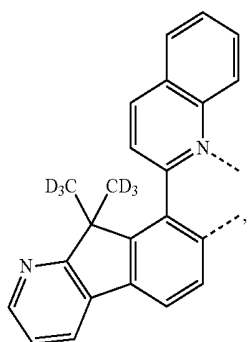
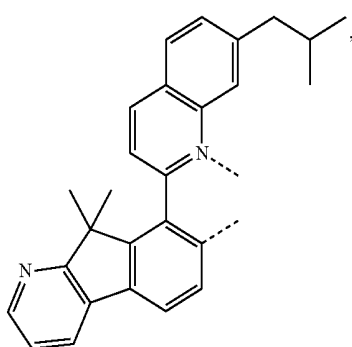
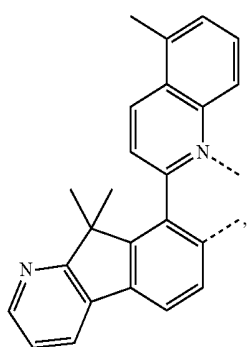
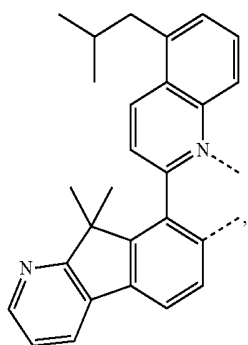
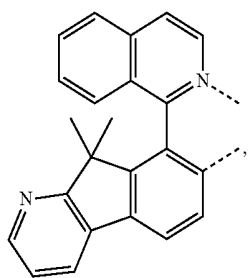
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L<sub>A150</sub>

L<sub>A151</sub>

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L<sub>A152</sub>

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L<sub>A153</sub>

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L<sub>A155</sub>

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L<sub>A156</sub>

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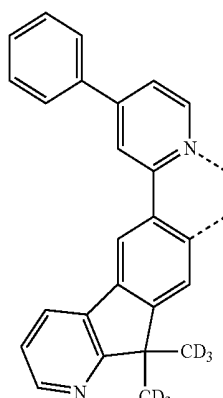
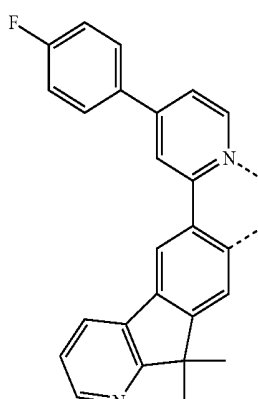
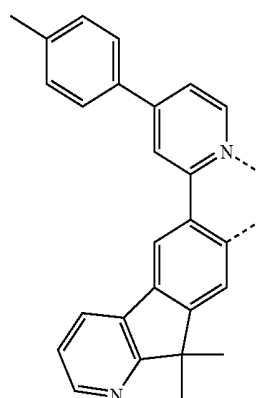
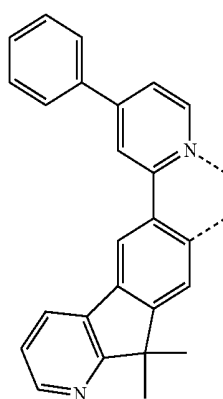
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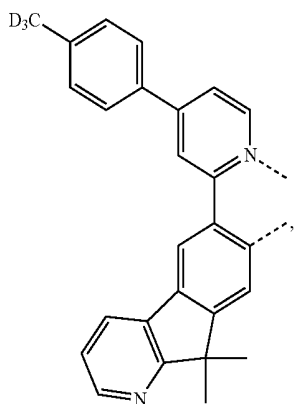
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L<sub>A159</sub>

L<sub>A160</sub>



**87**  
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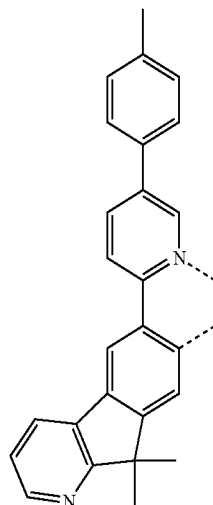
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**88**  
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L<sub>A164</sub>



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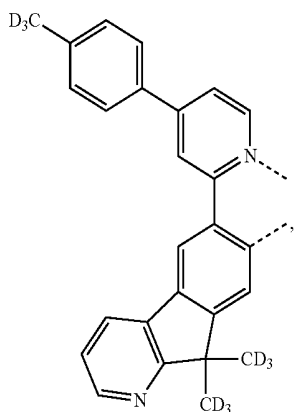
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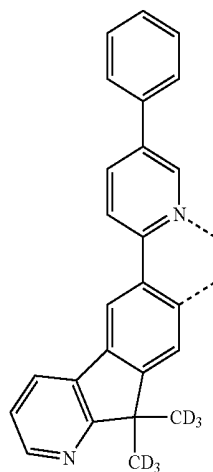
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L<sub>A165</sub>



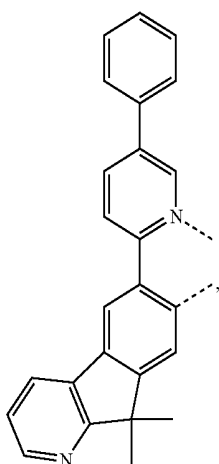
L<sub>A163</sub>

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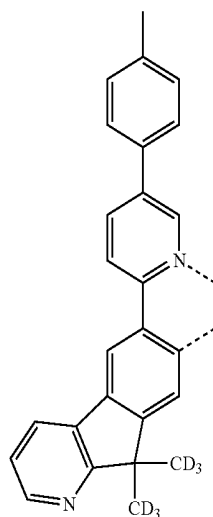
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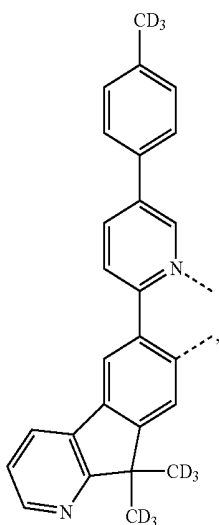
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L<sub>A166</sub>



**89**  
-continued



L<sub>A167</sub>

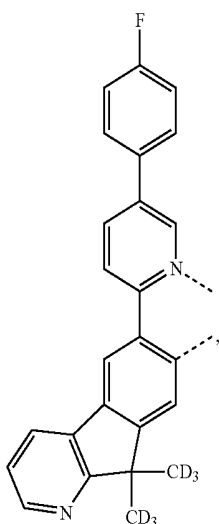
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L<sub>A168</sub>



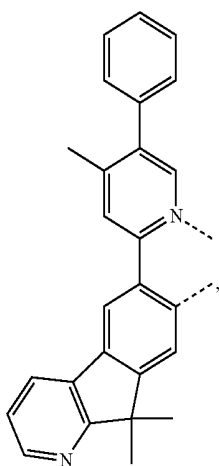
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L<sub>A169</sub>



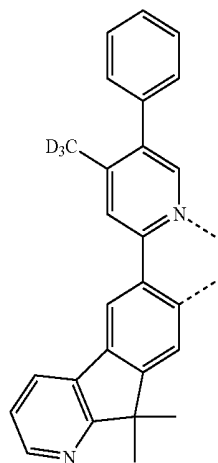
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**90**  
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L<sub>A170</sub>

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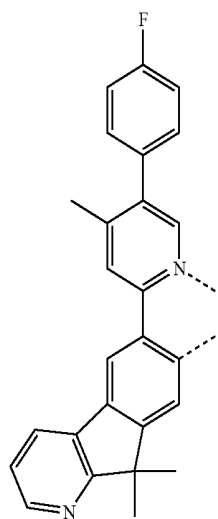
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L<sub>A168</sub>



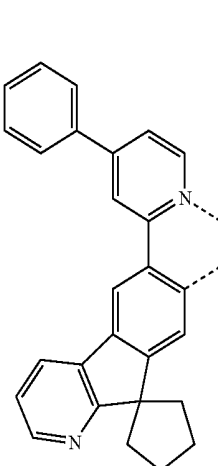
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L<sub>A169</sub>



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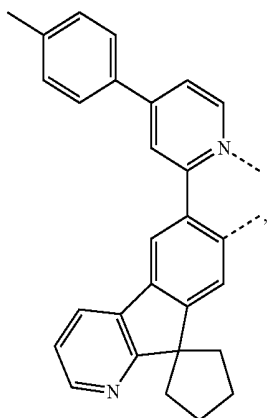
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L<sub>A172</sub>

**91**  
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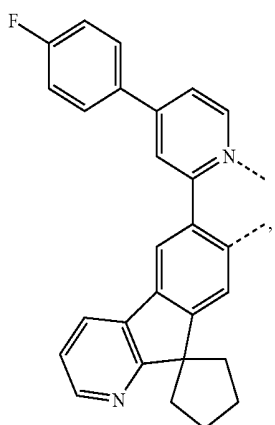
L<sub>A173</sub>

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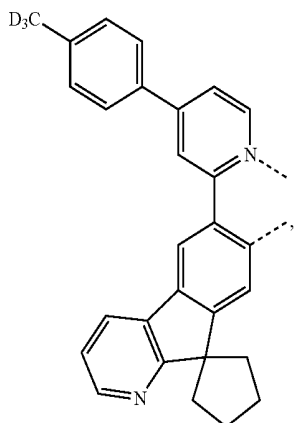
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L<sub>A175</sub>

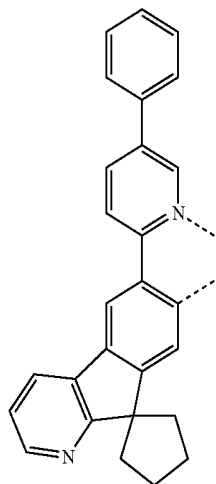
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**92**  
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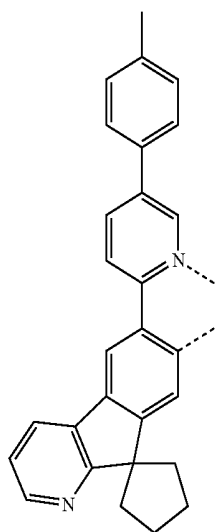
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L<sub>A177</sub>

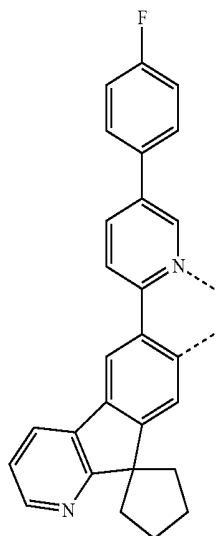
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L<sub>A178</sub>

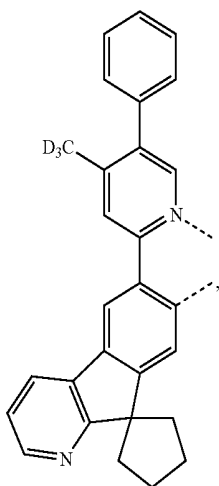
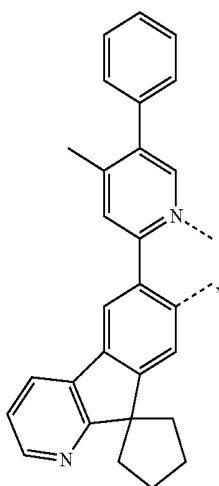
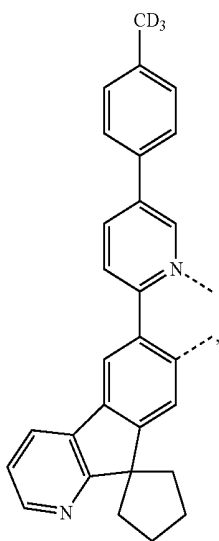
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**93**  
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**94**  
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L<sub>A179</sub>

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L<sub>A180</sub>

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L<sub>A181</sub>

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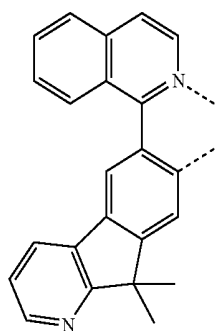
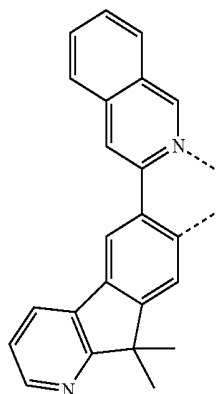
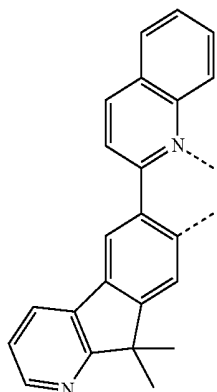
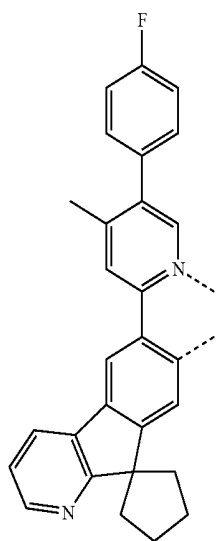
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L<sub>A182</sub>



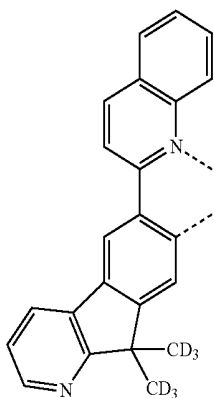
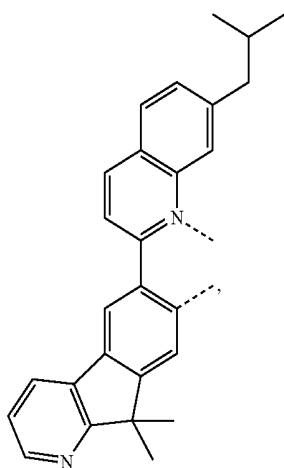
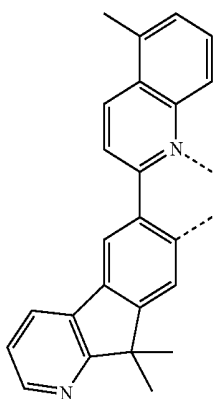
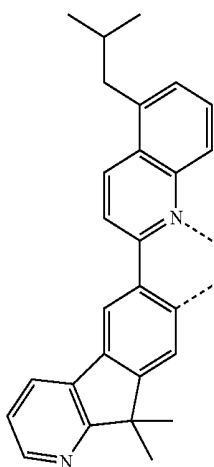
L<sub>A183</sub>

L<sub>A184</sub>

L<sub>A185</sub>

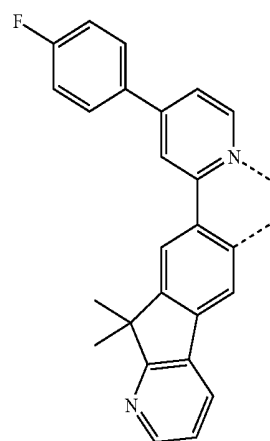
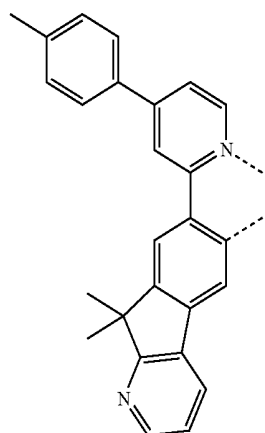
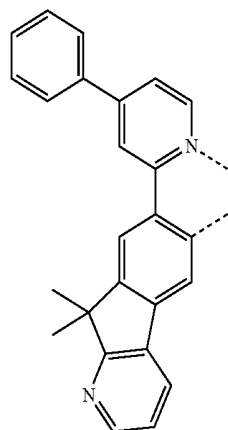
95

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L<sub>A186</sub>

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L<sub>A187</sub>

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L<sub>A188</sub>

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L<sub>A189</sub>

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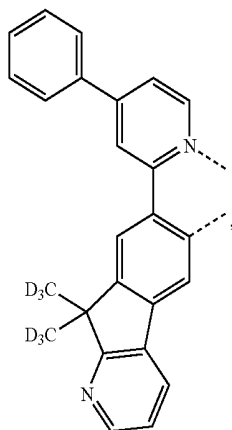
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L<sub>A190</sub>

L<sub>A191</sub>

L<sub>A192</sub>

**97**  
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L<sub>A193</sub>

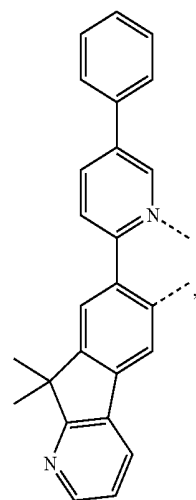
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**98**  
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L<sub>A196</sub>

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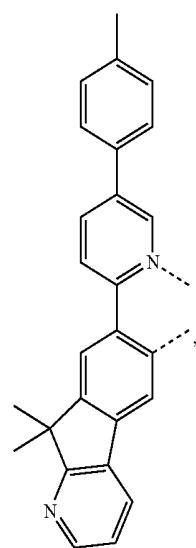
L<sub>A194</sub>

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L<sub>A197</sub>

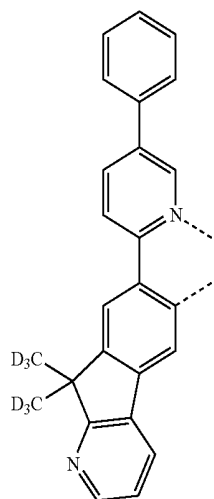
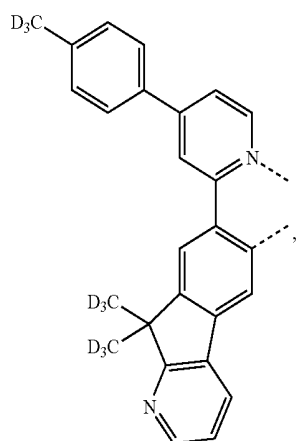
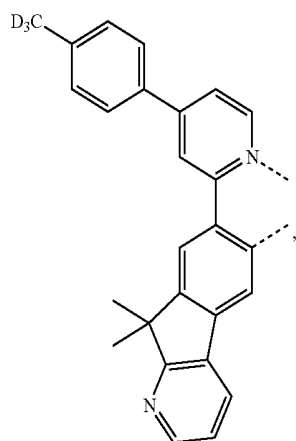
L<sub>A195</sub>

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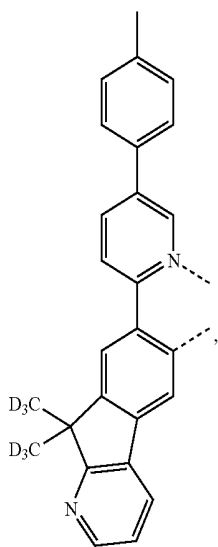
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L<sub>A198</sub>

**99**  
-continued



L<sub>4199</sub>

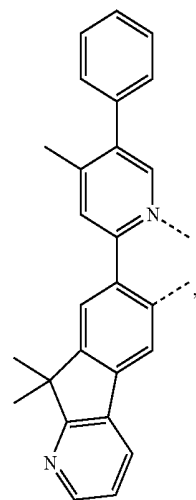
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**100**  
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L<sub>4202</sub>

L<sub>4200</sub>

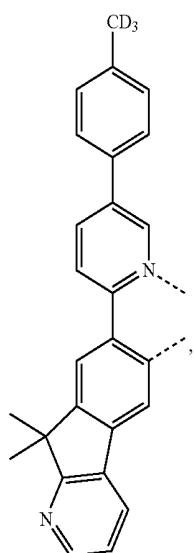
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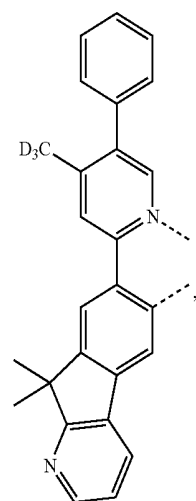
L<sub>4201</sub>

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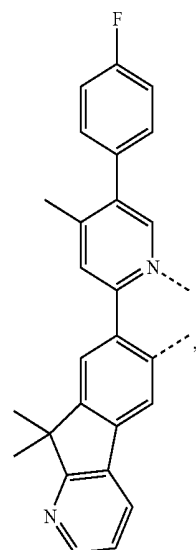
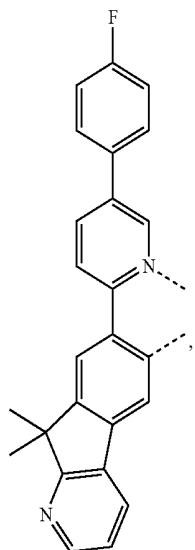
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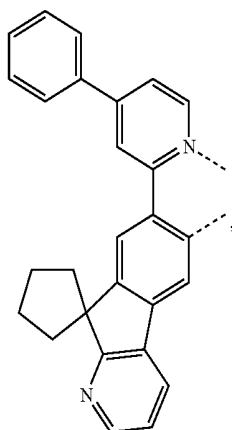


L<sub>4203</sub>

L<sub>4204</sub>



**101**  
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L<sub>4205</sub>

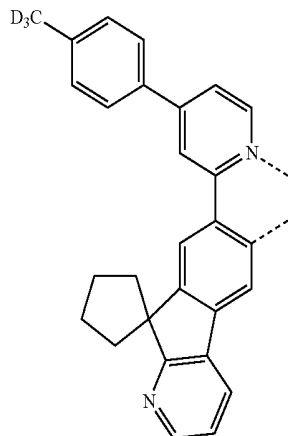
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**102**  
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L<sub>4208</sub>

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L<sub>4206</sub>

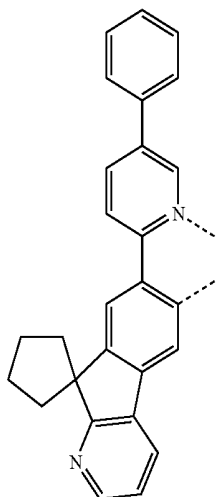
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L<sub>4209</sub>



L<sub>4207</sub>

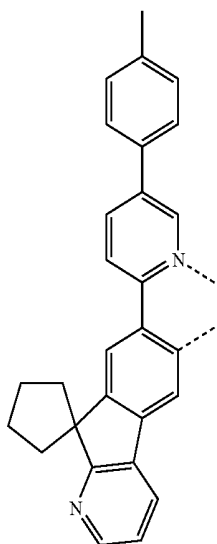
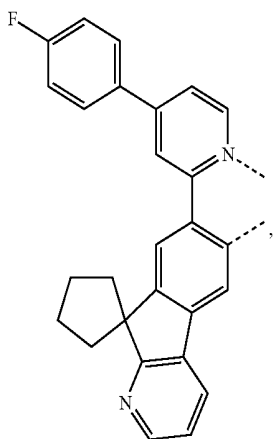
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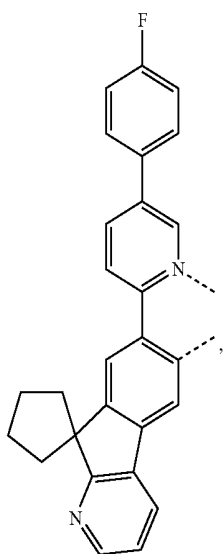
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L<sub>4210</sub>



**103**  
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L<sub>A211</sub>

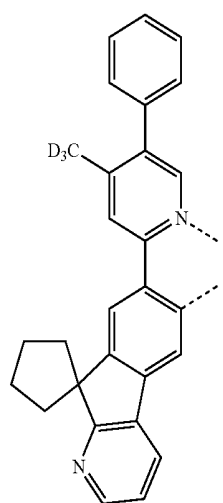
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**104**  
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L<sub>A214</sub>

L<sub>A212</sub>

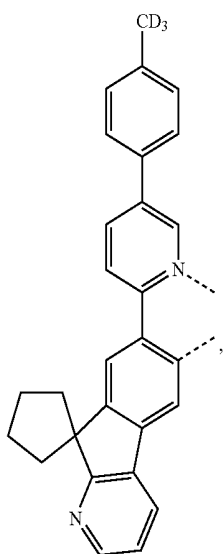
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L<sub>A215</sub>

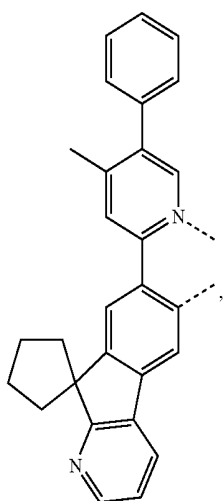
L<sub>A213</sub>

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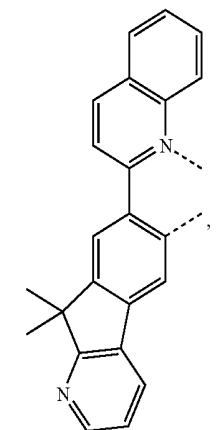
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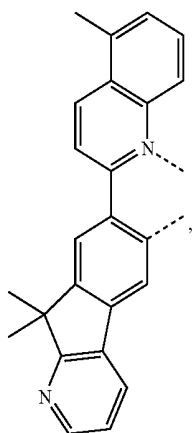
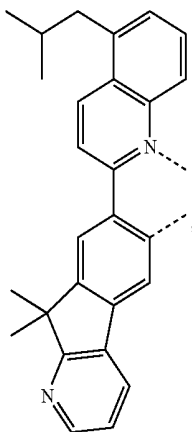
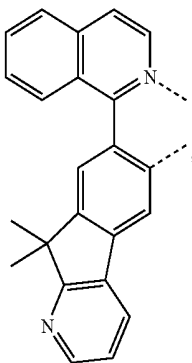
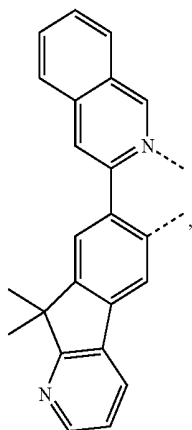


L<sub>A216</sub>



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106

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L<sub>4217</sub>

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L<sub>4218</sub>

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L<sub>4219</sub>

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L<sub>4220</sub>

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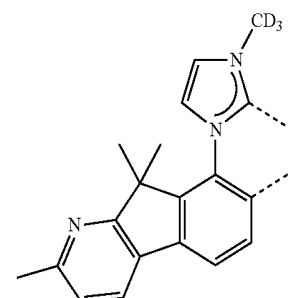
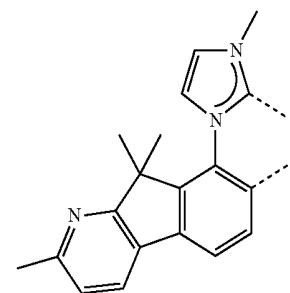
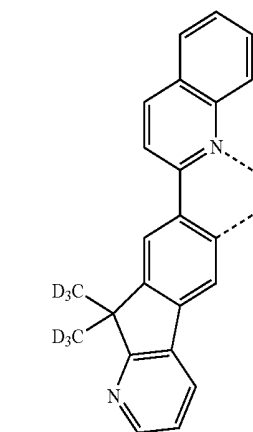
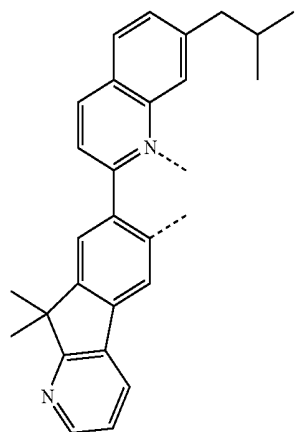
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L<sub>4221</sub>

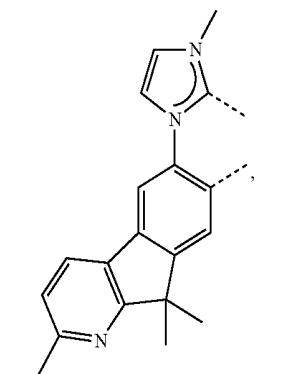
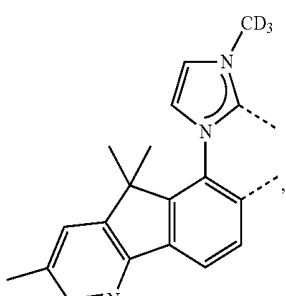
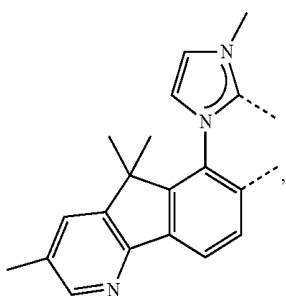
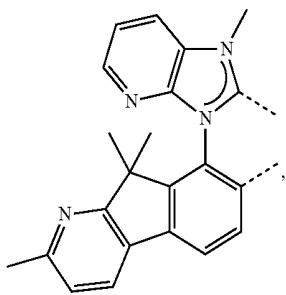
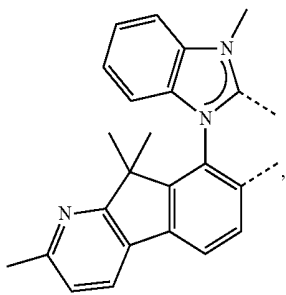
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L<sub>4223</sub>

L<sub>4224</sub>



**107**  
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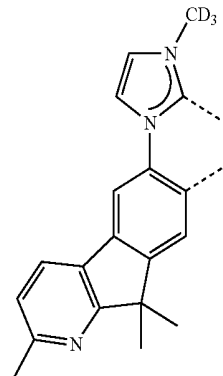


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L<sub>4225</sub>

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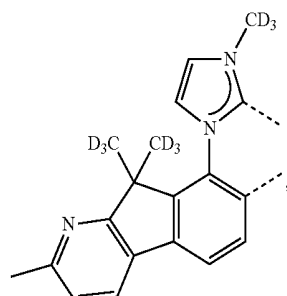
L<sub>4230</sub>



L<sub>4226</sub>

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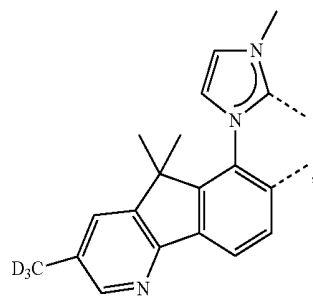
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L<sub>4227</sub>

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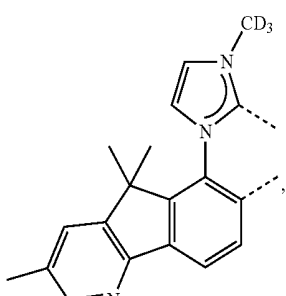
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L<sub>4228</sub>

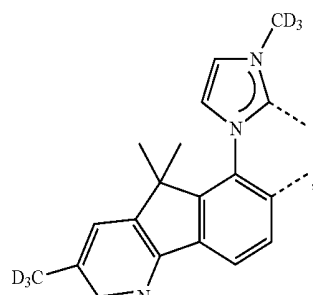
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L<sub>4233</sub>



L<sub>4229</sub>

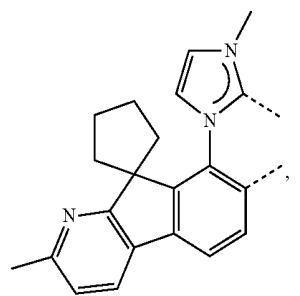
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L<sub>4234</sub>

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L<sub>4234</sub>

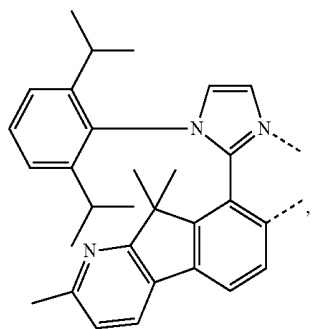


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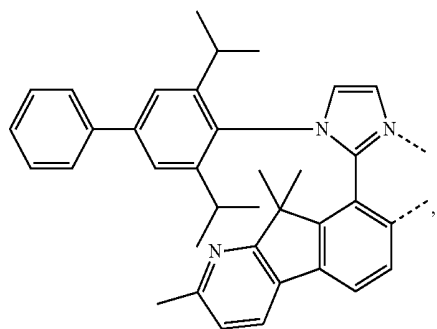
L<sub>4234</sub>

**109**  
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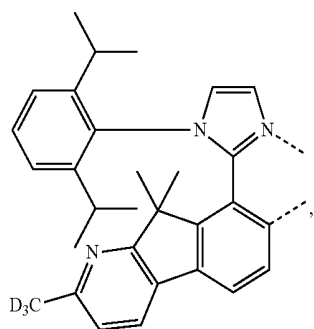
L<sub>4235</sub>

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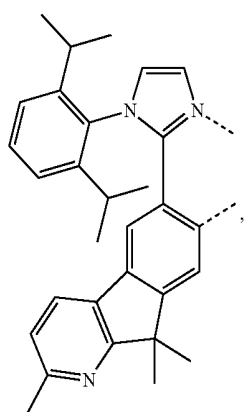
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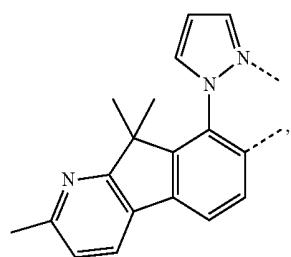
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L<sub>4238</sub>

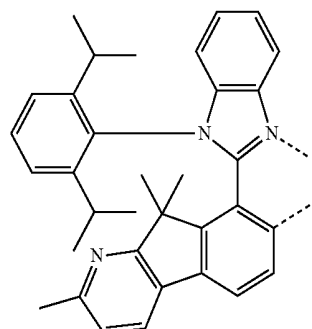
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L<sub>4239</sub>

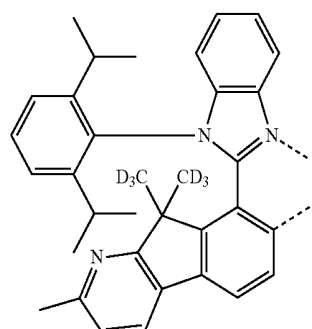
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**110**  
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L<sub>4240</sub>

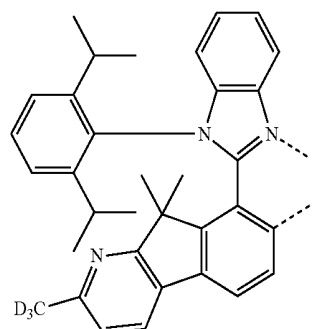
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L<sub>4241</sub>

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L<sub>4242</sub>

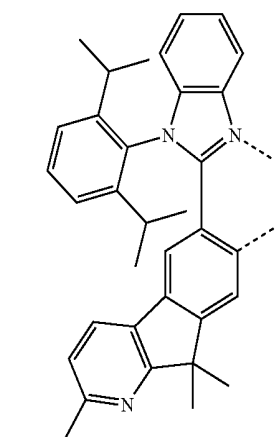
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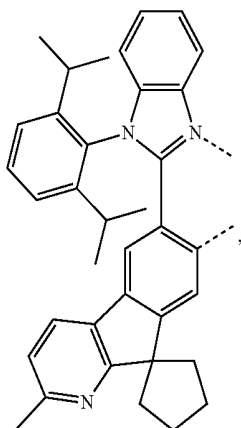
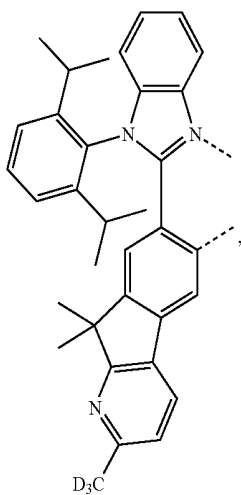
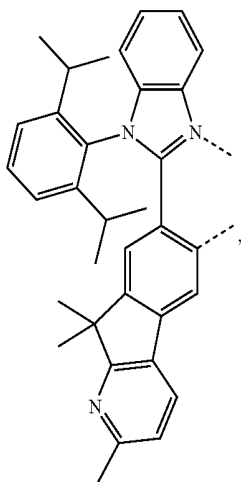


L<sub>4243</sub>

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**111**  
-continued



**112**  
-continued

L<sub>A244</sub>

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L<sub>A245</sub>

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L<sub>A246</sub>

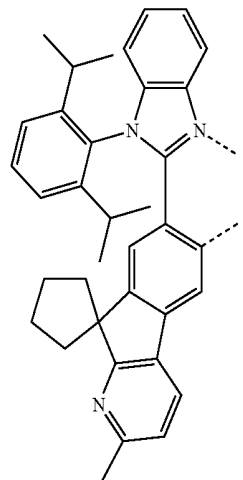
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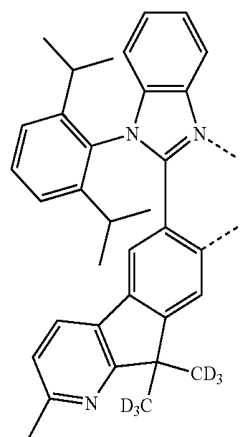
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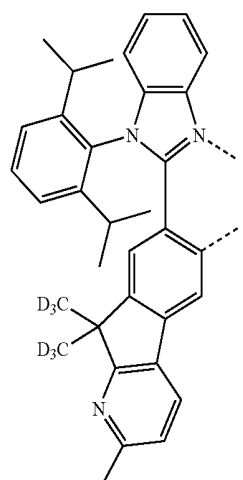
L<sub>A247</sub>



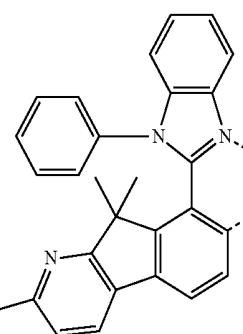
L<sub>A248</sub>



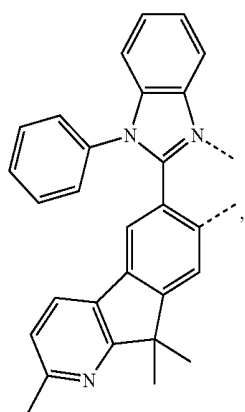
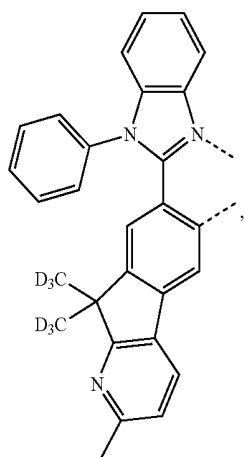
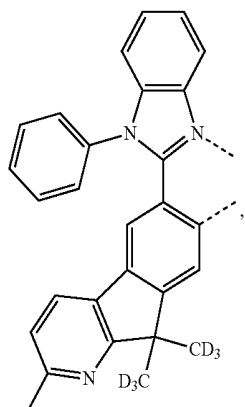
L<sub>A249</sub>



L<sub>A250</sub>



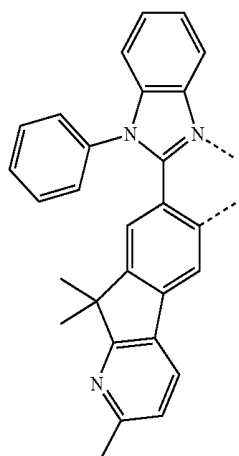
**113**  
-continued



**114**  
-continued

L<sub>4251</sub>

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L<sub>4254</sub>

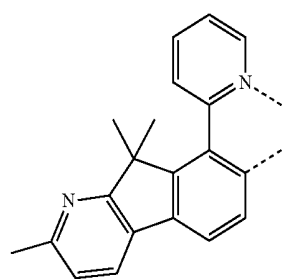
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L<sub>4252</sub>

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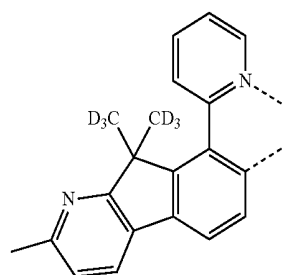
L<sub>4255</sub>

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L<sub>4256</sub>

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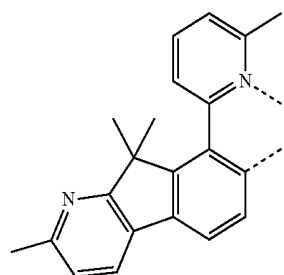


L<sub>4256</sub>

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L<sub>4253</sub>

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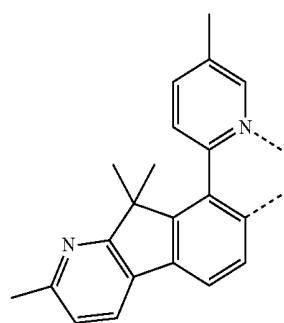
L<sub>4257</sub>

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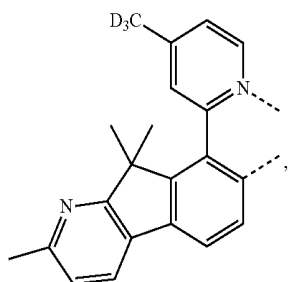
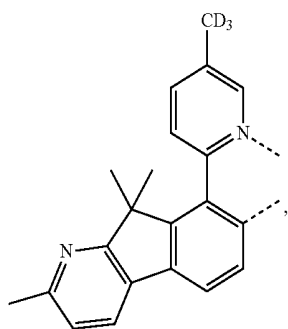
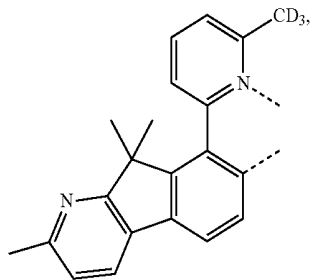
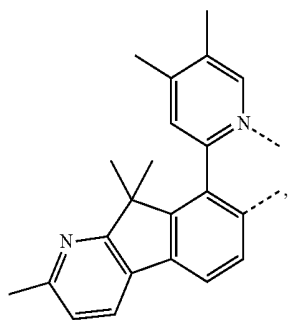
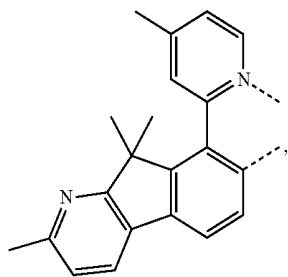
L<sub>4258</sub>

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L<sub>4258</sub>

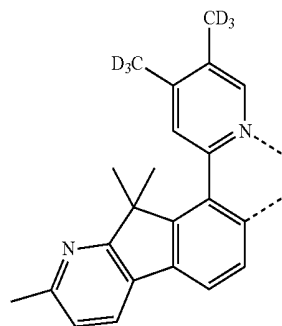
**115**  
-continued



**116**  
-continued

L<sub>A259</sub>

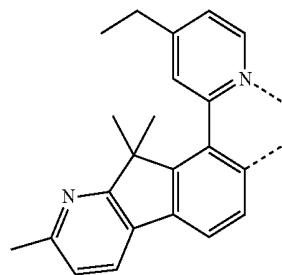
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L<sub>A264</sub>

L<sub>A260</sub>

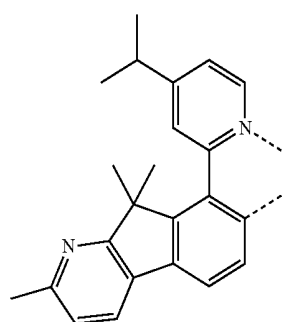
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L<sub>A265</sub>

L<sub>A261</sub>

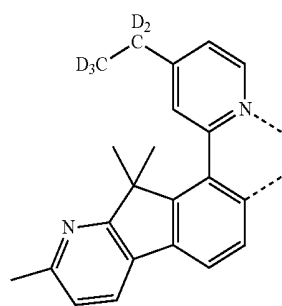
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L<sub>A266</sub>

L<sub>A262</sub>

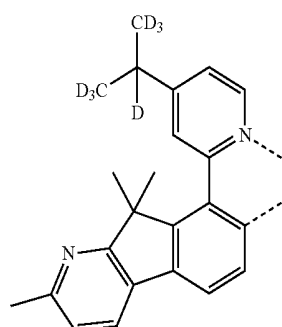
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L<sub>A267</sub>

L<sub>A263</sub>

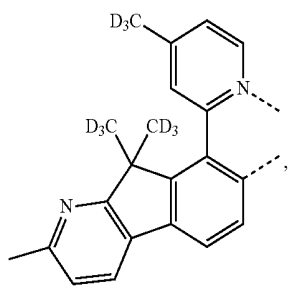
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L<sub>A268</sub>

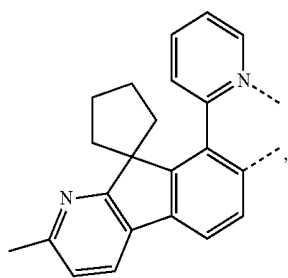
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**117**  
-continued



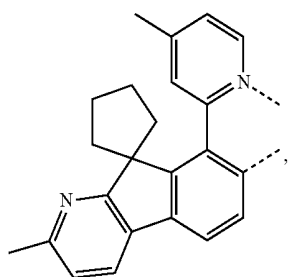
L<sub>4269</sub>

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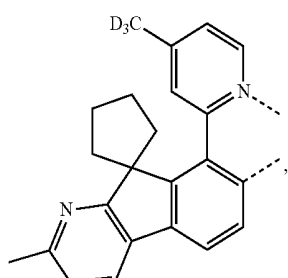
L<sub>4270</sub>

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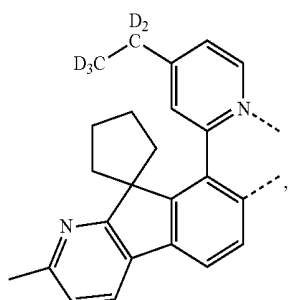
L<sub>4271</sub>

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L<sub>4272</sub>

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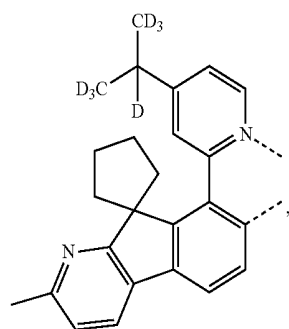


L<sub>4273</sub>

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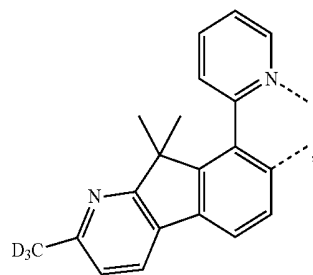
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**118**  
-continued



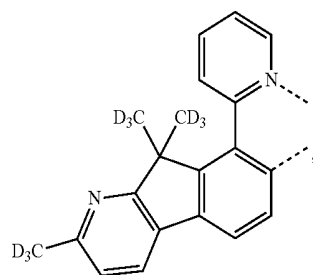
L<sub>4274</sub>

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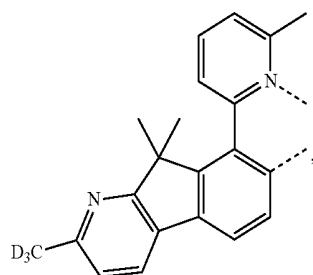
L<sub>4275</sub>

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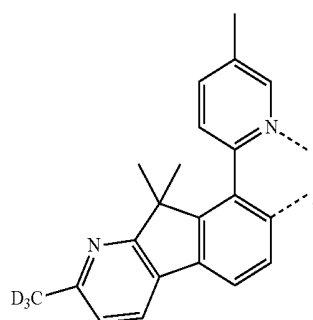
L<sub>4276</sub>

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L<sub>4277</sub>

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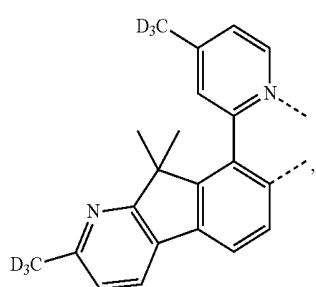
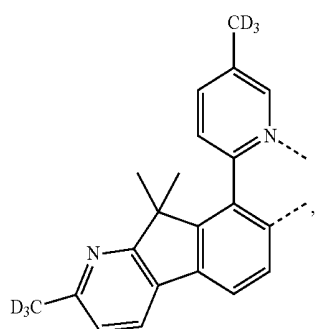
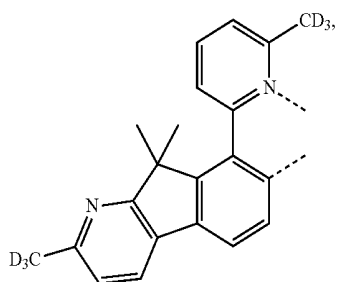
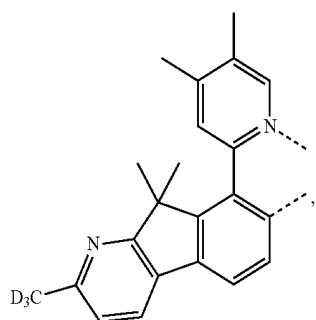
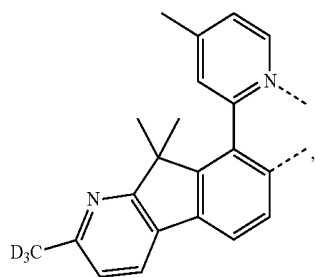
L<sub>4278</sub>

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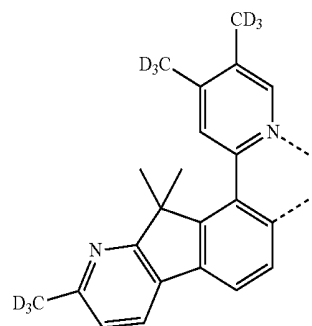
**119**  
-continued



**120**  
-continued

L<sub>4279</sub>

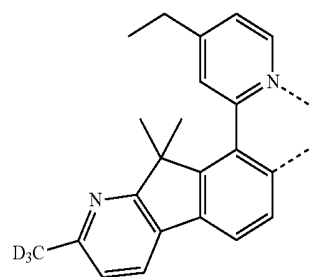
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L<sub>4284</sub>

L<sub>4280</sub>

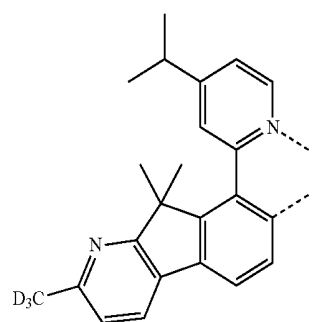
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L<sub>4285</sub>

L<sub>4281</sub>

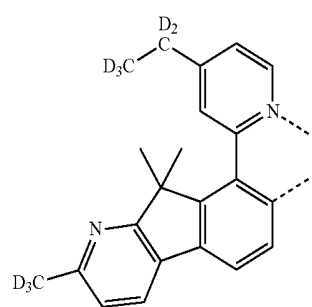
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L<sub>4286</sub>

L<sub>4282</sub>

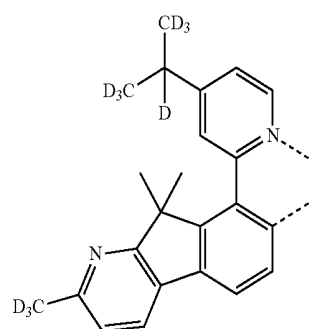
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L<sub>4287</sub>

L<sub>4283</sub>

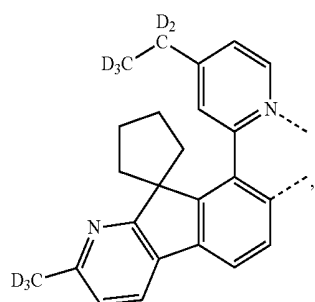
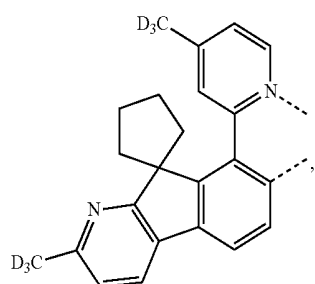
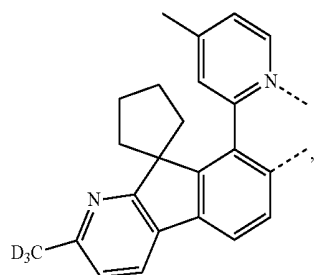
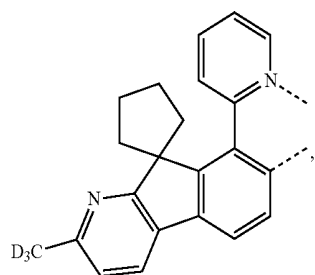
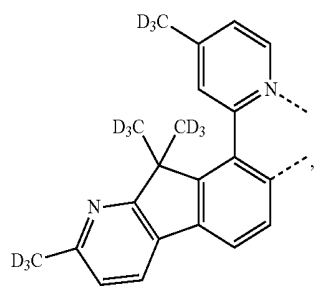
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L<sub>4288</sub>

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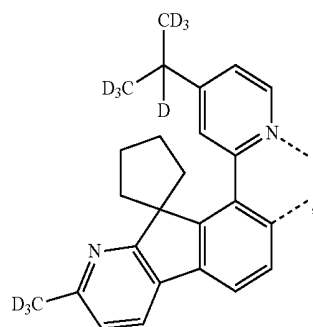
**121**  
-continued



**122**  
-continued

L<sub>4289</sub>

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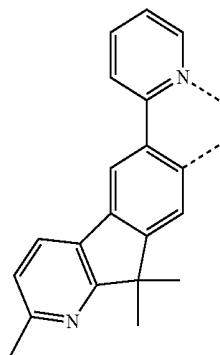
L<sub>4294</sub>

L<sub>4290</sub>

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L<sub>4291</sub>

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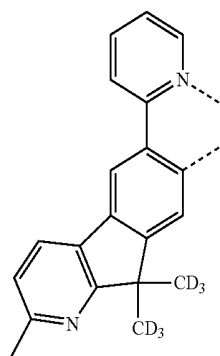


L<sub>4295</sub>

L<sub>4292</sub>

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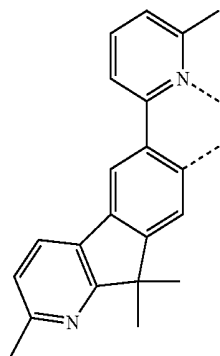
L<sub>4296</sub>

L<sub>4293</sub>

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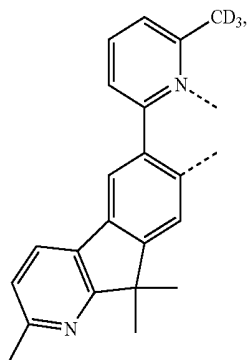
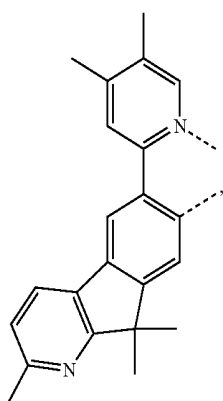
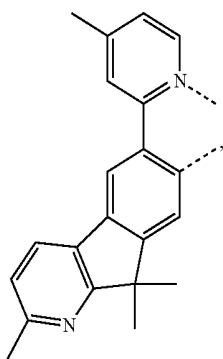
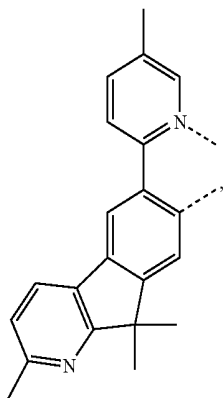
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L<sub>4297</sub>

**123**  
-continued



**124**  
-continued

L<sub>4298</sub>

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L<sub>4299</sub>

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L<sub>4300</sub>

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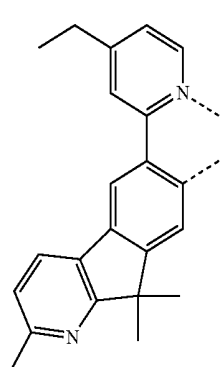
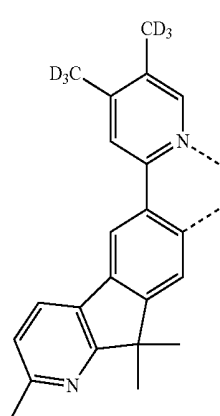
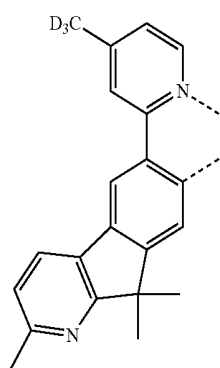
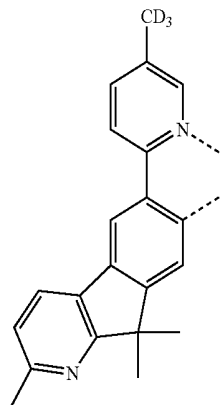
L<sub>4301</sub>

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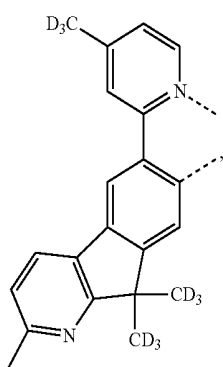
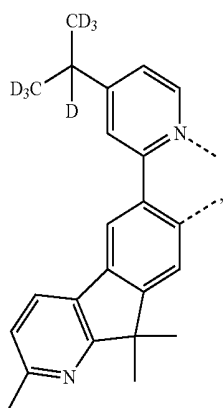
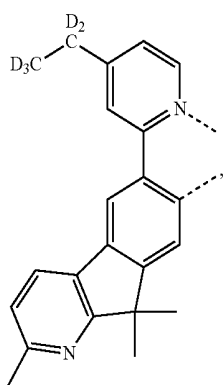
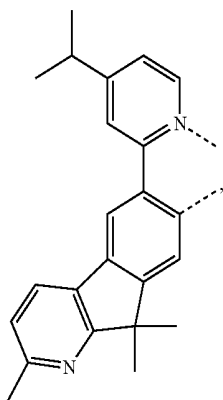
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L<sub>4302</sub>



**125**  
-continued



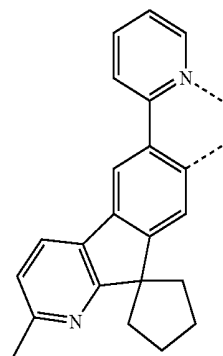
**126**  
-continued

L<sub>A306</sub>

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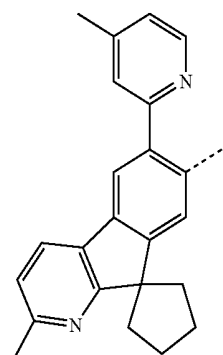
L<sub>A310</sub>

L<sub>A307</sub>

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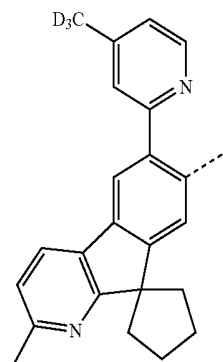
L<sub>A311</sub>

L<sub>A308</sub>

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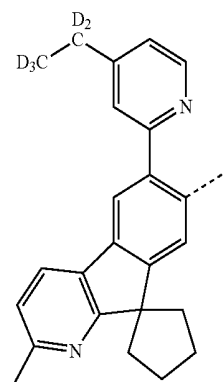
L<sub>A312</sub>

L<sub>A309</sub>

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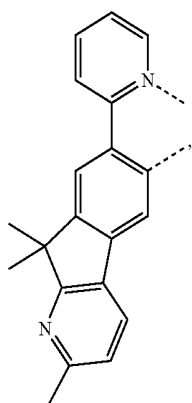
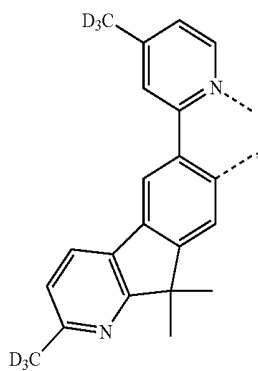
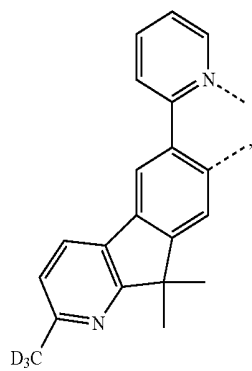
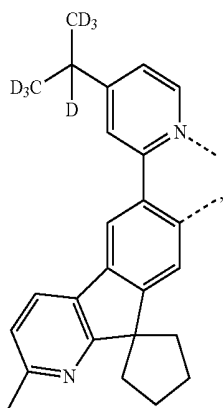
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L<sub>A313</sub>

**127**  
-continued



**128**  
-continued

L<sub>A314</sub>

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L<sub>A315</sub>

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L<sub>A316</sub>

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L<sub>A317</sub>

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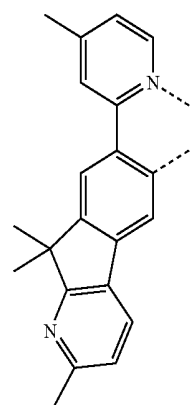
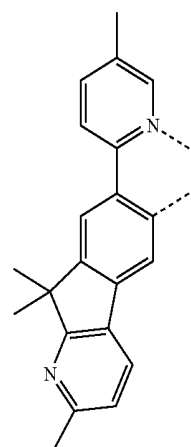
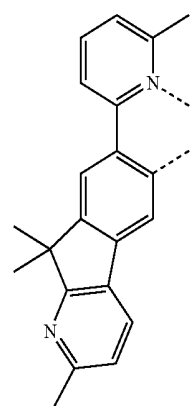
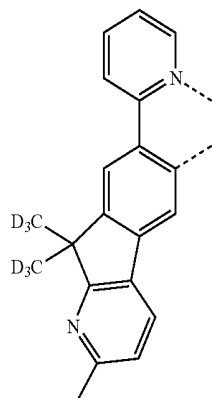
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L<sub>A318</sub>

L<sub>A319</sub>

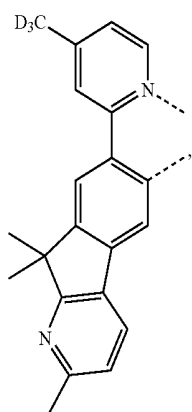
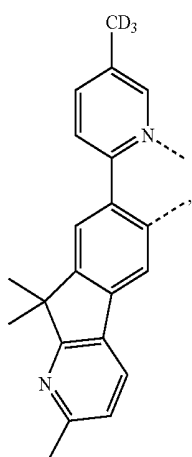
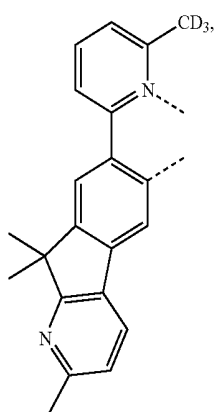
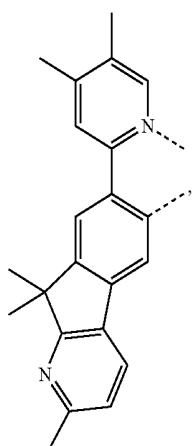
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L<sub>A321</sub>



129

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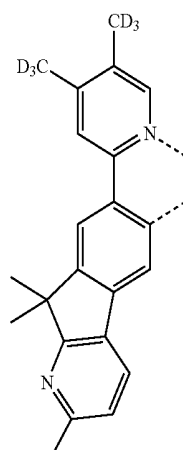


130

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L<sub>4322</sub>

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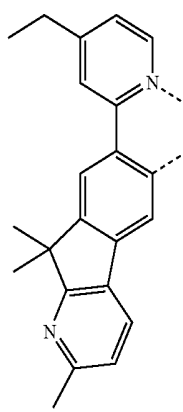


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L<sub>4323</sub>

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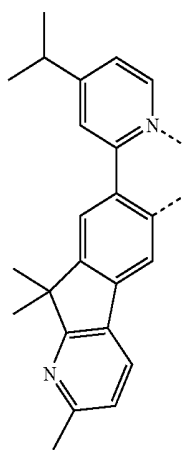


L<sub>4327</sub>

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L<sub>4324</sub>

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L<sub>4328</sub>

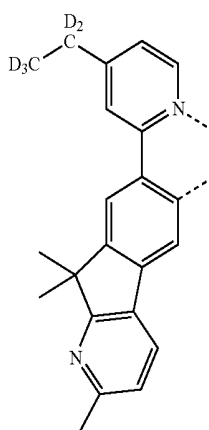
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L<sub>4325</sub>

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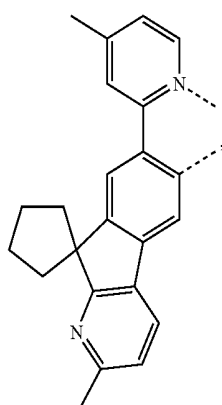
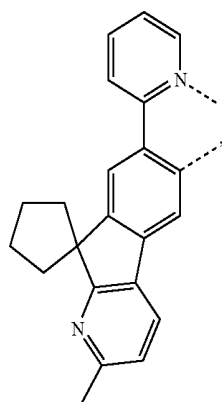
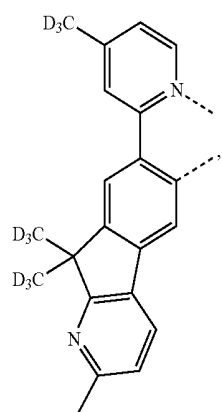
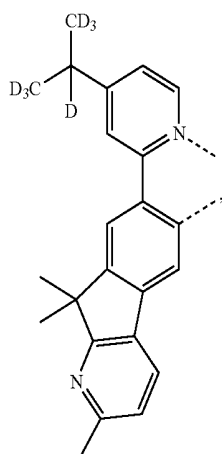


L<sub>4329</sub>

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**131**  
-continued



**132**  
-continued

L<sub>4330</sub>

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L<sub>4331</sub>

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L<sub>4332</sub>

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L<sub>4333</sub>

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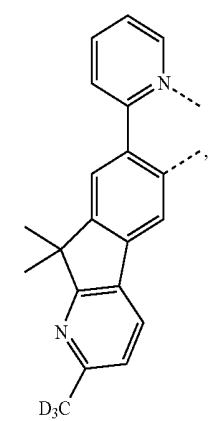
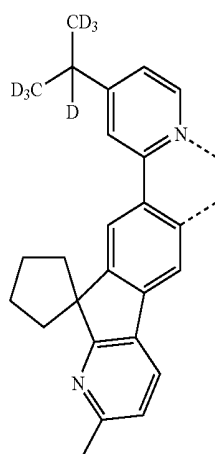
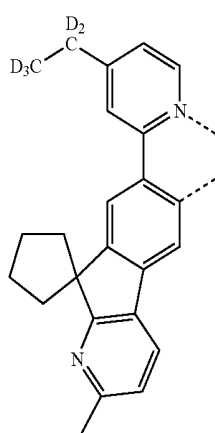
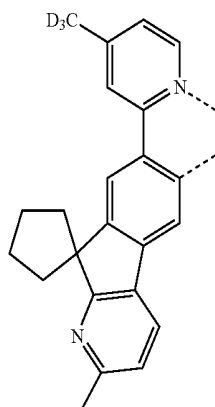
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L<sub>4334</sub>

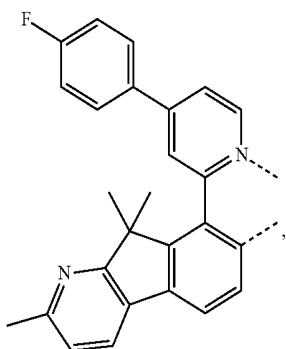
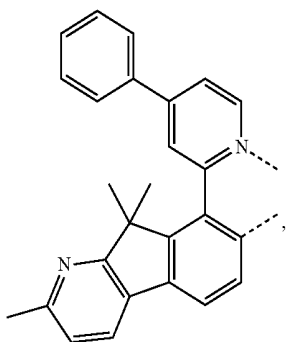
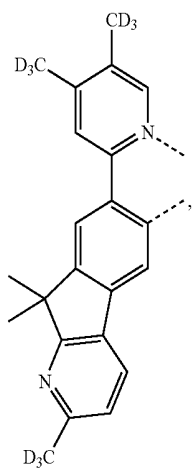
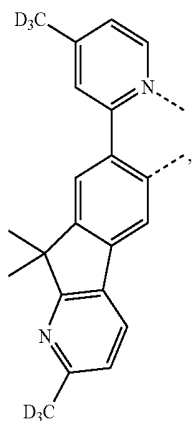
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L<sub>4336</sub>

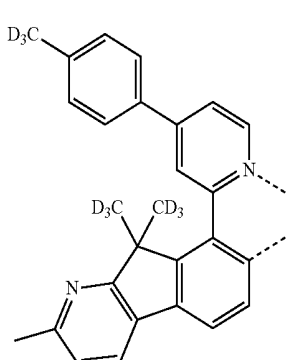
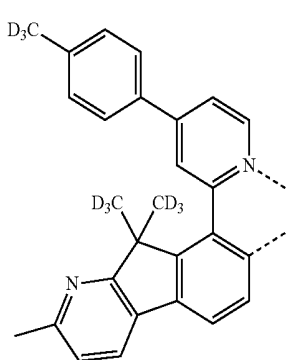
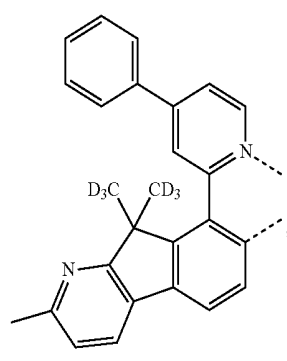
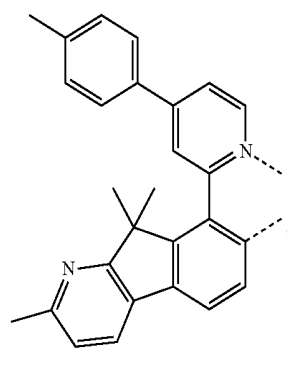
L<sub>4337</sub>



**133**  
-continued



**134**  
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L<sub>A338</sub>

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L<sub>A339</sub>

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L<sub>A340</sub>

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L<sub>A341</sub>

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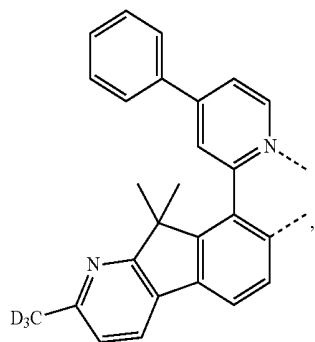
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L<sub>A343</sub>

L<sub>A344</sub>

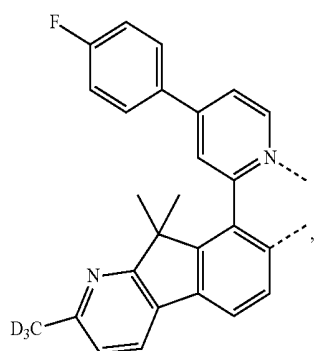
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**135**  
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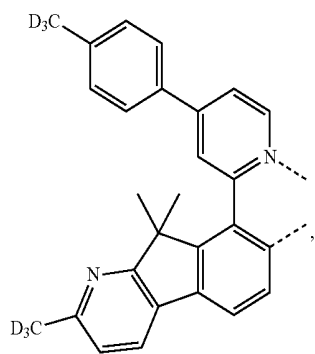
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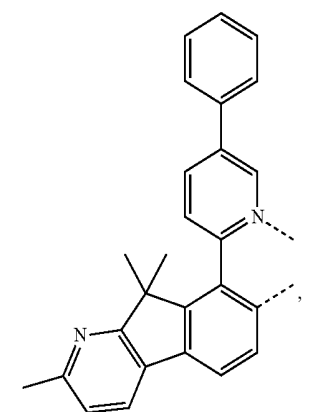
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L<sub>A348</sub>

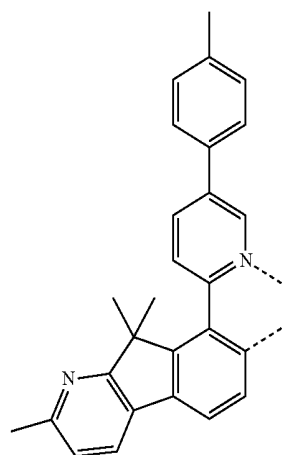
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L<sub>A349</sub>

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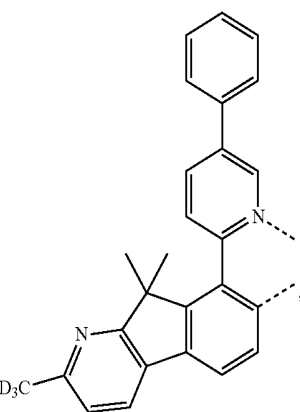
**136**  
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L<sub>A350</sub>

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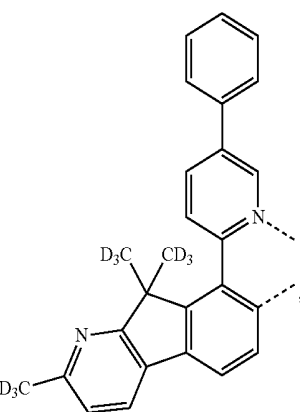
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L<sub>A352</sub>

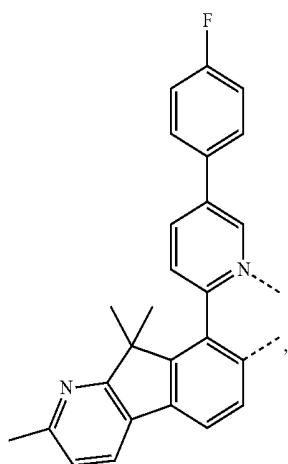
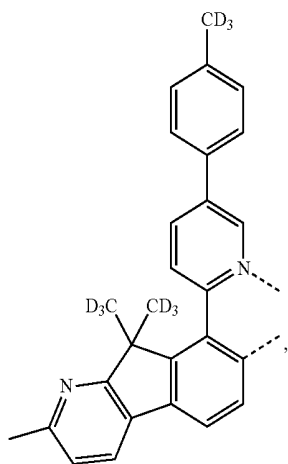
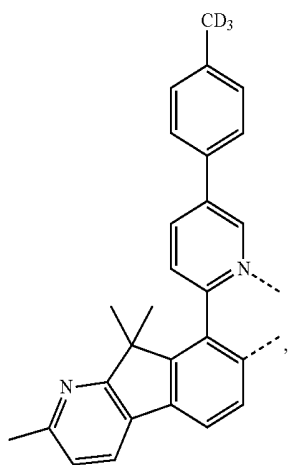
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**137**  
-continued



L<sub>4353</sub>

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L<sub>4354</sub>

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L<sub>4355</sub>

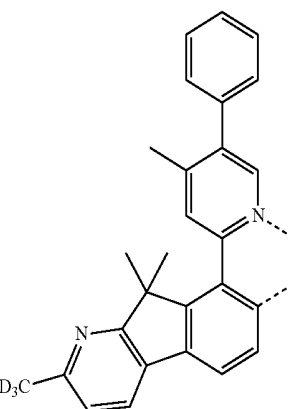
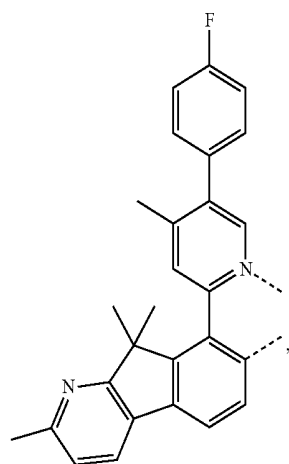
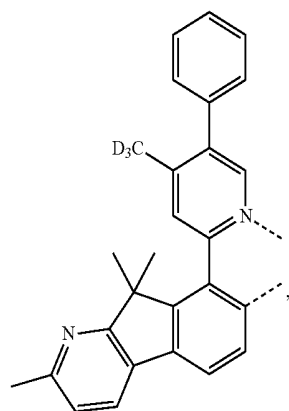
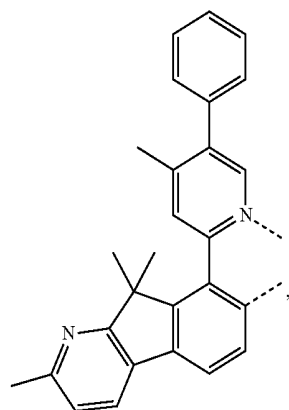
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**138**  
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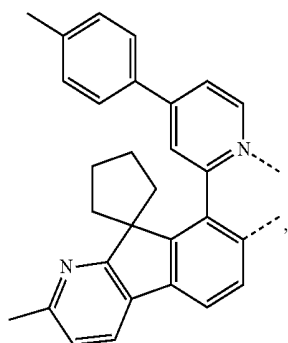
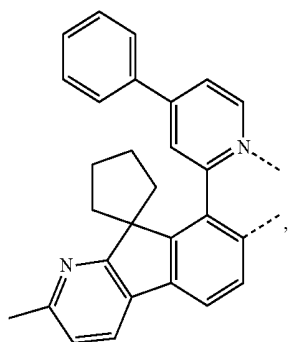
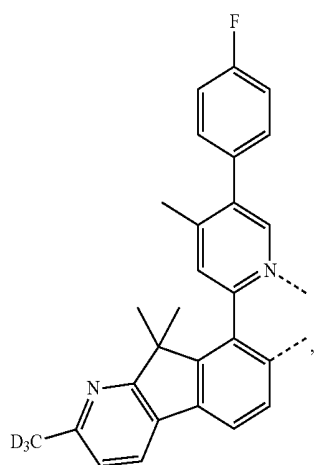
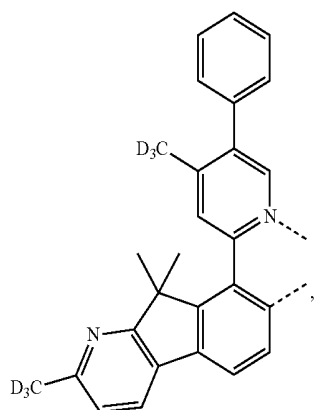
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L<sub>4357</sub>

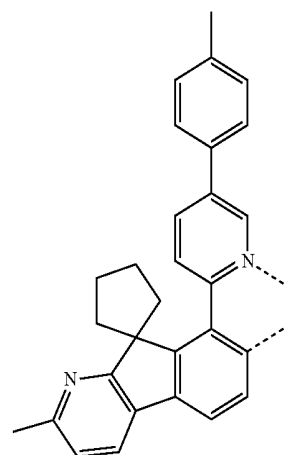
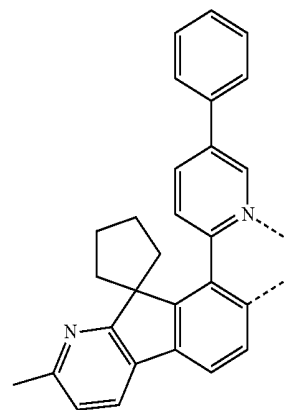
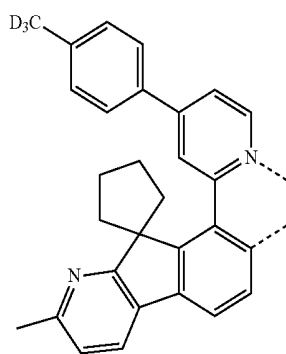
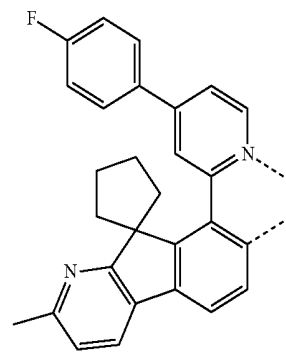
L<sub>4358</sub>

L<sub>4359</sub>

**139**  
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**140**  
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L<sub>A360</sub>

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L<sub>A361</sub>

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L<sub>A362</sub>

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L<sub>A363</sub>

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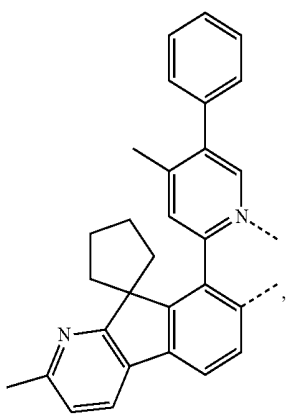
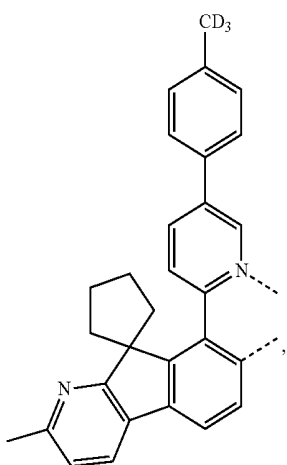
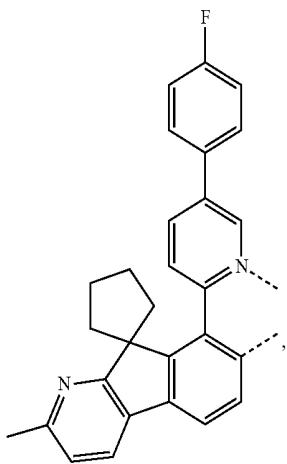
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L<sub>A366</sub>

L<sub>A367</sub>

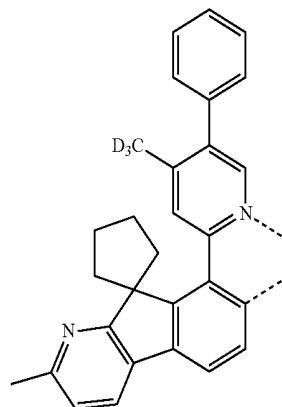
**141**  
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**142**  
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L<sub>A371</sub>

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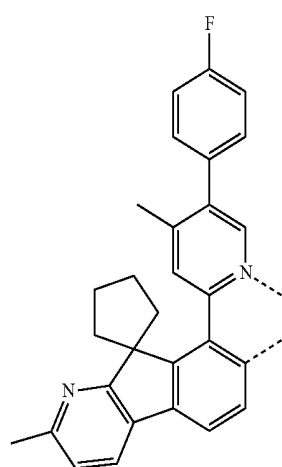
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L<sub>A369</sub>

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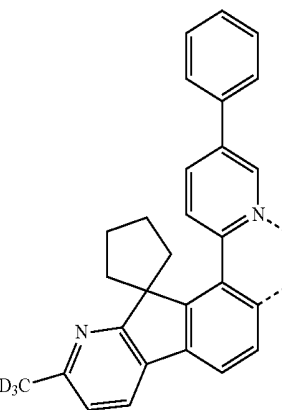
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L<sub>A370</sub>

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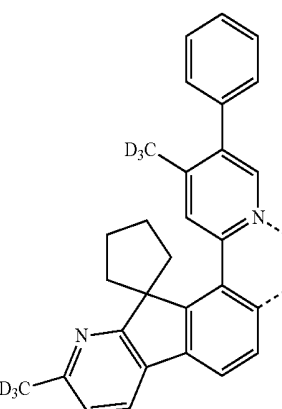


L<sub>A373</sub>

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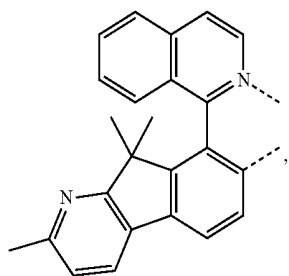
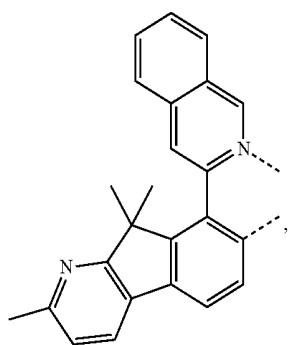
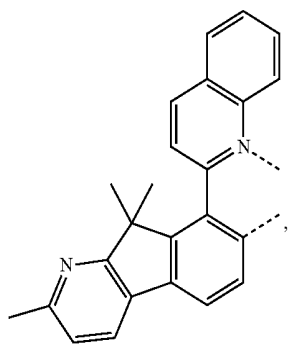
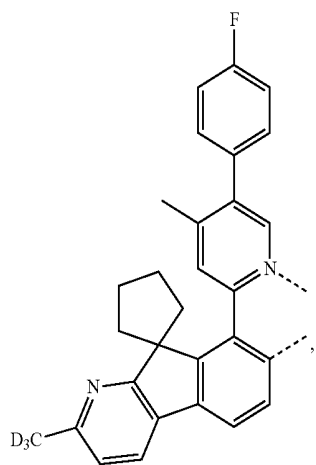
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L<sub>A374</sub>

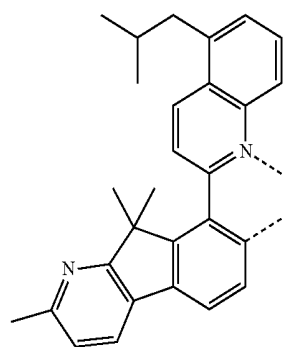
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**144**  
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L<sub>4375</sub>

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L<sub>4379</sub>

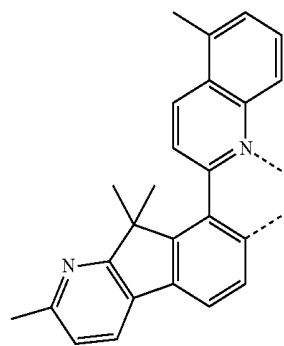
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L<sub>4376</sub>

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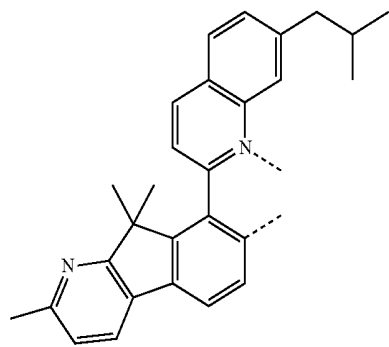
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L<sub>4377</sub>

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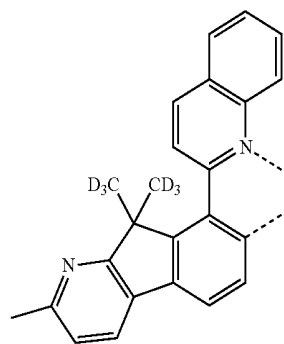
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L<sub>4378</sub>

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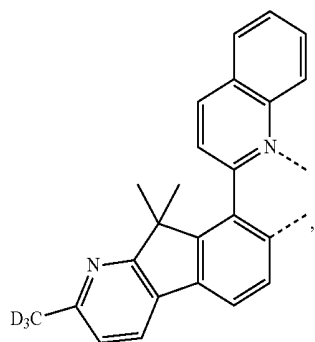


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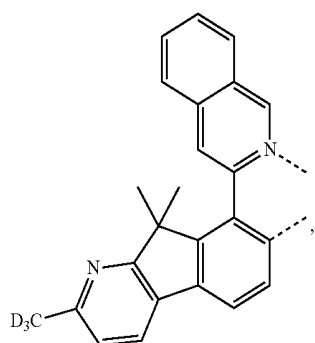
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**145**  
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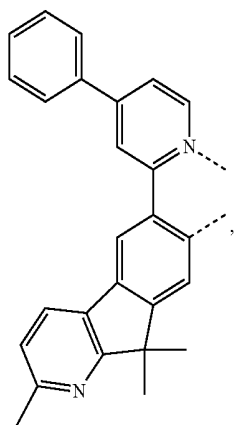
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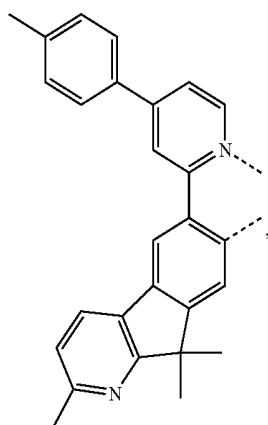
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L<sub>4385</sub>

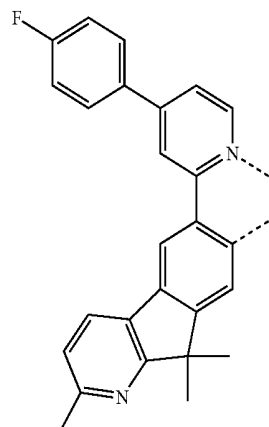
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L<sub>4386</sub>

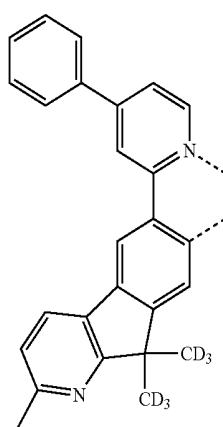
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**146**  
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L<sub>4387</sub>

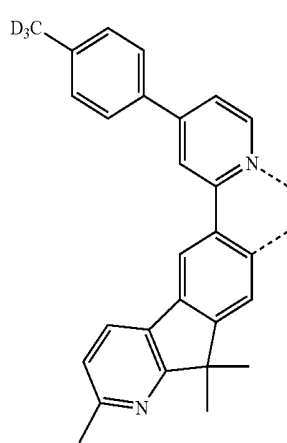
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L<sub>4388</sub>

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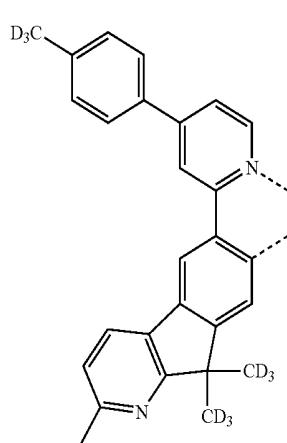
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L<sub>4389</sub>

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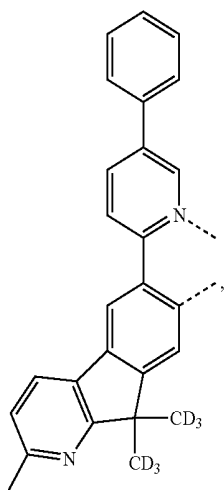
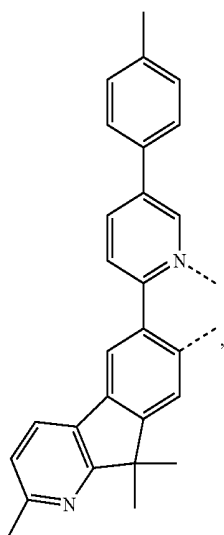
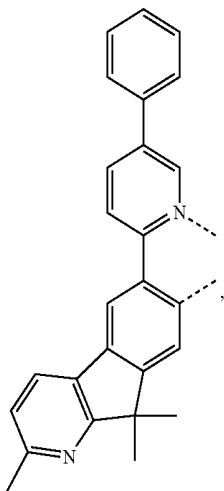
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**147**  
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**148**  
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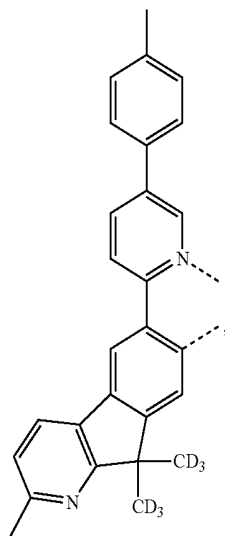
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L<sub>4394</sub>

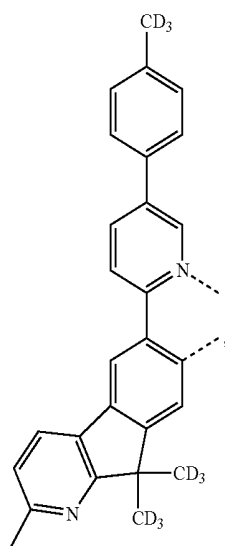
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L<sub>4395</sub>

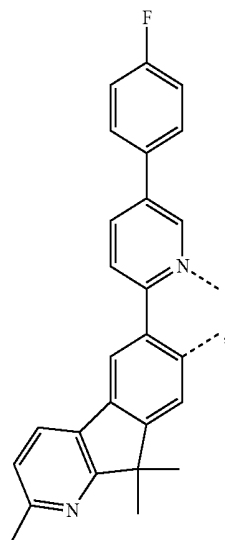
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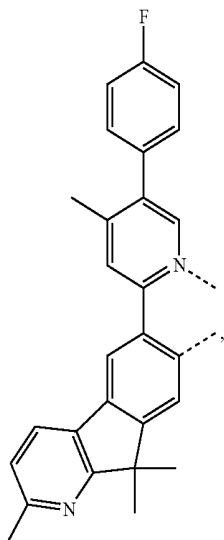
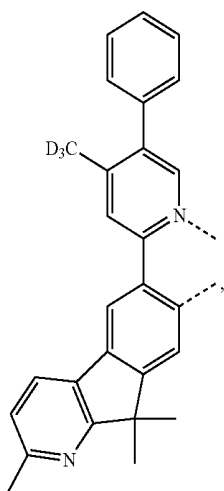
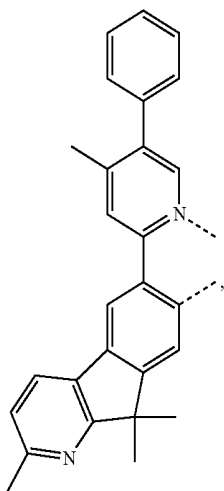
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L<sub>4396</sub>

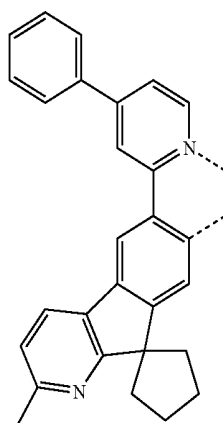
**149**  
-continued



**150**  
-continued

L<sub>4397</sub>

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L<sub>4400</sub>

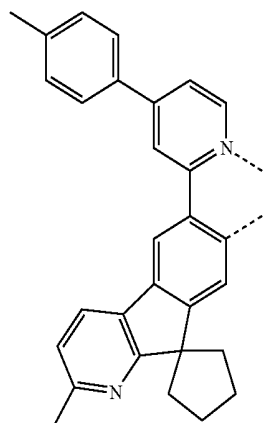
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L<sub>4398</sub>

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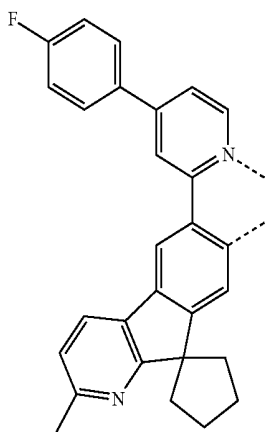
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L<sub>4399</sub>

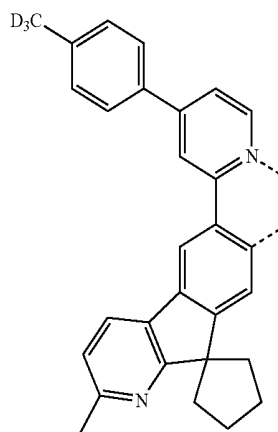
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L<sub>4402</sub>

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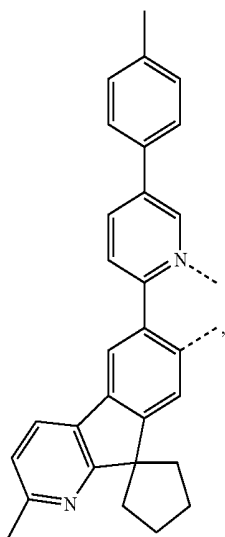
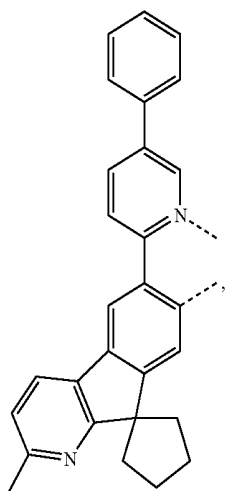
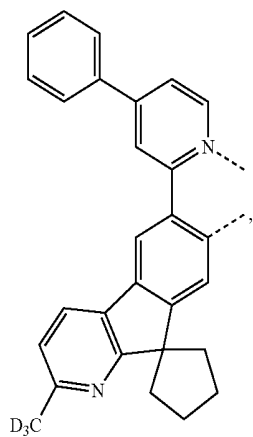


L<sub>4403</sub>

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**151**  
-continued



**152**  
-continued

L<sub>4404</sub>

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L<sub>4405</sub>

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L<sub>4406</sub>

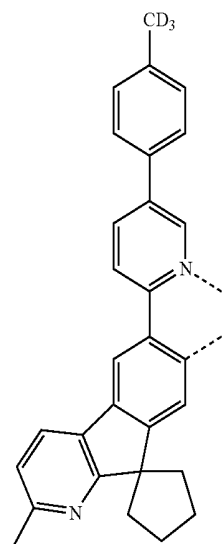
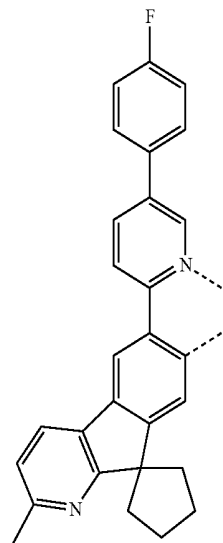
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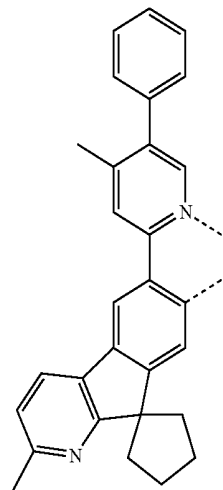
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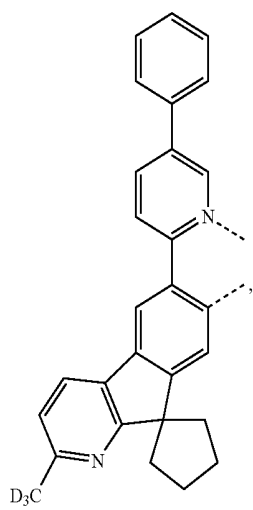
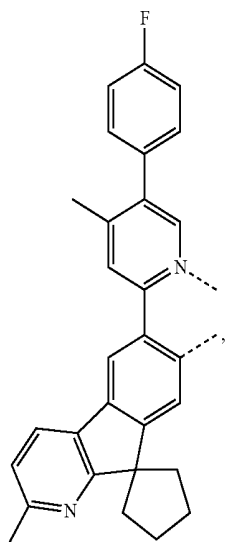
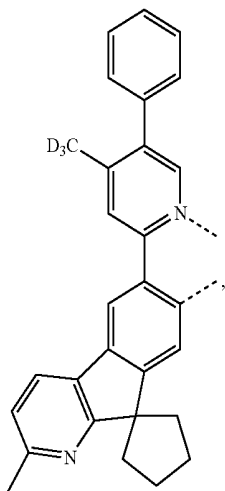


L<sub>4408</sub>

L<sub>4409</sub>



**153**  
-continued



**154**  
-continued

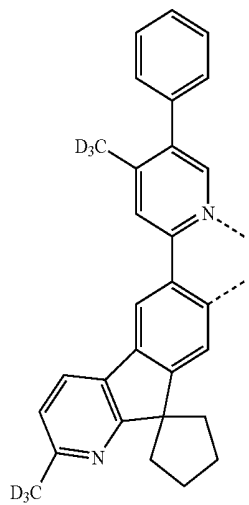
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L<sub>4413</sub>

L<sub>4411</sub>

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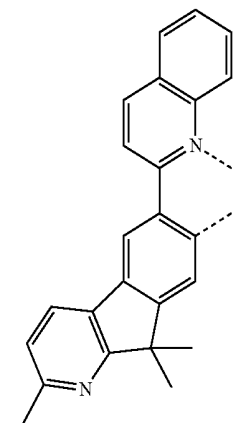
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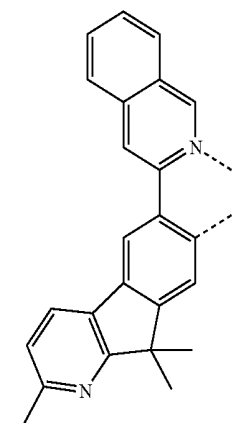
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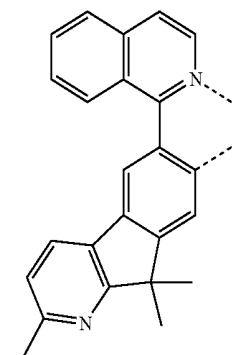


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L<sub>4415</sub>

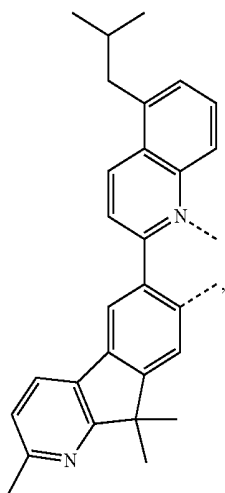


L<sub>4416</sub>



155

-continued



L<sub>4417</sub>

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L<sub>4418</sub>

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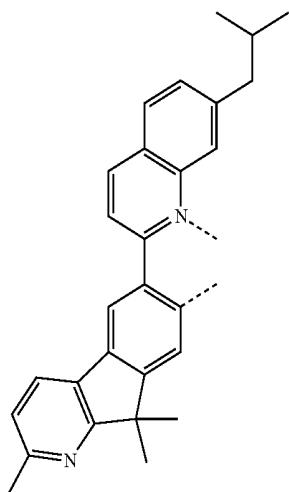
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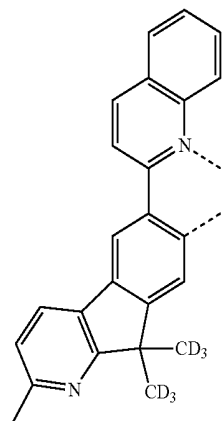
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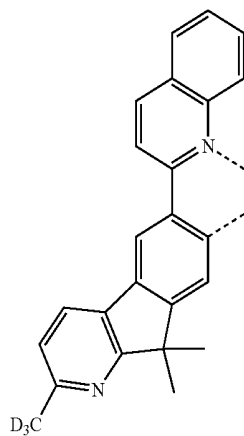


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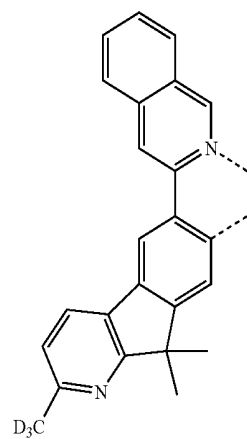
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L<sub>4420</sub>

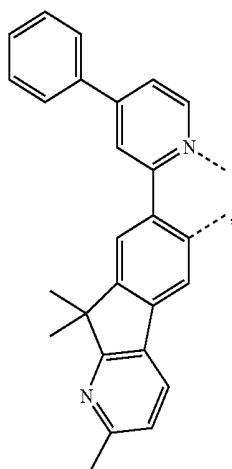


L<sub>4421</sub>



L<sub>4422</sub>

**157**  
-continued



L<sub>4423</sub>

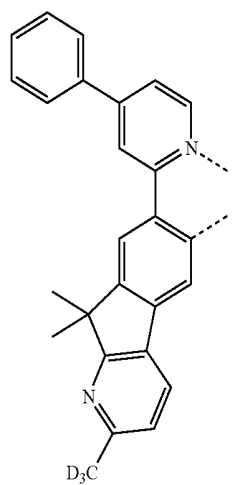
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**158**  
-continued



L<sub>4426</sub>

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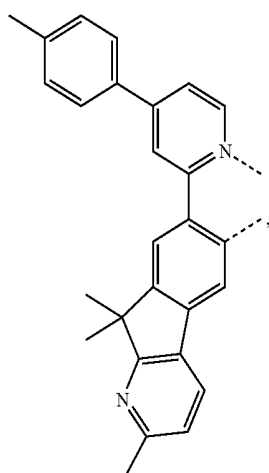
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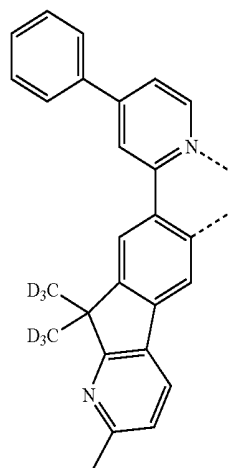
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L<sub>4427</sub>



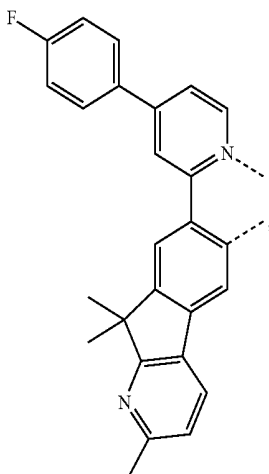
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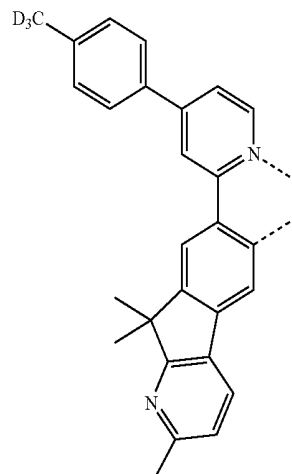
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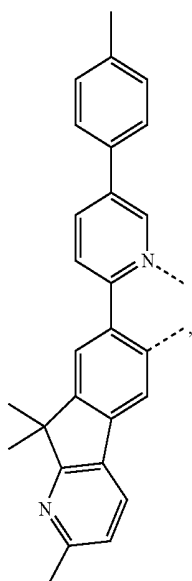
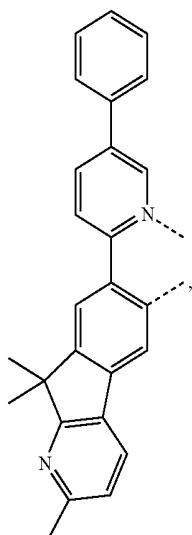
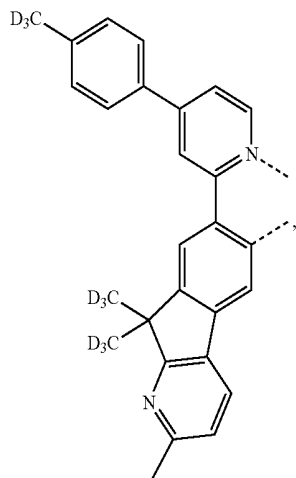
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L<sub>4428</sub>



**159**  
-continued



**160**  
-continued

L<sub>4429</sub>

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L<sub>4430</sub>

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L<sub>4431</sub>

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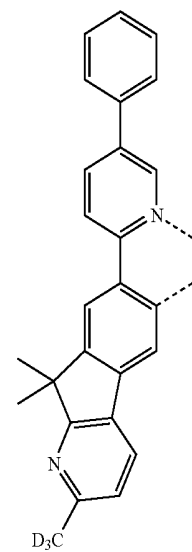
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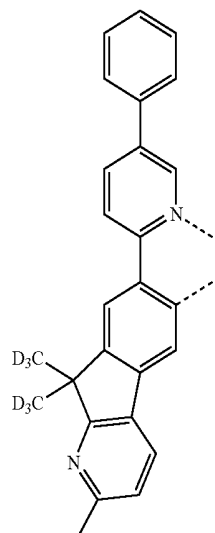
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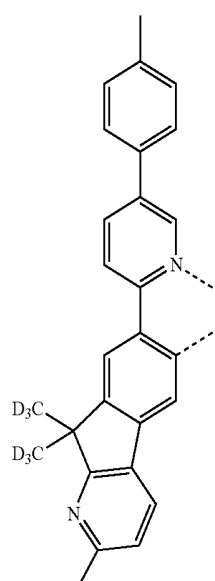
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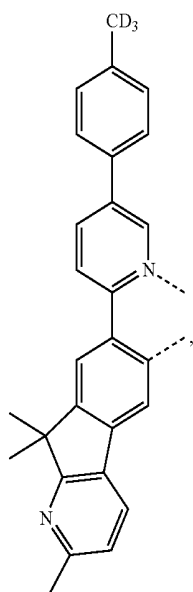
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L<sub>4434</sub>



**161**  
-continued



L<sub>4435</sub>

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L<sub>4436</sub>

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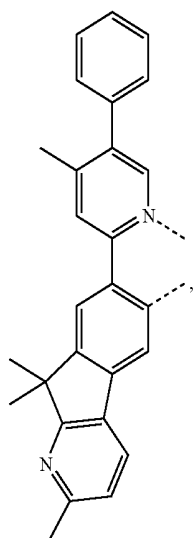
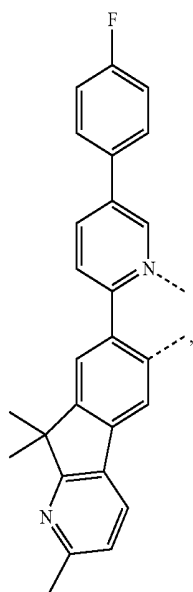
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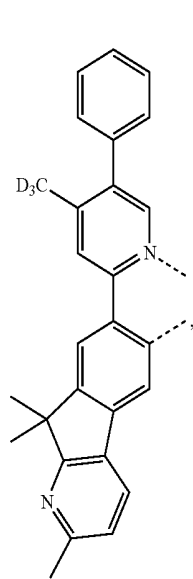
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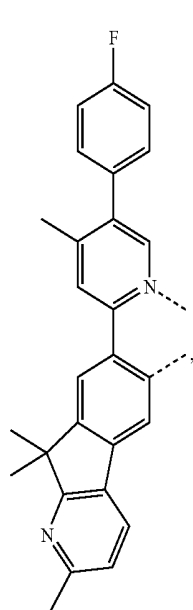
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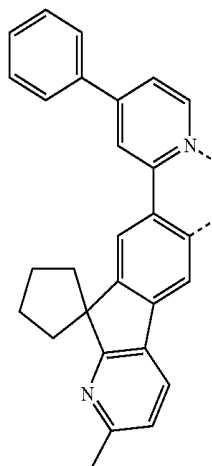
**162**  
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L<sub>4438</sub>

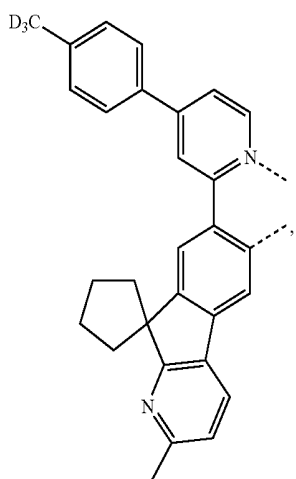
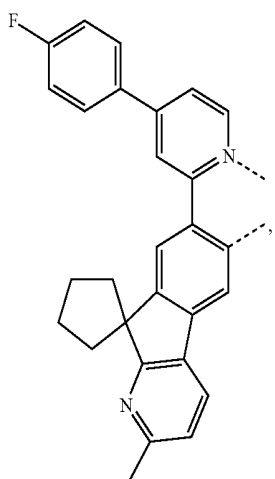
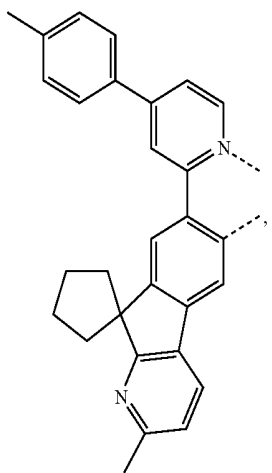


L<sub>4439</sub>



L<sub>4440</sub>

**163**  
-continued



**164**  
-continued

L<sub>441</sub>

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L<sub>442</sub>

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L<sub>443</sub>

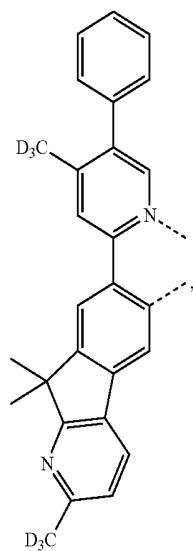
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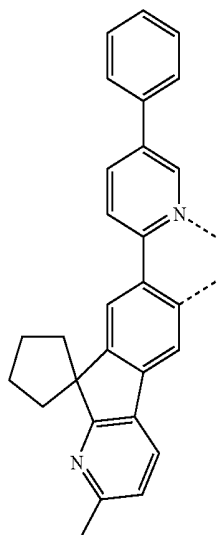
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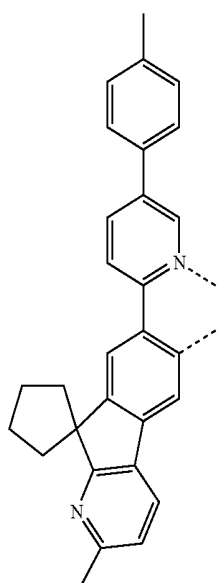
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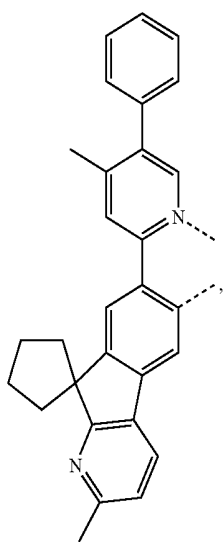
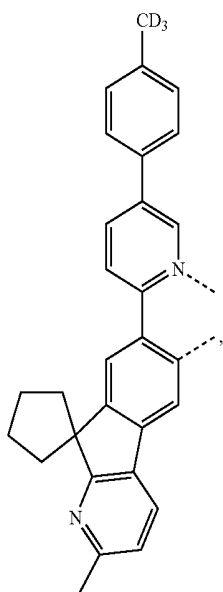
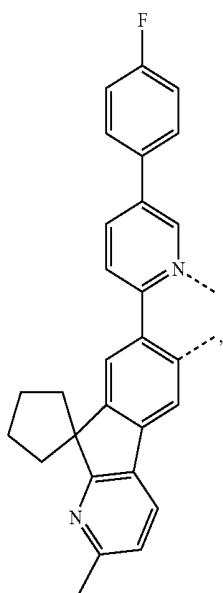
L<sub>445</sub>



L<sub>446</sub>



**165**  
-continued



L<sub>4447</sub>

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L<sub>4448</sub>

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L<sub>4449</sub>

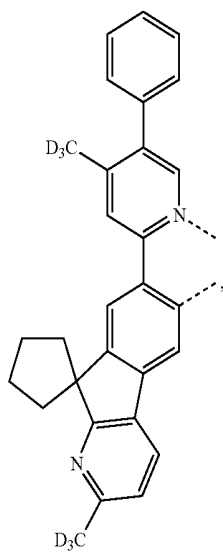
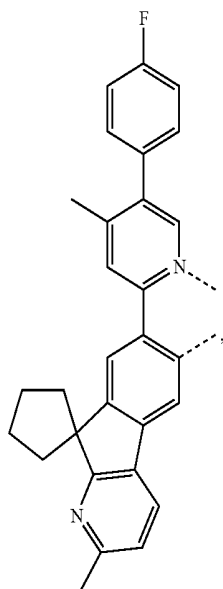
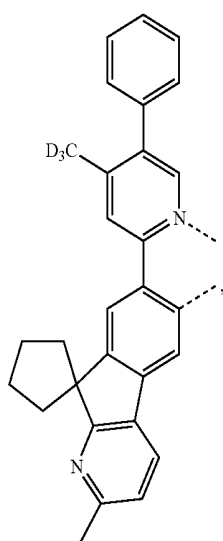
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**166**  
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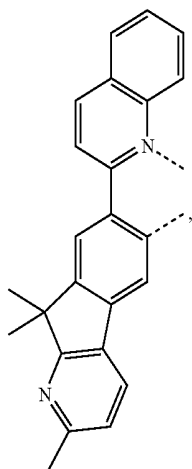


L<sub>4450</sub>

L<sub>4451</sub>

L<sub>4452</sub>

**167**  
-continued



L4453

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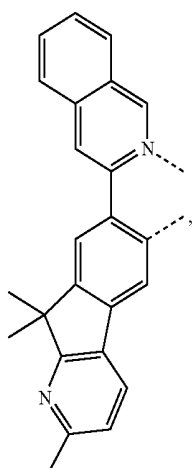
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L4454



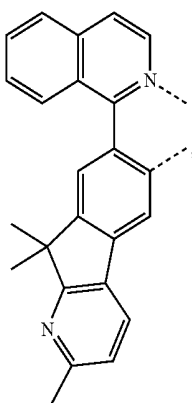
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L4455

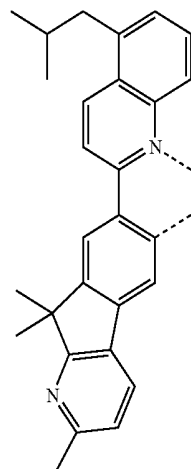


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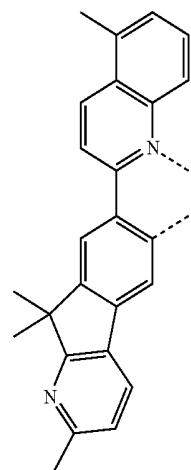
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**168**  
-continued

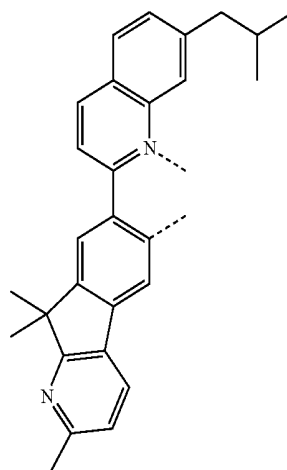


L4456

L4457

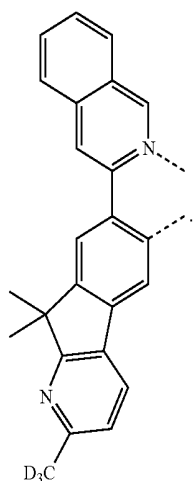
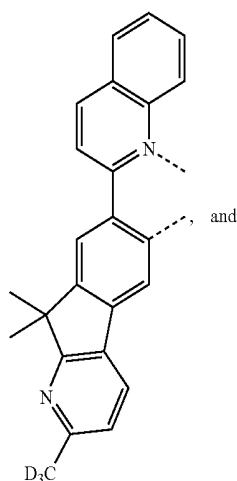
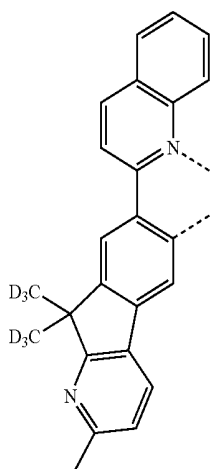


L4458



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-continued



In some embodiments, the compound is selected from the group consisting of Compound 1 through Compound 66,384, where each Compound x has the formula  $\text{Ir}(\text{L}_{Ak})_2(\text{L}_{Bj})_2$ , wherein  $x=461j+k-461$ ,  $k$  is an integer from 1 to 461, and  $j$  is an integer from 1 to 144.

According to another aspect of the present disclosure, a first device is also provided. The first device includes a first organic light emitting device, that includes an anode, a cathode, and an organic layer disposed between the anode

170

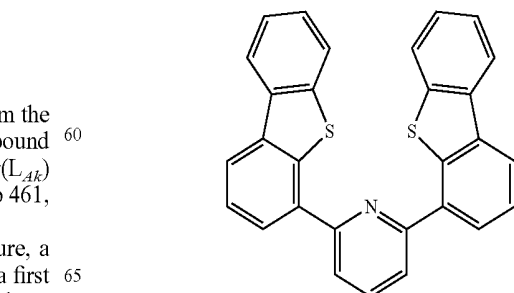
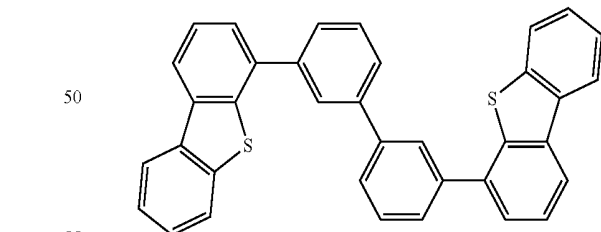
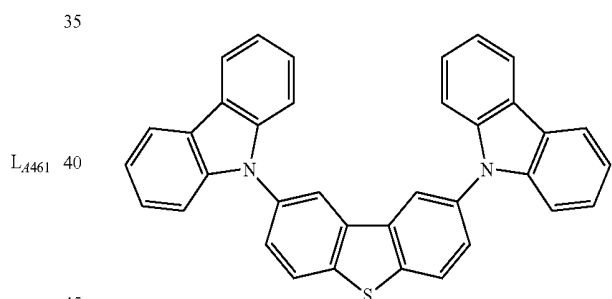
and the cathode. The organic layer may include a host and a phosphorescent dopant. The organic layer can be an emissive layer that includes a compound according to Formula I, and its variations as described herein.

The first device can be one or more of a consumer product, an organic light-emitting device and a lighting panel. The organic layer can be an emissive layer and the compound can be an emissive dopant in some embodiments, while the compound can be a non-emissive dopant in other embodiments.

The organic layer can also include a host. In some embodiments, the host can include a metal complex. The host can be a triphenylene containing benzo-fused thiophene or benzo-fused furan. Any substituent in the host can be an unfused substituent independently selected from the group consisting of  $\text{C}_n\text{H}_{2n+1}$ ,  $\text{OC}_n\text{H}_{2n+1}$ ,  $\text{OAr}_1$ ,  $\text{N}(\text{C}_n\text{H}_{2n+1})_2$ ,  $\text{N}(\text{Ar}_1)(\text{Ar}_2)$ ,  $\text{CH}=\text{CH}-\text{C}_n\text{H}_{2n+1}$ ,  $\text{C}\equiv\text{C}-\text{C}_n\text{H}_{2n+1}$ ,  $\text{Ar}_1$ ,  $\text{Ar}_1-\text{Ar}_2$ , and  $\text{C}_n\text{H}_{2n}-\text{Ar}_1$ , or no substitution. In the preceding substituents  $n$  can range from 1 to 10; and  $\text{Ar}_1$  and  $\text{Ar}_2$  can be independently selected from the group consisting of benzene, biphenyl, naphthalene, triphenylene, carbazole, and heteroaromatic analogs thereof.

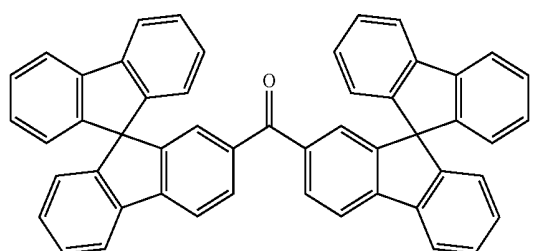
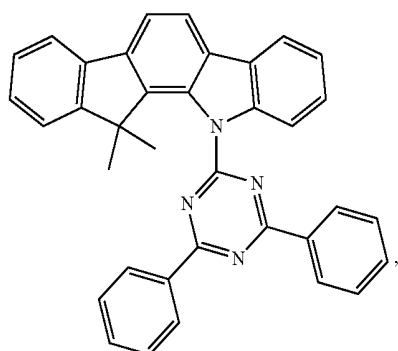
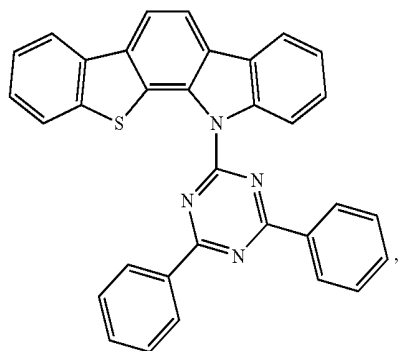
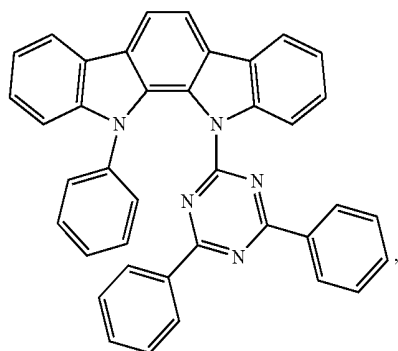
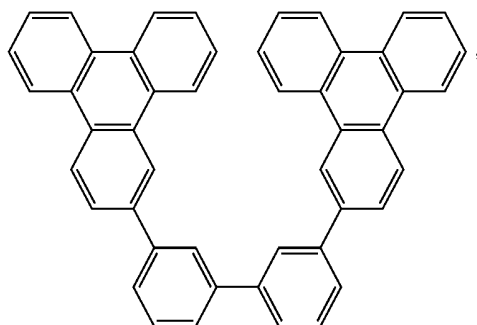
The host can be a compound comprising at least one chemical group selected from the group consisting of triphenylene, carbazole, dibenzothiophene, dibenzofuran, dibenzoselenophene, azatriphenylene, azacarbazole, aza-dibenzothiophene, aza-dibenzofuran, and aza-dibenzoselenophene.

The host can include a metal complex. The host can be a specific compound selected from the group consisting of:



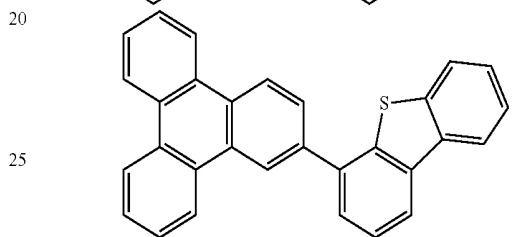
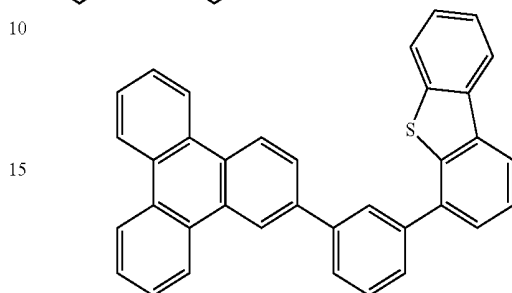
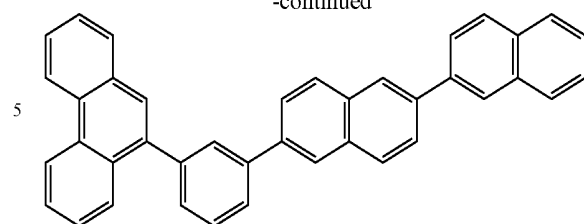
171

-continued



172

-continued



30 and combinations thereof.

In yet another aspect of the present disclosure, a formulation that comprises a compound according to Formula I, and its variations described herein is described. The formulation can include one or more components selected from the group consisting of a solvent, a host, a hole injection material, hole transport material, and an electron transport layer material, disclosed herein.

#### Combination with Other Materials

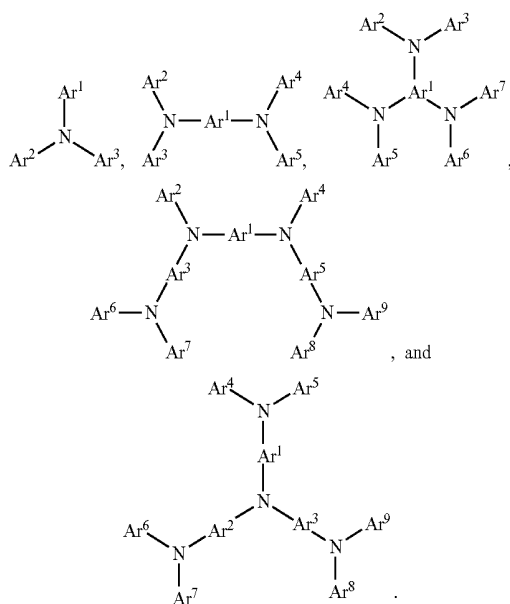
The materials described herein as useful for a particular layer in an organic light emitting device may be used in combination with a wide variety of other materials present in the device. For example, emissive dopants disclosed herein may be used in conjunction with a wide variety of hosts, transport layers, blocking layers, injection layers, electrodes and other layers that may be present. The materials described or referred to below are non-limiting examples of materials that may be useful in combination with the compounds disclosed herein, and one of skill in the art can readily consult the literature to identify other materials that may be useful in combination.

50 HIL/HTL:

A hole injecting/transporting material to be used in the present invention is not particularly limited, and any compound may be used as long as the compound is typically used as a hole injecting/transporting material. Examples of the material include, but not limit to: a phthalocyanine or porphyrin derivative; an aromatic amine derivative; an indolocarbazole derivative; a polymer containing fluorohydrocarbon; a polymer with conductivity dopants; a conducting polymer, such as PEDOT/PSS; a self-assembly monomer derived from compounds such as phosphonic acid and silane derivatives; a metal oxide derivative, such as MoO<sub>3</sub>; a p-type semiconducting organic compound, such as 1,4,5,8,9,12-Hexaazatriphenylenehexacarbonitrile; a metal complex, and a cross-linkable compounds.

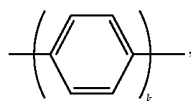
65 Examples of aromatic amine derivatives used in HIL or HTL include, but not limit to the following general structures:

173

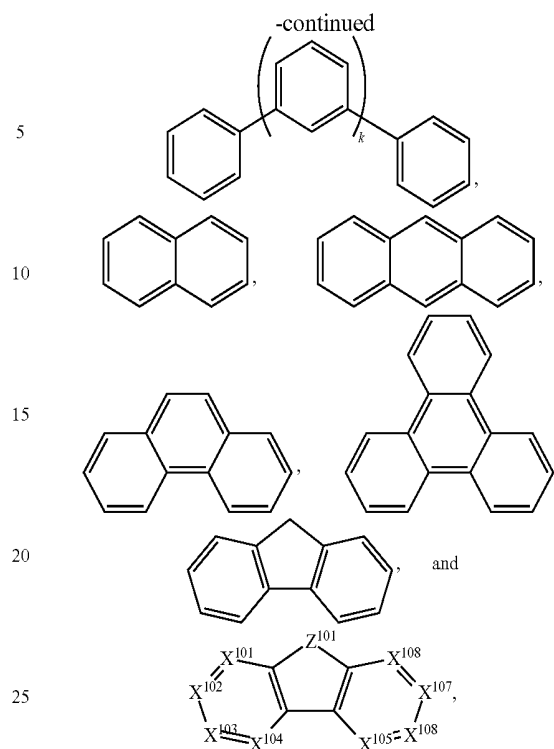


Each of Ar<sup>1</sup> to Ar<sup>9</sup> is selected from the group consisting of aromatic hydrocarbon cyclic compounds such as benzene, biphenyl, triphenyl, triphenylene, naphthalene, anthracene, phenalene, phenanthrene, fluorene, pyrene, chrysene, perylene, and azulene; the group consisting of aromatic heterocyclic compounds such as dibenzothiophene, dibenzofuran, dibenzoselenophene, furan, thiophene, benzofuran, benzothiophene, benzoselenophene, carbazole, indolocarbazole, pyridylindole, pyrrolodipyridine, pyrazole, imidazole, triazole, thiazole, oxadiazole, oxatriazole, dioxazole, thiadiazole, pyridine, pyridazine, pyrimidine, pyrazine, triazine, oxazine, oxathiazine, oxadiazine, indole, benzimidazole, indazole, indoxazine, benzoxazole, benzisoxazole, benzothiazole, quinoline, isoquinoline, cinoline, quinazoline, quinoxaline, naphthyridine, phthalazine, pteridine, xanthene, acridine, phenazine, phenothiazine, phenoxazine, benzofurpyridine, furodipyridine, benzothienopyridine, thienodipyridine, benzoselenophenopyridine, and selenophenodipyridine; and the group consisting of 2 to 10 cyclic structural units which are groups of the same type or different types selected from the aromatic hydrocarbon cyclic group and the aromatic heterocyclic group and are bonded to each other directly or via at least one of oxygen atom, nitrogen atom, sulfur atom, silicon atom, phosphorus atom, boron atom, chain structural unit and the aliphatic cyclic group. Wherein each Ar is further substituted by a substituent selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrite, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In one aspect, Ar<sup>1</sup> to Ar<sup>9</sup> is independently selected from the group consisting of:

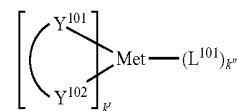


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wherein k is an integer from 1 to 20; X<sup>101</sup> to X<sup>108</sup> is C (including CH) or N; Z<sup>101</sup> is NAr<sup>1</sup>, O, or S; Ar<sup>1</sup> has the same group defined above.

Examples of metal complexes used in HIL or HTL include, but not limit to the following general formula:



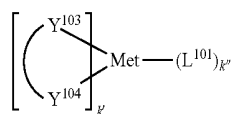
wherein Met is a metal, which can have an atomic weight greater than 40; (Y<sup>101</sup>-Y<sup>102</sup>) is a bidentate ligand, Y<sup>101</sup> and Y<sup>102</sup> are independently selected from C, N, Ca, P, and S; L<sup>101</sup> is an ancillary ligand; k' is an integer value from 1 to the maximum number of ligands that may be attached to the metal; and k'+k'' is the maximum number of ligands that may be attached to the metal.

In one aspect, (Y<sup>101</sup>-Y<sup>102</sup>) is a 2-phenylpyridine derivative. In another aspect, (Y<sup>101</sup>-Y<sup>102</sup>) is a carbene ligand. In another aspect, Met is selected from Ir, Pt, Os, and Zn. In a further aspect, the metal complex has a smallest oxidation potential in solution vs. Fe<sup>3+</sup>/Fe couple less than about 0.6 V. Host:

The light emitting layer of the organic EL device of the present invention preferably contains at least a metal complex as light emitting material, and may contain a host material using the metal complex as a dopant material. Examples of the host material are not particularly limited, and any metal complexes or organic compounds may be used as long as the triplet energy of the host is larger than that of the dopant. While the Table below categorizes host materials as preferred for devices that emit various colors, any host material may be used with any dopant so long as the triplet criteria is satisfied.

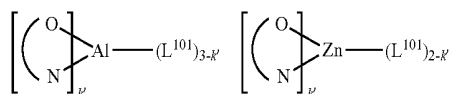
Examples of metal complexes used as host are preferred to have the following general formula:

175



wherein Met is a metal; (Y<sup>103</sup>-Y<sup>104</sup>) is a bidentate ligand, Y<sup>103</sup> and Y<sup>104</sup> are independently selected from C, N, O, P, and S; L<sup>101</sup> is an another ligand; k' is an integer value from 1 to the maximum number of ligands that may be attached to the metal; and k'+k'' is the maximum number of ligands that may be attached to the metal.

In one aspect, the metal complexes are:

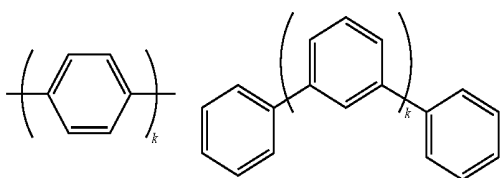


wherein (O—N) is a bidentate ligand, having metal coordinated to atoms O and N.

In another aspect, Met is selected from Ir and Pt. In a further aspect, (Y<sup>103</sup>-Y<sup>104</sup>) is a carbene ligand.

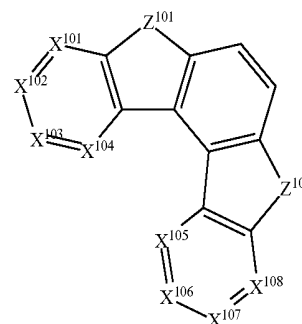
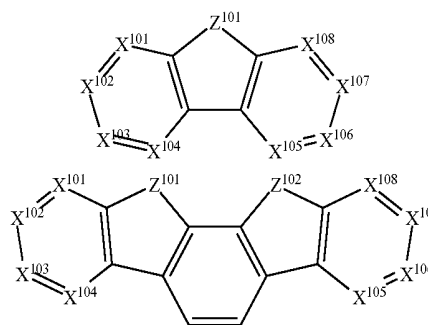
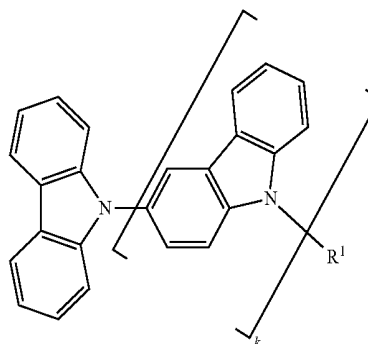
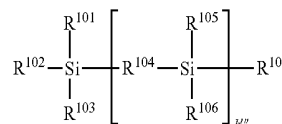
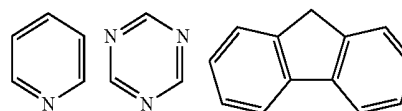
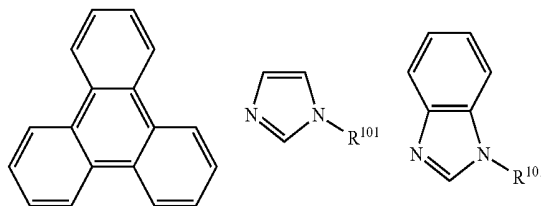
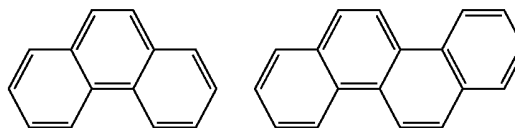
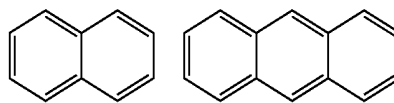
Examples of organic compounds used as host are selected from the group consisting of aromatic hydrocarbon cyclic compounds such as benzene, biphenyl, triphenyl, triphenylene, naphthalene, anthracene, phenalene, phenanthrene, fluorene, pyrene, chrysene, perylene, and azulene; the group consisting of aromatic heterocyclic compounds such as dibenzothiophene, dibenzofuran, dibenzoselenophene, furan, thiophene, benzofuran, benzothiophene, benzoselenophene, carbazole, indolocarbazole, pyridylindole, pyrrolodipyridine, pyrazole, imidazole, triazole, oxazole, thiazole, oxadiazole, oxatriazole, dioxazole, thiadiazole, pyridine, pyridazine, pyrimidine, pyrazine, triazine, oxazine, oxathiazine, oxadiazine, benzimidazole, indazole, indoxazine, benzoxazole, benzisoxazole, benzothiazole, quinine, isoquinoline, cinnoline, quinazoline, quinoxaline, naphthyridine, phthalazine, pteridine, xanthene, acridine, phenazine, phenothiazine, phenoxazine, benzofuropridine, benzothienopyridine, thienodipyridine, benzoselenophenopyridine, and selenophenodipyridine; and the group consisting of 2 to 10 cyclic structural units which are groups of the same type or different types selected from the aromatic hydrocarbon cyclic group and the aromatic heterocyclic group and are bonded to each other directly or via at least one of oxygen atom, nitrogen atom, sulfur atom, silicon atom, phosphorus atom, boron atom, chain structural unit and the aliphatic cyclic group. Wherein each group is further substituted by a substituent selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkenyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In one aspect, host compound contains at least one of the following groups in the molecule:

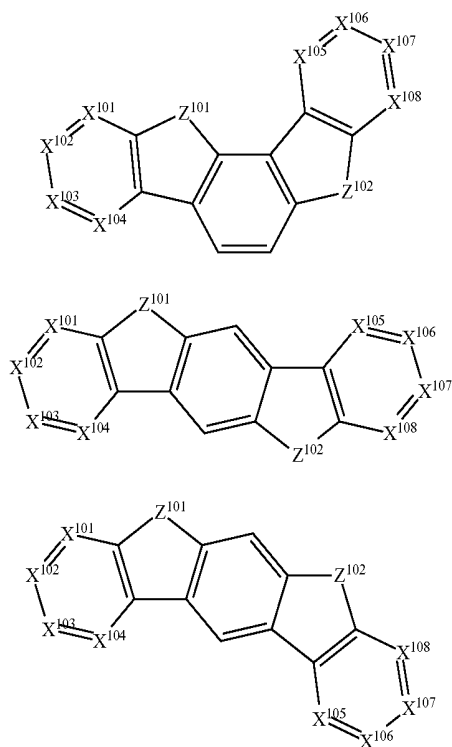


176

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177  
-continued



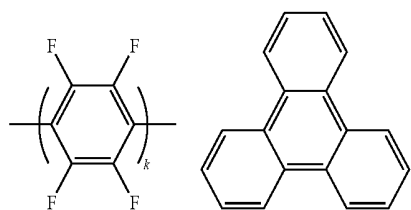
wherein  $R^{101}$  to  $R^{107}$  is independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, when it is aryl or heteroaryl, it has the similar definition as Ar's mentioned above.  $k$  is an integer from 0 to 20 or 1 to 20;  $k''$  is an integer from 0 to 20.  $X^{101}$  to  $X^{108}$  is selected from C (including CH) or N.  $Z^{101}$  and  $Z^{102}$  is selected from  $NR^{101}$ , O, or S.

HBL:

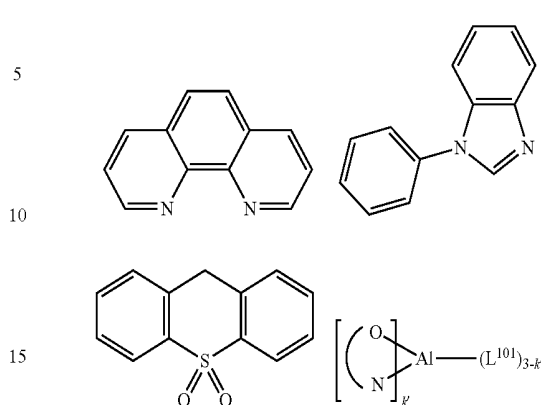
A hole blocking layer (HBL) may be used to reduce the number of holes and/or excitons that leave the emissive layer. The presence of such a blocking layer in a device may result in substantially higher efficiencies as compared to a similar device lacking a blocking layer. Also, a blocking layer may be used to confine emission to a desired region of an OLED.

In one aspect, compound used in HBL, contains the same molecule or the same functional groups used as host described above.

In another aspect, compound used in HBL contains at least one of the following groups in the molecule:



178  
-continued

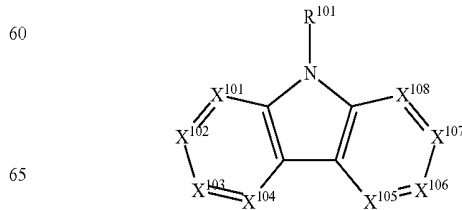
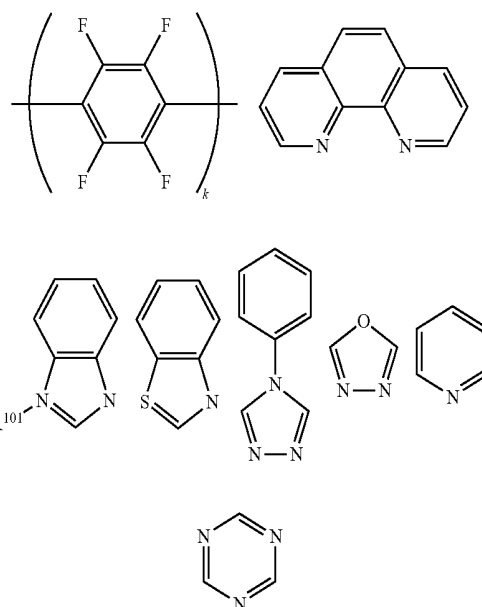


wherein  $k$  is an integer from 1 to 20;  $L^{101}$  is another ligand,  $k'$  is an integer from 1 to 3.

ETL:

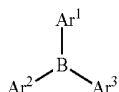
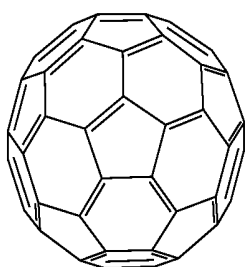
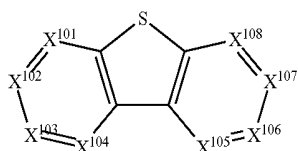
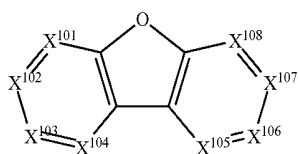
Electron transport layer (ETL) may include a material capable of transporting electrons. Electron transport layer may be intrinsic (undoped), or doped. Doping may be used to enhance conductivity. Examples of the ETL material are not particularly limited, and any metal complexes or organic compounds may be used as long as they are typically used to transport electrons.

In one aspect, compound used in ETL contains at least one of the following groups in the molecule:



179

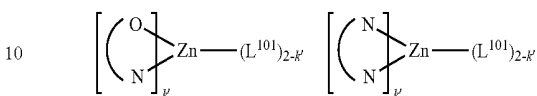
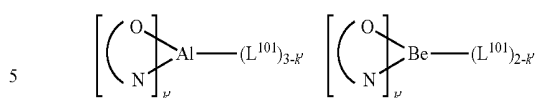
-continued



wherein  $R^{101}$  is selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, aryl-alkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, when it is aryl or heteroaryl, it has the similar definition as Ar's mentioned above.  $Ar^1$  to  $Ar^3$  has the similar definition as Ar's mentioned above.  $k$  is an integer from 1 to 20.  $X^{101}$  to  $X^{108}$  is selected from C (including CH) or N.

In another aspect, the metal complexes used in ETL contains, but not limit to the following general formula:

180



15

wherein (O—N) or (N—N) is a bidentate ligand, having metal coordinated to atoms O, N or N, N;  $L^{101}$  is another ligand;  $k$  is an integer value from 1 to the maximum number of ligands that may be attached to the metal.

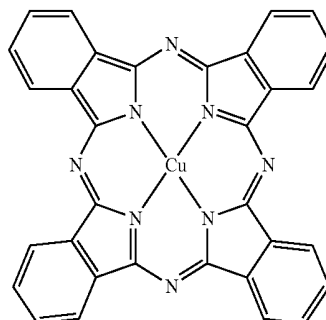
In any above-mentioned compounds used in each layer of the OLED device, the hydrogen atoms can be partially or fully deuterated. Thus, any specifically listed substituent, such as, without limitation, methyl, phenyl, pyridyl, etc. encompasses undeuterated, partially deuterated, and fully deuterated versions thereof. Similarly, classes of substituents such as, without limitation, alkyl, aryl, cycloalkyl, heteroaryl, etc. also encompass undeuterated, partially deuterated, and fully deuterated versions thereof.

In addition to and/or in combination with the materials disclosed herein, many hole injection materials, hole transporting materials, host materials, dopant materials, exciton/hole blocking layer materials, electron transporting and electron injecting materials may be used in an OLED. Non-limiting examples of the materials that may be used in an OLED in combination with materials disclosed herein are listed in Table A below. Table A lists non-limiting classes of materials, non-limiting examples of compounds for each class, and references that disclose the materials.

TABLE A

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Hole injection materials		

Phthalocyanine and porphyrin compounds



Appl. Phys. Lett. 69, 2160 (1996)

TABLE A-continued

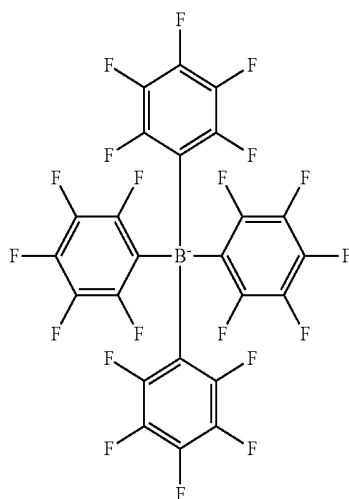
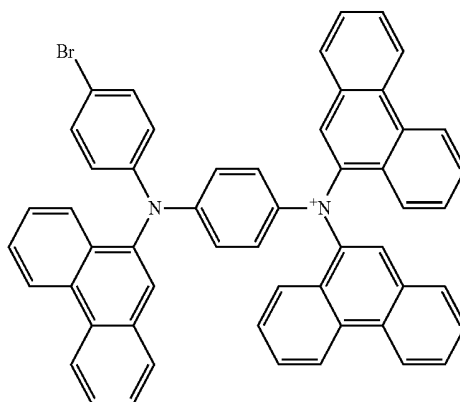
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Starburst triarylaminines		J. Lumin. 72-74, 985 (1997)
CF <sub>x</sub> Fluorohydrocarbon polymer	$\text{---}[\text{CH}_x\text{F}_y]_n\text{---}$	Appl. Phys. Lett. 78, 673 (2001)
Conducting polymers (e.g., PEDOT:PSS, polyaniline, polythiophene)		Synth. Met. 87, 171 (1997) WO2007002683
Phosphonic acid and silane SAMs	$\text{N} \left( \text{C}_6\text{H}_4 \text{---} \text{SiCl}_3 \right)_3$	US20030162053
Triarylamine or polythiophene polymers with conductivity dopants		EP1725079A1  and

TABLE A-continued

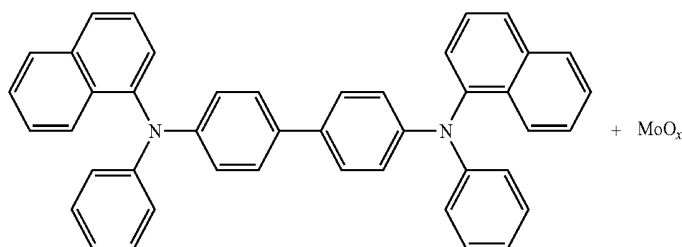
MATERIAL

EXAMPLES OF MATERIAL

PUBLICATIONS

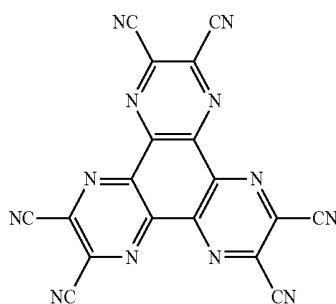


Organic compounds  
with conductive  
inorganic compounds,  
such as molybdenum  
and tungsten oxides



US20050123751  
SID Symposium  
Digest, 37, 923  
(2006)  
WO2009018009

n-type  
semiconducting  
organic complexes



US20020158242

TABLE A-continued

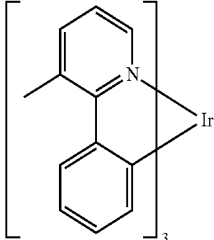
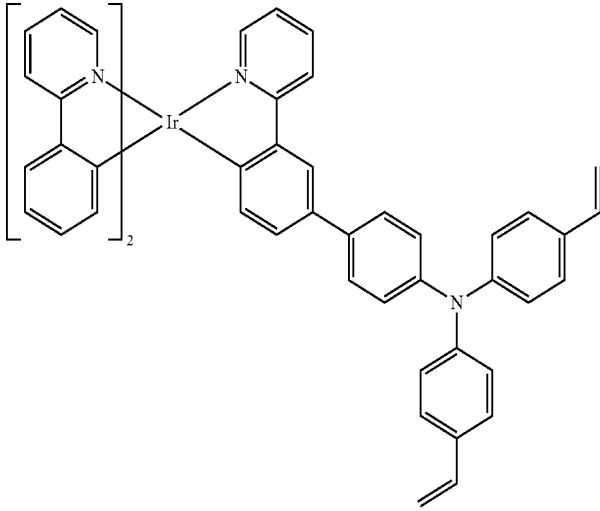
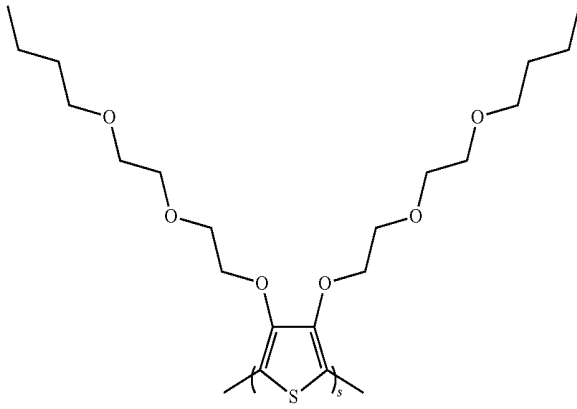
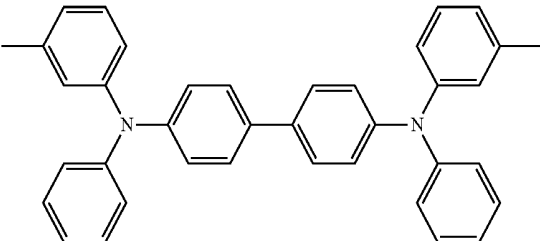
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal organometallic complexes		US20060240279
Cross-linkable compounds		US20080220265
Polythiophene based polymers and copolymers		WO 2011075644 EP2350216
Hole transporting materials		
Triarylamines (e.g., TPD, $\alpha$ -NPD)		Appl. Phys. Lett. 51, 913 (1987)

TABLE A-continued

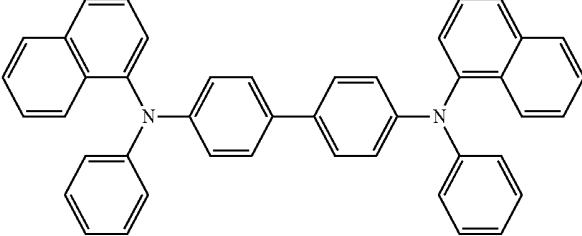
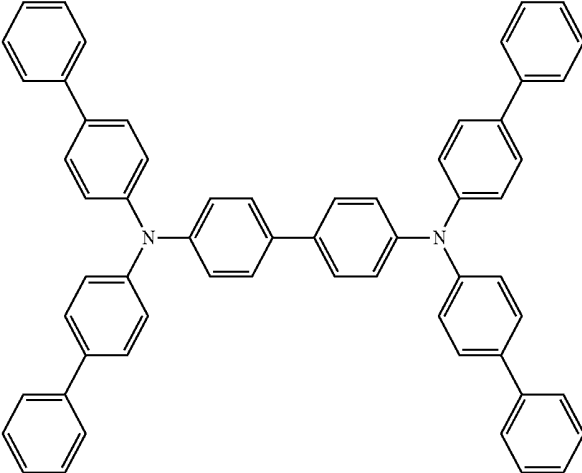
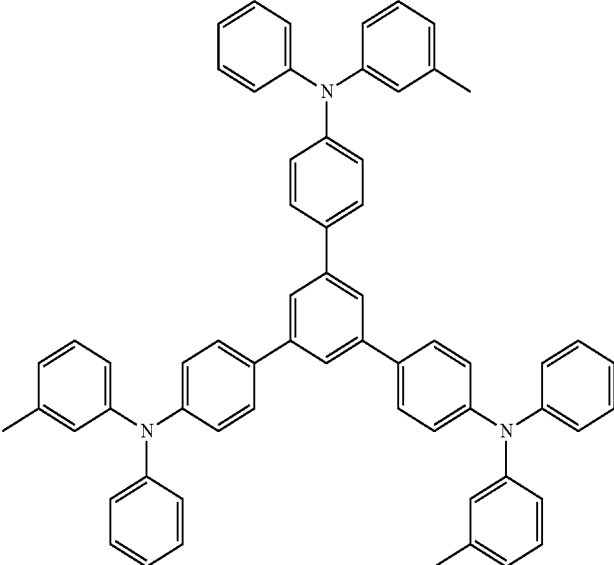
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		U.S. Pat. No. 5,061,569
		EP650955
		J. Mater. Chem. 3, 319 (1993)

TABLE A-continued

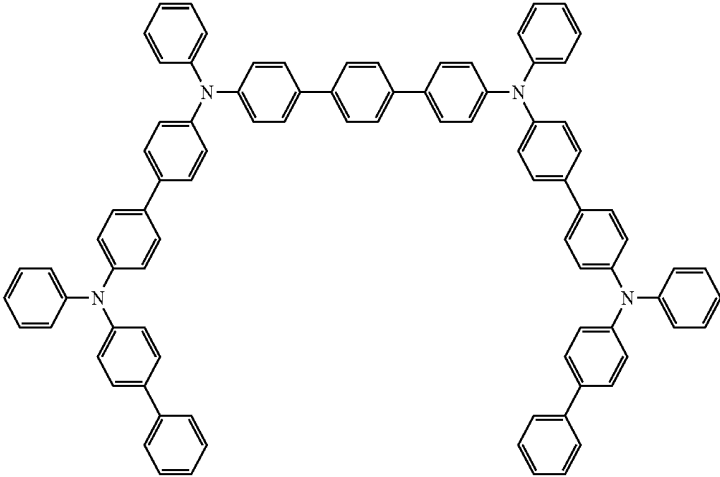
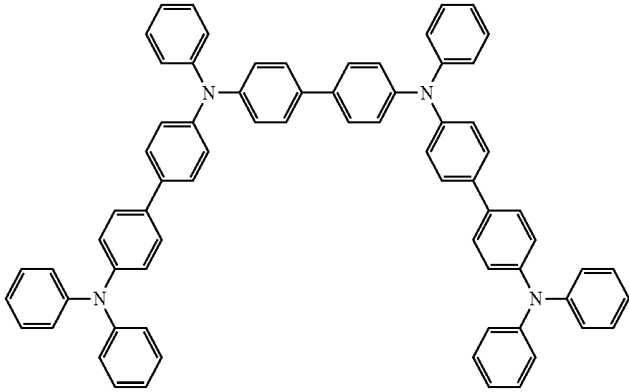
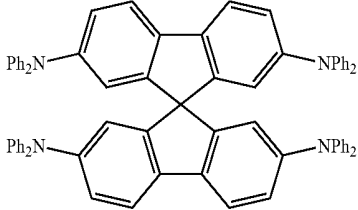
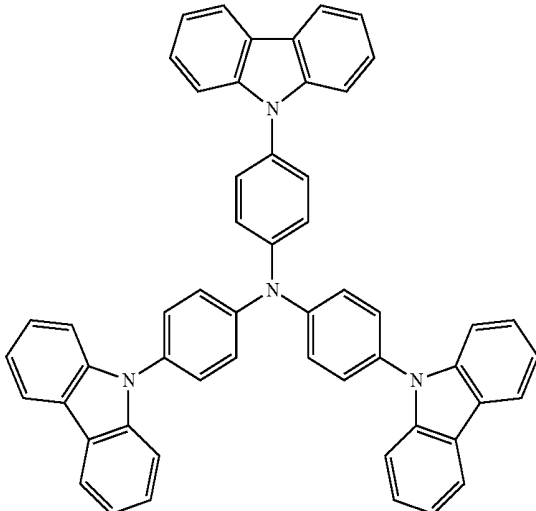
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		Appl. Phys. Lett. 90, 183503 (2007)
		Appl. Phys. Lett. 90, 183503 (2007)
Triarylamine on spirofluorene core		Synth. Met. 91, 209 (1997)
Arylamine carbazole compounds		Adv. Mater. 6, 677 (1994), US20080124572

TABLE A-continued

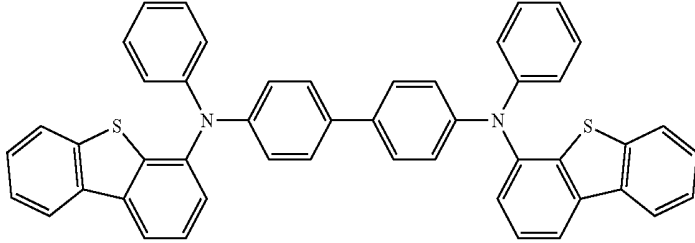
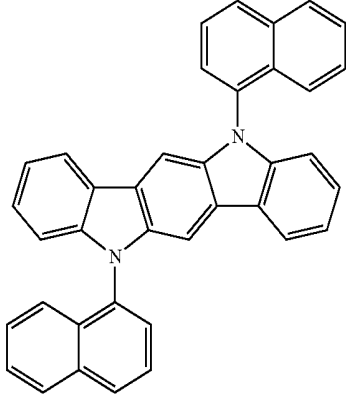
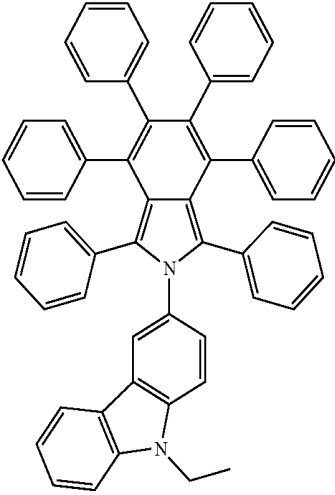
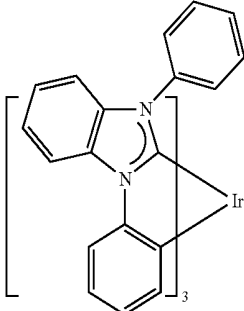
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Triarylamine with (di)benzothiophene/ (di)benzofuran		US20070278938, US20080106190 US20110163302
Indolocarbazoles		Synth. Met. 111, 421 (2000)
Isoindole compounds		Chem. Mater. 15, 3148 (2003)
Metal carbene complexes		US20080018221

TABLE A-continued

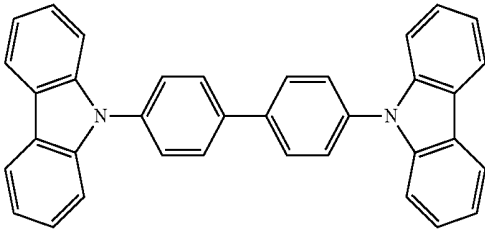
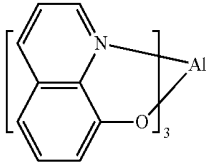
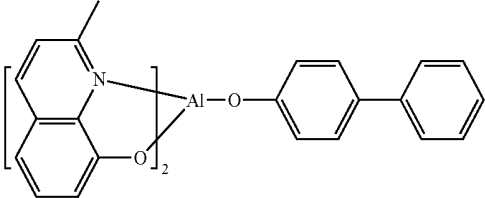
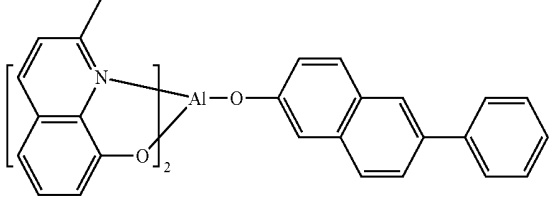
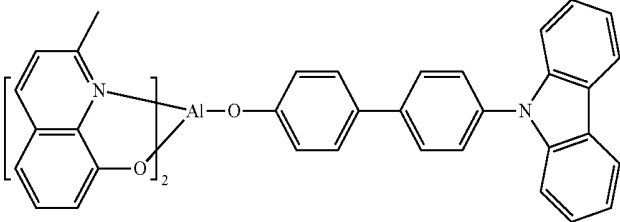
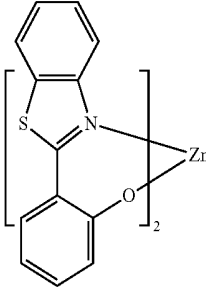
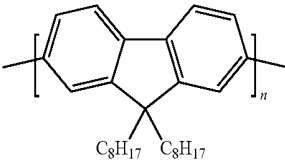
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Phosphorescent OLED host materials Red hosts		
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
Metal 8-hydroxyquinolates (e.g., Alq <sub>3</sub> , BALq)		Nature 395, 151 (1998)
		US20060202194
		WO2005014551
		WO2006072002
Metal phenoxybenzothiazole compounds		Appl. Phys. Lett. 90, 123509 (2007)
Conjugated oligomers and polymers (e.g., polyfluorene)		Org. Electron. 1, 15 (2000)

TABLE A-continued

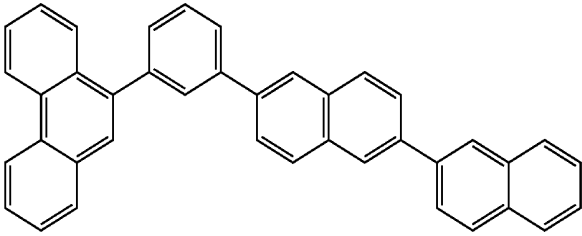
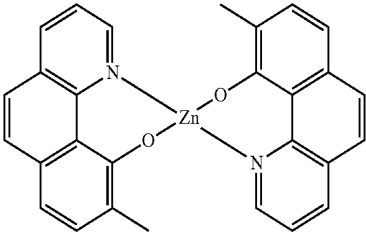
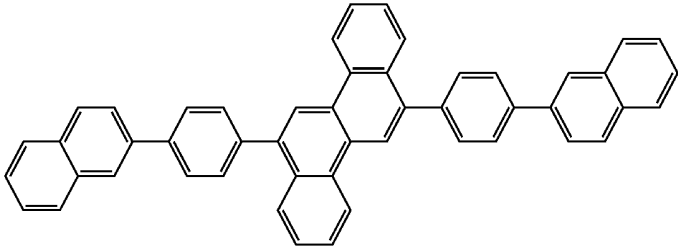
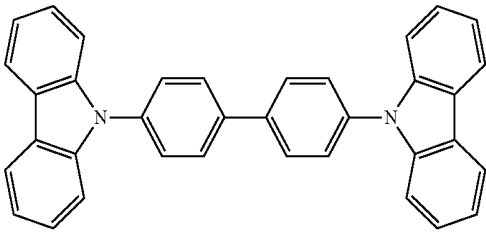
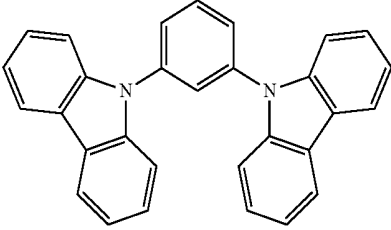
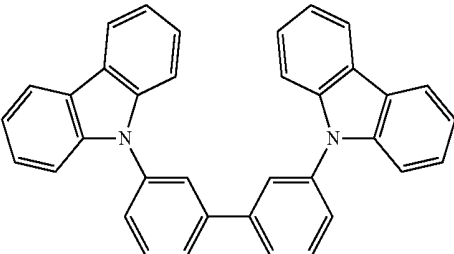
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Aromatic fused rings		WO2009066779, WO2009066778, WO2009063833, US20090045731, US20090045730, WO2009008311, US20090008605, US20090009065
Zinc complexes		WO2010056066
Chrysene based compounds		WO2011086863
Green hosts		
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
		US20030175553
		WO2001039234

TABLE A-continued

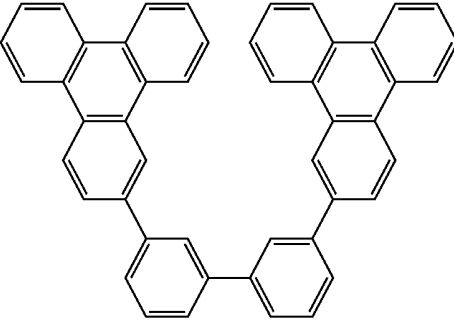
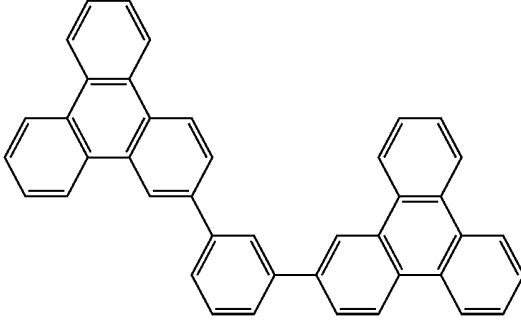
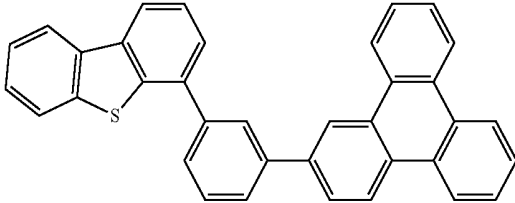
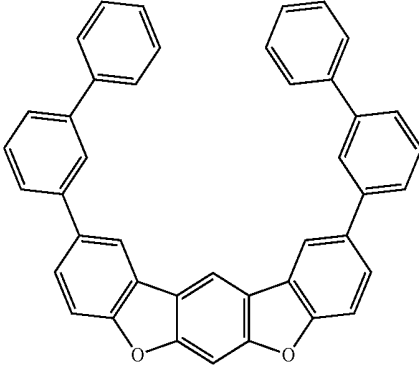
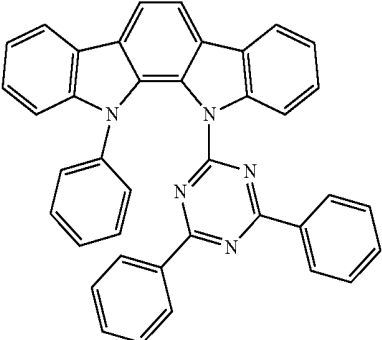
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Aryltriphenylene compounds		US20060280965
		US20060280965
		WO2009021126
Poly-fused heteroaryl compounds		US20090309488 US20090302743 US20100012931
Donor acceptor type molecules		WO2008056746

TABLE A-continued

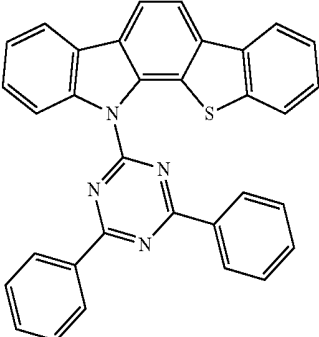
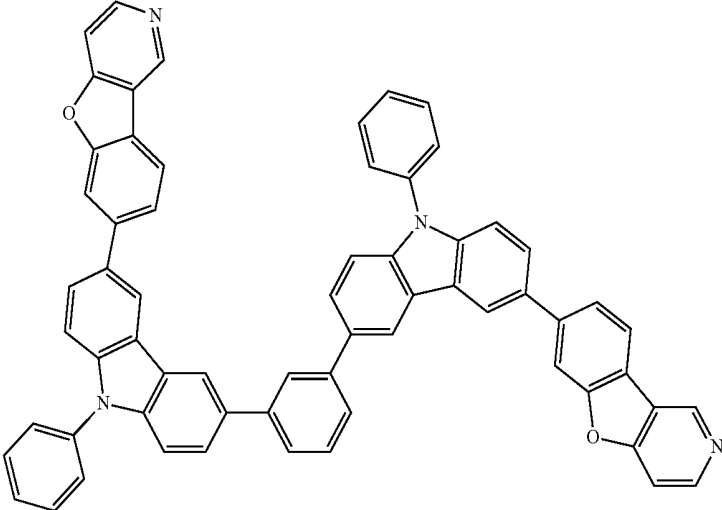
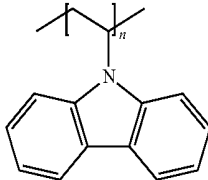
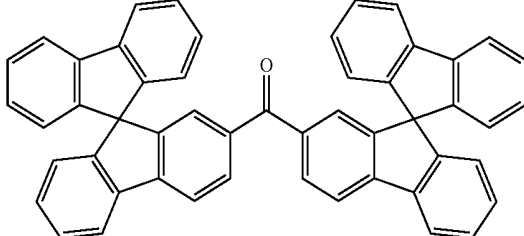
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Aza-carbazole/ DBT/DBF		WO2010107244
Aza-carbazole/ DBT/DBF		JP2008074939
Polymers (e.g., PVK)		Appl. Phys. Lett. 77, 2280 (2000)
Spirofluorene compounds		WO2004093207

TABLE A-continued

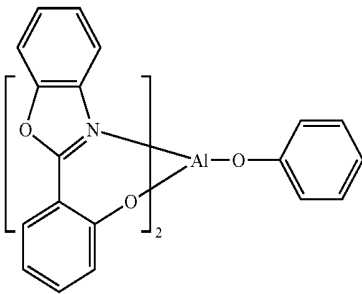
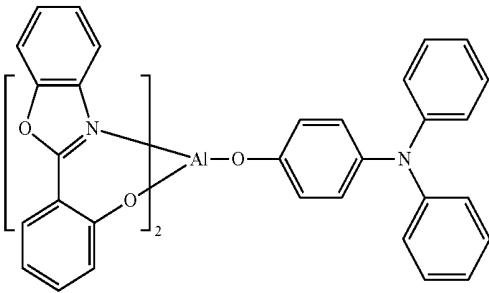
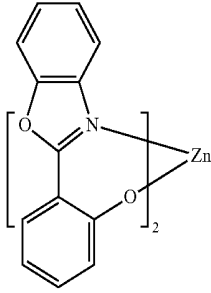
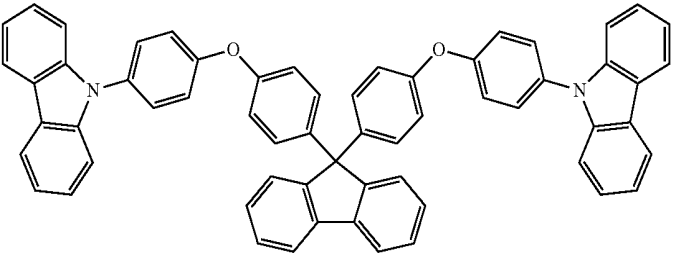
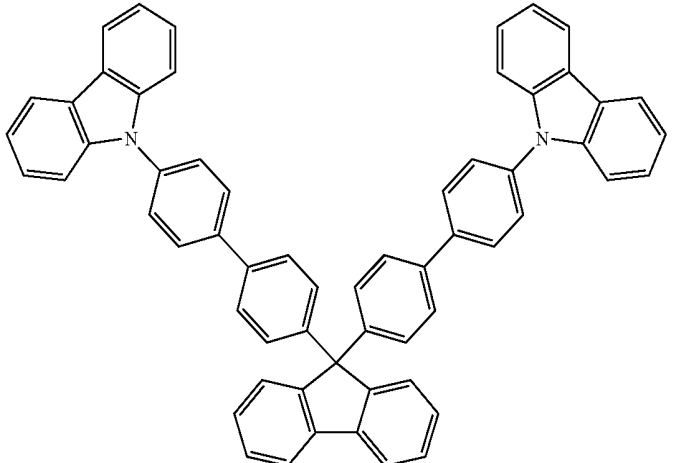
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal phenoxybenzoxazole compounds		WO2005089025
		WO2006132173
		JP200511610
Spirofluorene-carbazole compounds		JP2007254297
		JP2007254297

TABLE A-continued

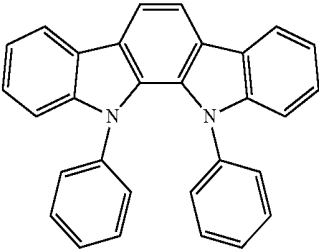
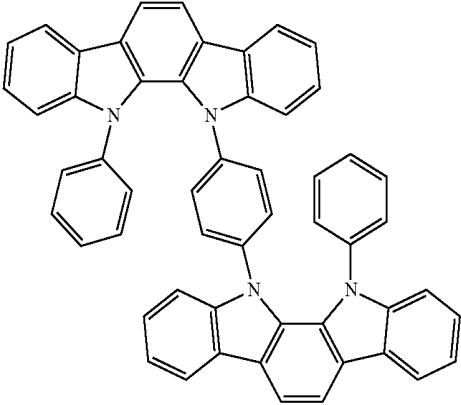
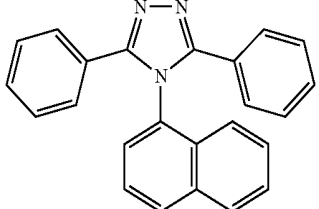
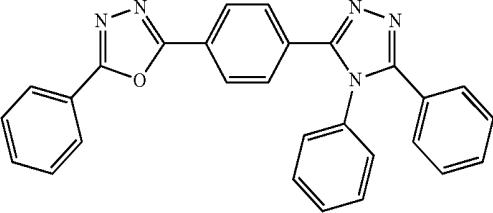
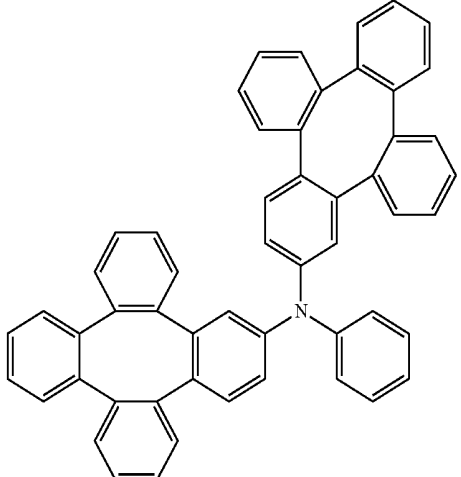
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Indolocarbazoles		WO2007063796
		WO2007063754
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole)		J. Appl. Phys. 90, 5048 (2001)
		WO2004107822
Tetraphenylene complexes		US20050112407

TABLE A-continued

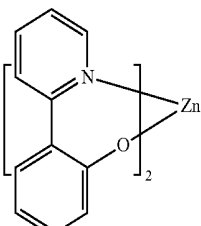
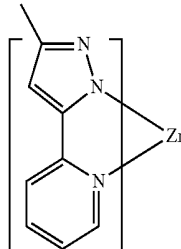
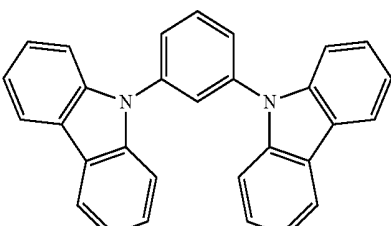
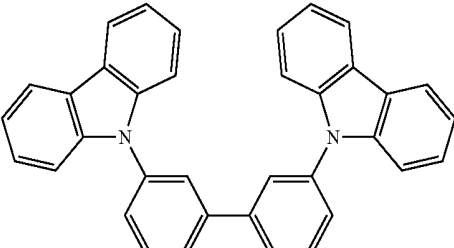
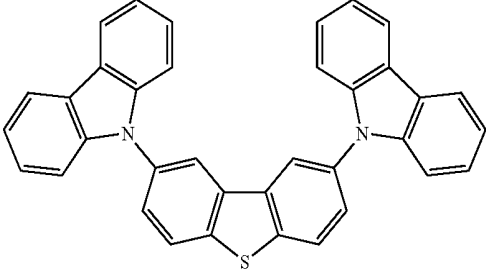
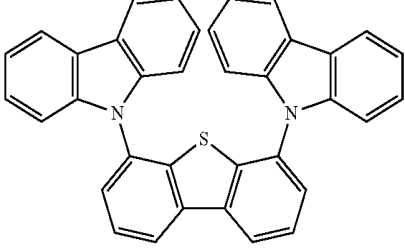
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal phenoxypyridine compounds		WO2005030900
Metal coordination complexes (e.g., Zn, Al, with N N ligands)		US20040137268, US20040137267
Blue hosts		
Arylcarbazoles		Appl. Phys. Lett., 82, 2422 (2003)
		US20070190359
Dibenzothiophene/ Dibenzofuran- carbazole compounds		WO2006114966, US20090167162
		US20090167162

TABLE A-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2009086028
		US20090030202, US20090017330
		US20100084966
Silicon aryl compounds		US20050238919
		WO2009003898

TABLE A-continued

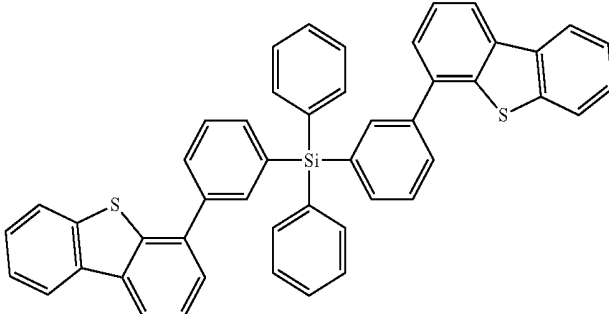
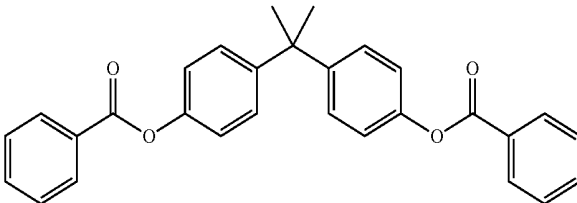
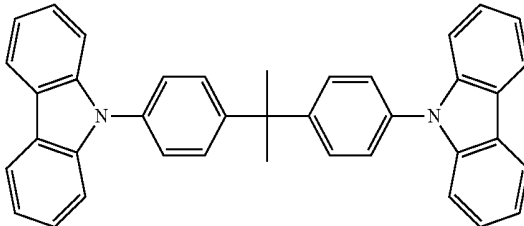
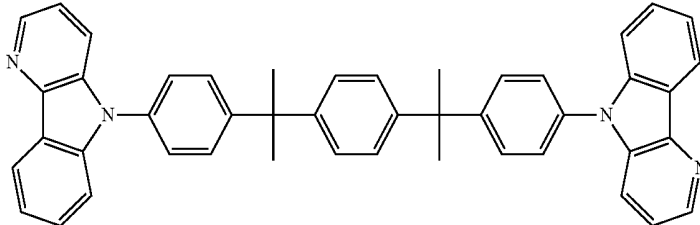
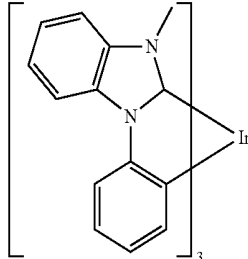
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Silicon/Germanium aryl compounds		EP2034538A
Aryl benzoyl ester		WO2006100298
Carbazole linked by non-conjugated groups		US20040115476
Aza-carbazoles		US20060121308
High triplet metal organometallic complex		U.S. Pat. No. 7,154,114

TABLE A-continued

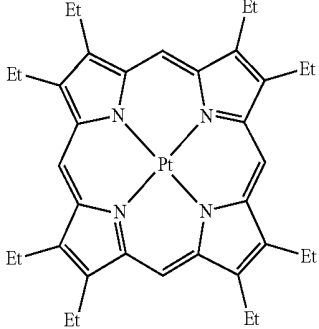
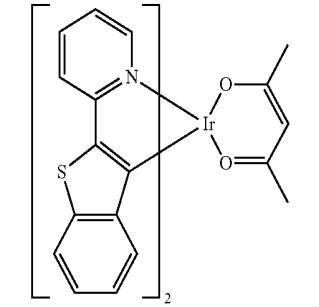
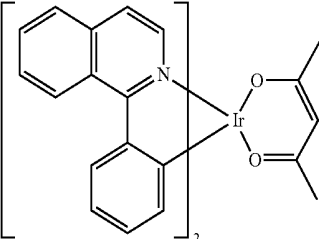
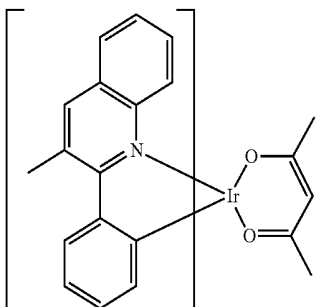
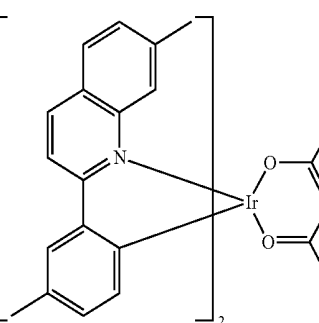
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Phosphorescent dopants Red dopants		
Heavy metal porphyrins (e.g., PtOEP)		Nature 395, 151 (1998)
Iridium (III) organometallic complexes		Appl. Phys. Lett. 78, 1622 (2001)
		US20030072964
		US20030072964
		US20060202194

TABLE A-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20060202194
		US20070087321
		US20080261076 US20100090591
		US20070087321
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TABLE A-continued

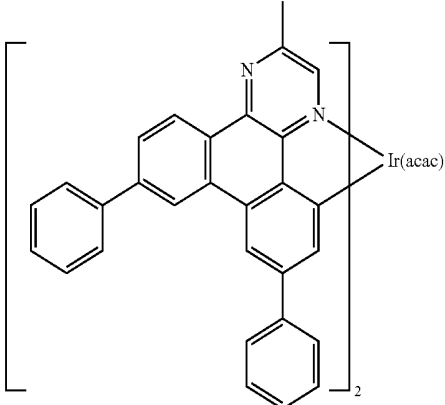
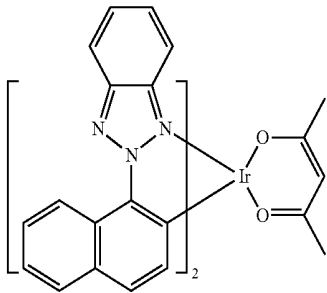
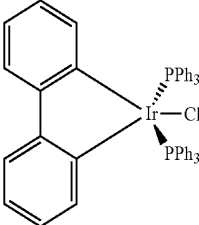
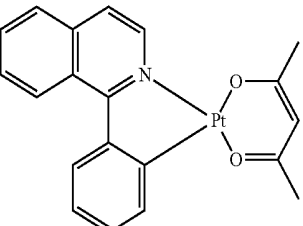
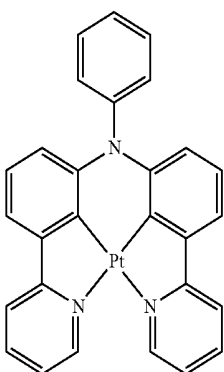
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Platinum (II) organometallic complexes		WO2009100991
		WO2008101842
		U.S. Pat. No. 7,232,618
		WO2003040257
		US20070103060

TABLE A-continued

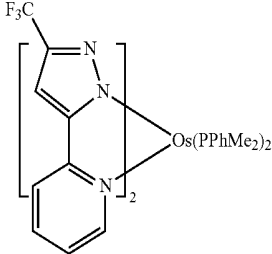
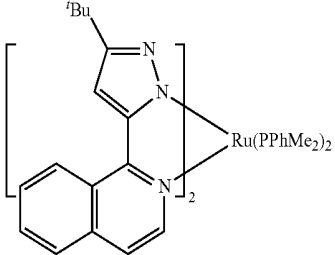
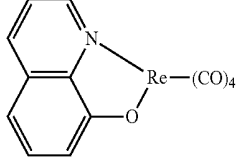
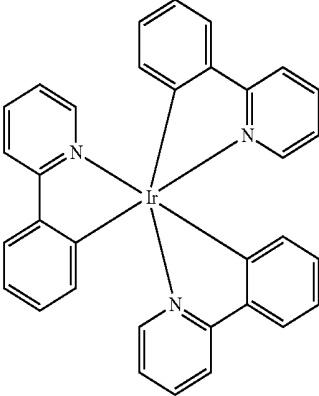
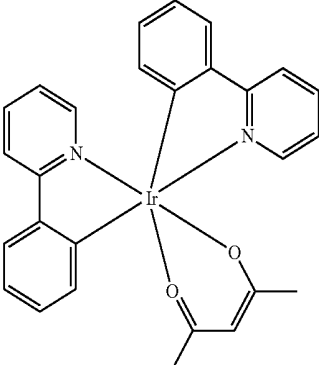
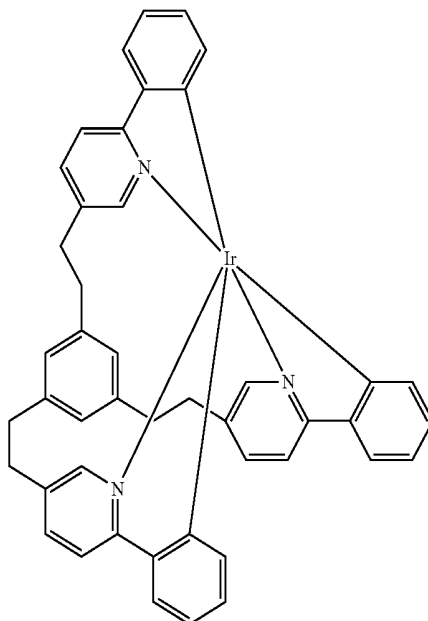
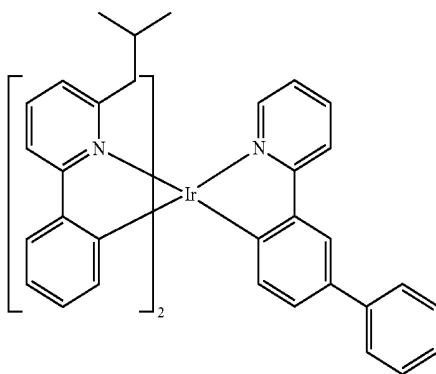
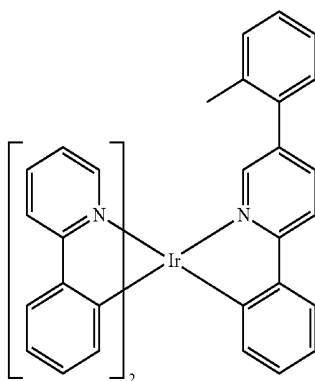
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Osmium (III) complexes		Chem. Mater. 17, 3532 (2005)
Ruthenium (II) complexes		Adv. Mater. 17, 1059 (2005)
Rhenium (I), (II), and (III) complexes		US20050244673
Green dopants		
Iridium (III) organometallic complexes		Inorg. Chem. 40, 1704 (2001)
and its derivatives		
		US20020034656

TABLE A-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
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U.S. Pat. No.  
7,332,232

US20090108737



WO2010028151

TABLE A-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	<p>The structure shows an Iridium (Ir) center coordinated to two phenanthroline ligands (represented by a bracket with a subscript 2) and one phenylpyridine ligand. The phenylpyridine ligand consists of a pyridine ring substituted with a phenyl group.</p>	EP1841834B
	<p>The structure shows an Iridium (Ir) center coordinated to three phenanthroline ligands, all enclosed within a single large bracket with a subscript 3.</p>	US20060127696
	<p>The structure shows an Iridium (Ir) center coordinated to three phenanthroline ligands, all enclosed within a single large bracket with a subscript 3.</p>	US20090039776
	<p>The structure shows an Iridium (Ir) center coordinated to three phenanthroline ligands, all enclosed within a single large bracket with a subscript 3. One of the phenanthroline ligands is substituted with a thiophene ring at the 9-position.</p>	U.S. Pat. No. 6,921,915
	<p>The structure shows an Iridium (Ir) center coordinated to two phenanthroline ligands (represented by a bracket with a subscript 2) and one thienophenanthroline ligand (a phenanthroline ring with a thiophene ring fused at the 9-position).</p>	US20100244004

TABLE A-continued

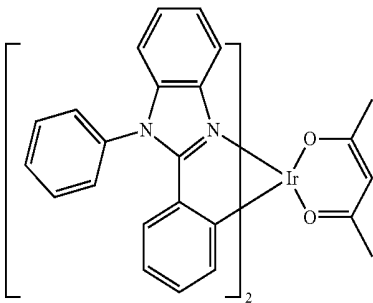
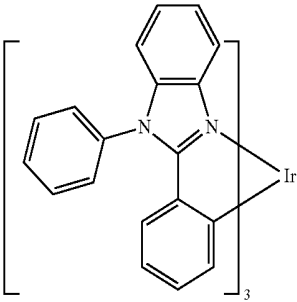
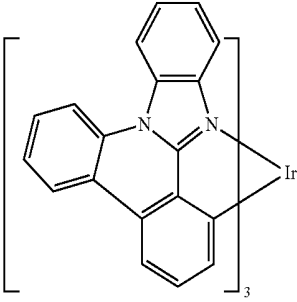
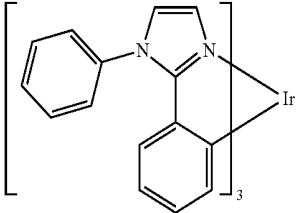
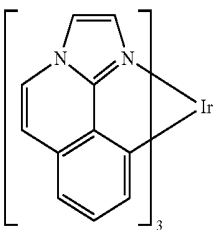
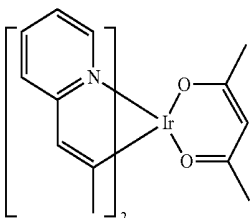
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		U.S. Pat. No. 6,687,266
		Chem. Mater. 16, 2480 (2004)
		US20070190359
		US 20060008670 JP2007123392
		WO2010086089, WO2011044988
		Adv. Mater. 16, 2003 (2004)

TABLE A-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	<p>The structure shows an Ir atom coordinated to a phenylpyridine ligand (a benzene ring fused to a pyridine ring) and a benzimidazole ligand (a benzene ring fused to an imidazole ring). The Ir atom is also coordinated to two other ligands, indicated by lines extending from the Ir atom. A subscript '3' is shown near the Ir atom, suggesting a trimeric complex.</p>	Angew. Chem. Int. Ed. 2006, 45, 7800
	<p>The structure shows an Ir atom coordinated to a phenylthiazole ligand (a benzene ring fused to a thiazole ring). The Ir atom is also coordinated to two other ligands, indicated by lines extending from the Ir atom. A subscript '3' is shown near the Ir atom, suggesting a trimeric complex.</p>	WO2009050290
	<p>The structure shows an Ir atom coordinated to a phenylthiazole ligand (a benzene ring fused to a thiazole ring). The Ir atom is also coordinated to two other ligands, indicated by lines extending from the Ir atom. A subscript '3' is shown near the Ir atom, suggesting a trimeric complex.</p>	US20090165846
	<p>The structure shows an Ir atom coordinated to a phenylpyridine ligand (a benzene ring fused to a pyridine ring) and a pyridine-2,6-dione ligand (a pyridine ring with two carbonyl groups at the 2 and 6 positions). The Ir atom is also coordinated to two other ligands, indicated by lines extending from the Ir atom. A subscript '2' is shown near the Ir atom, suggesting a dimeric complex.</p>	US20080015355
	<p>The structure shows an Ir atom coordinated to a phenylpyridine ligand (a benzene ring fused to a pyridine ring). The Ir atom is also coordinated to two other ligands, indicated by lines extending from the Ir atom. A subscript '3' is shown near the Ir atom, suggesting a trimeric complex. The counterion is PF<sub>6</sub><sup>-</sup>.</p>	US20010015432

TABLE A-continued

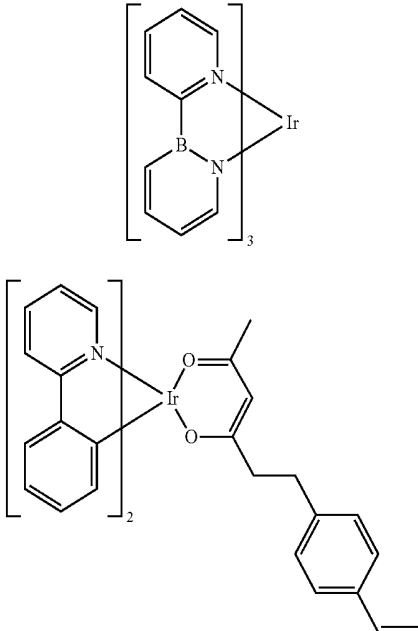
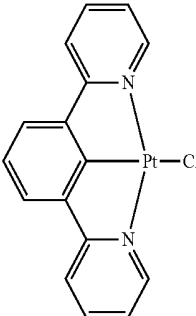
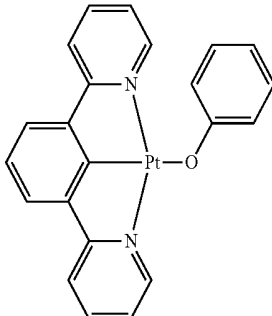
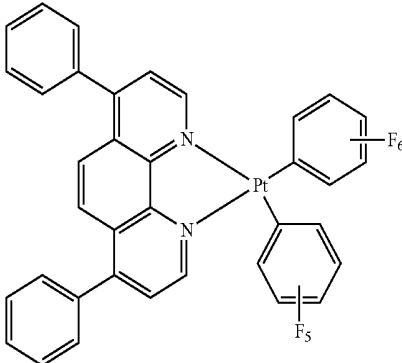
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Monomer for polymeric metal organometallic compounds		US20100295032  U.S. Pat. No. 7,250,226, U.S. Pat. No. 7,396,598
Pt (II) organometallic complexes, including polydentate ligands		Appl. Phys. Lett. 86, 153505 (2005)
		Appl. Phys. Lett. 86, 153505 (2005)
		Chem. Lett. 34, 592 (2005)

TABLE A-continued

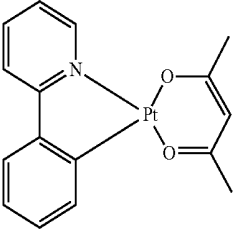
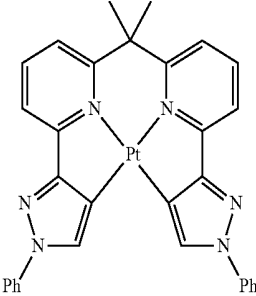
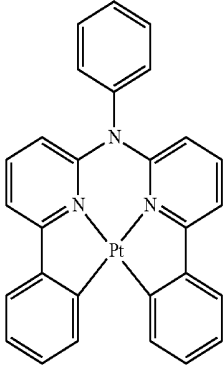
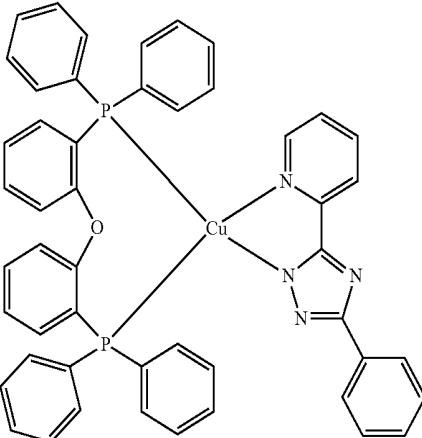
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		WO2002015645
		US20060263635
		US20060182992 US20070103060
Cu complexes		WO2009000673

TABLE A-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
		US20070111026
Gold complexes		Chem. Commun. 2906 (2005)
Rhenium (III) complexes		Inorg. Chem. 42, 1248 (2003)
Osmium (II) complexes		U.S. Pat. No. 7,279,704

TABLE A-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Deuterated organometallic complexes		US20030138657
Organometallic complexes with two or more metal centers		US20030152802
		U.S. Pat. No. 7,090,928
	Blue dopants	
Iridium (III) organometallic complexes		WO2002002714
		WO2006009024

TABLE A-continued

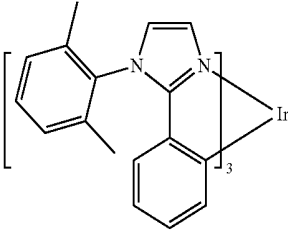
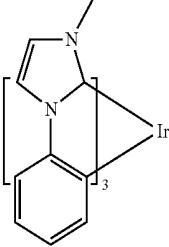
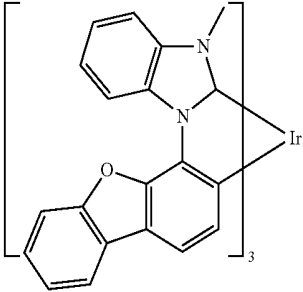
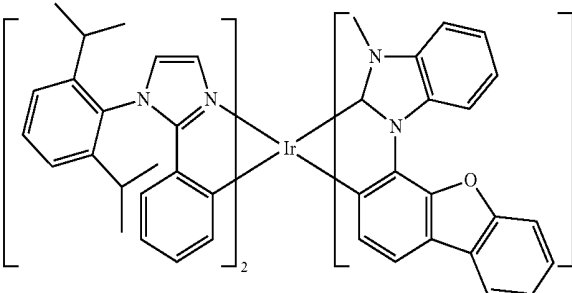
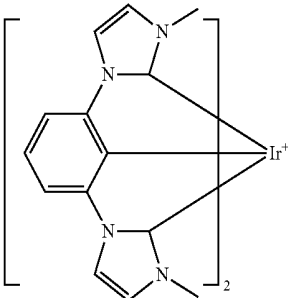
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		U.S. Pat. No. 7,393,599, WO2006056418, US20050260441, WO2005019373
		U.S. Pat. No. 7,534,505
		WO2011051404
		U.S. Pat. No. 7,445,855

TABLE A-continued

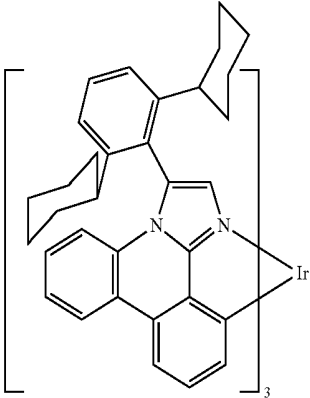
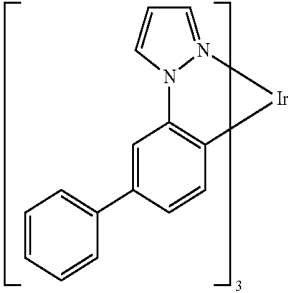
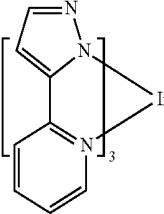
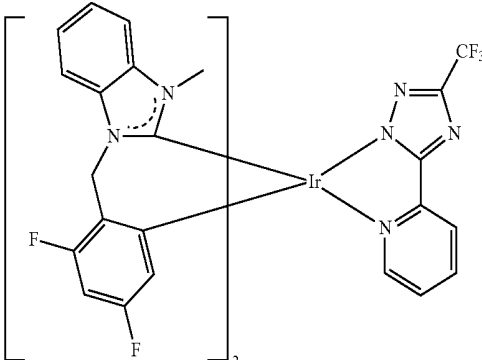
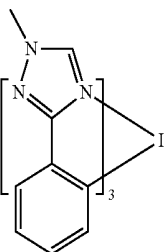
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		Angew. Chem. Int. Ed. 47, 4542 (2008)
		Chem. Mater. 18, 5119 (2006)

TABLE A-continued

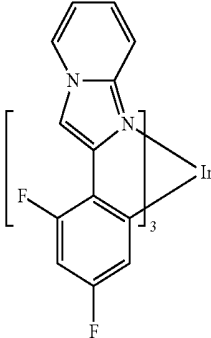
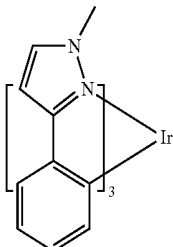
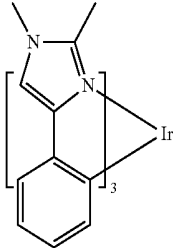
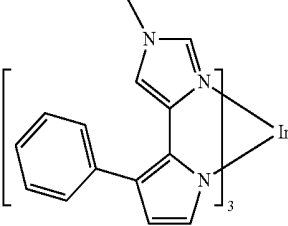
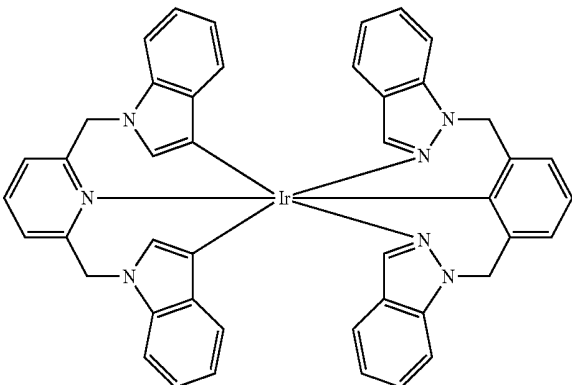
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
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		WO2007004380
		WO2006082742

TABLE A-continued

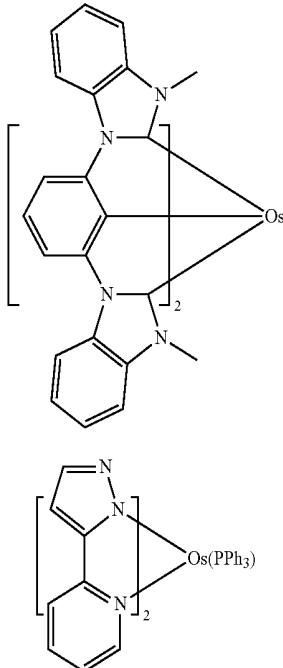
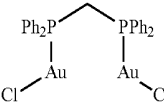
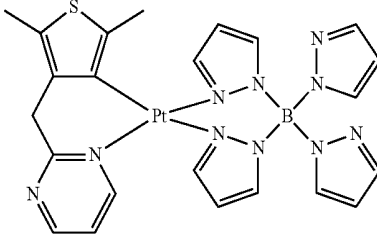
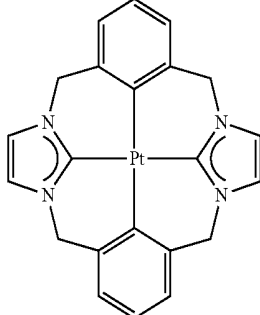
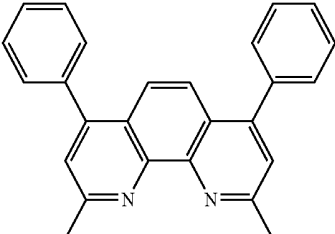
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Osmium (II) complexes		U.S. Pat. No. 7,279,704
Gold complexes		Appl. Phys. Lett. 74, 1361 (1999)
Platinum (II) complexes		WO2006098120, WO2006103874
Pt tetradentate complexes with at least one metal-carbene bond		U.S. Pat. No. 7,655,323
Exciton/hole blocking layer materials		
Bathocuprine compounds (e.g., BCP, BPhen)		Appl. Phys. Lett. 75, 4 (1999)

TABLE A-continued

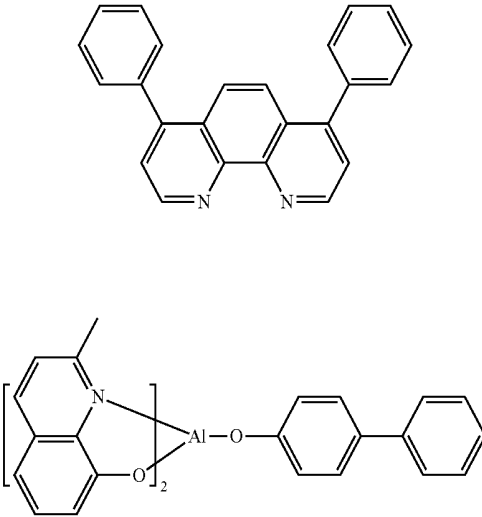
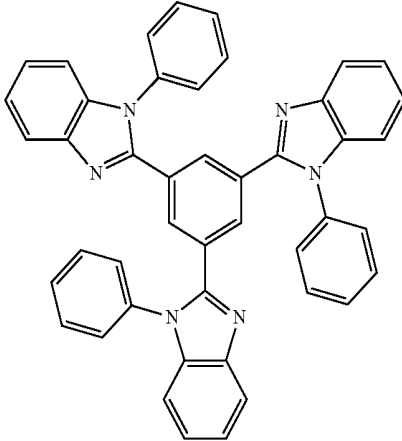
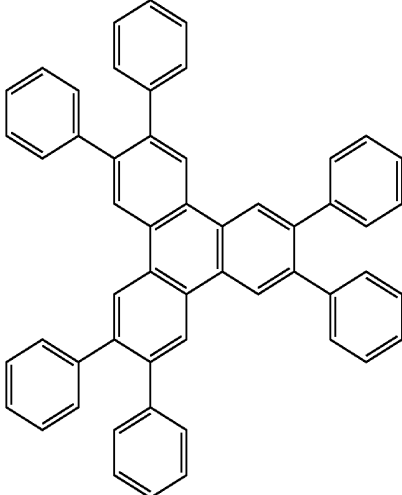
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal 8-hydroxyquinolates (e.g. BAlq)		Appl. Phys. Lett. 79, 449 (2001)
5-member ring electron deficient heterocycles such as triazole, oxadiazole, imidazole, benzimidazole		Appl. Phys. Lett. 81, 162 (2002)
Triphenylene compounds		US20050025993

TABLE A-continued

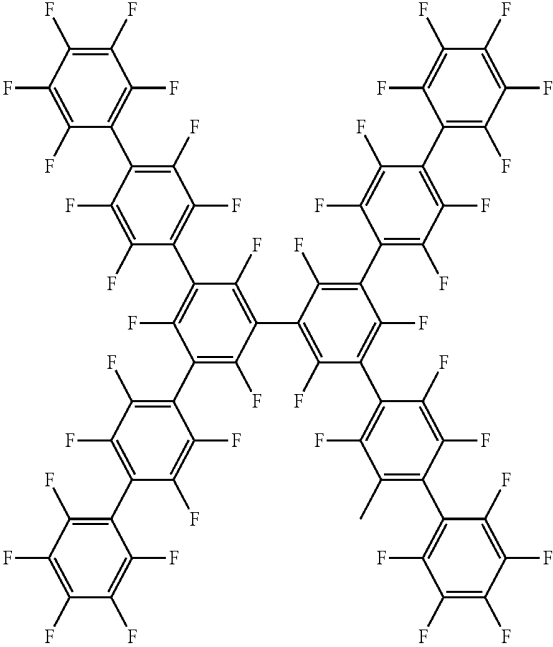
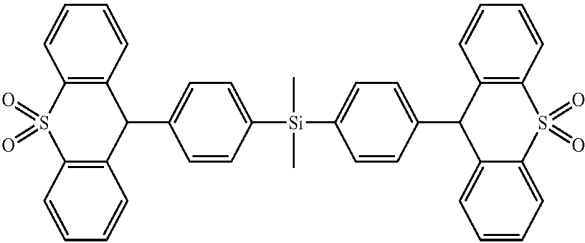
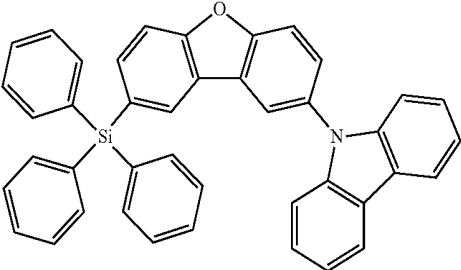
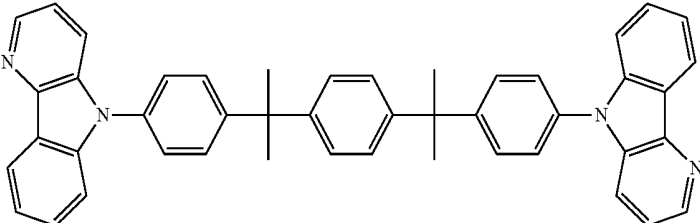
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Fluorinated aromatic compounds		Appl. Phys. Lett. 79, 156 (2001)
Phenothiazine-S-oxide		WO2008132085
Silylated five-membered nitrogen, oxygen, sulfur or phosphorus dibenzoheterocycles		WO2010079051
Aza-carbazoles		US20060121308

TABLE A-continued

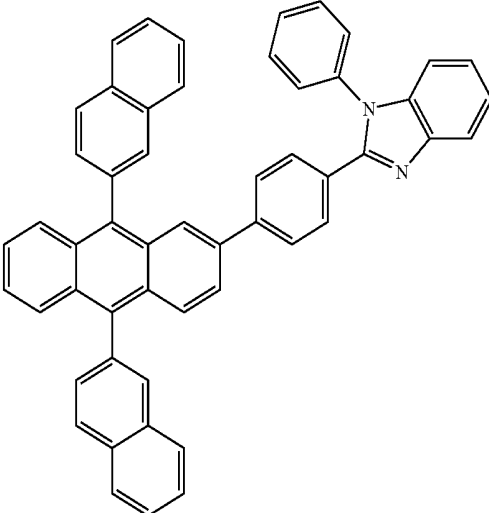
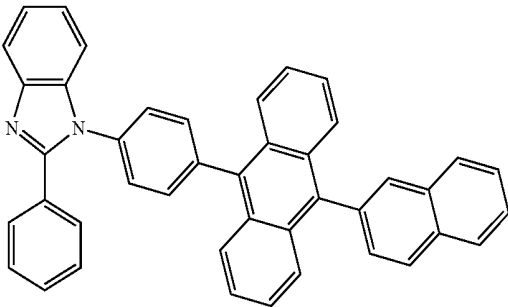
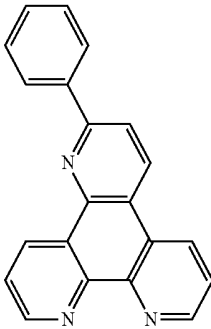
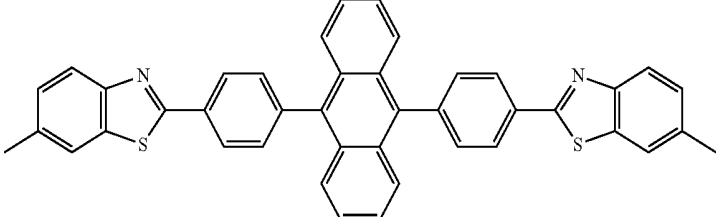
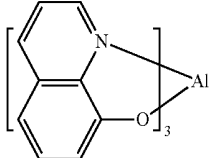
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Anthracene-benzimidazole compounds		WO2003060956
Aza triphenylene derivatives		US20090179554
Aza triphenylene derivatives		US20090115316
Anthracene-benzothiazole compounds		Appl. Phys. Lett. 89, 063504 (2006)
Metal 8-hydroxyquinolates (e.g., Alq <sub>3</sub> , Zrq <sub>4</sub> )		Appl. Phys. Lett. 51, 913 (1987) U.S. Pat. No. 7,230,107

TABLE A-continued

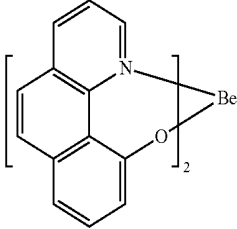
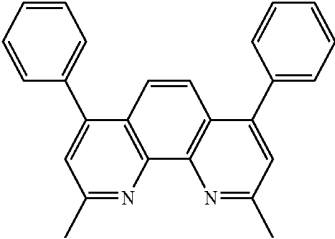
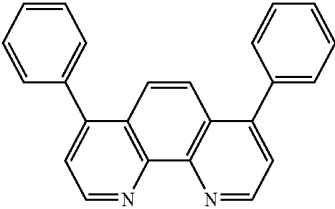
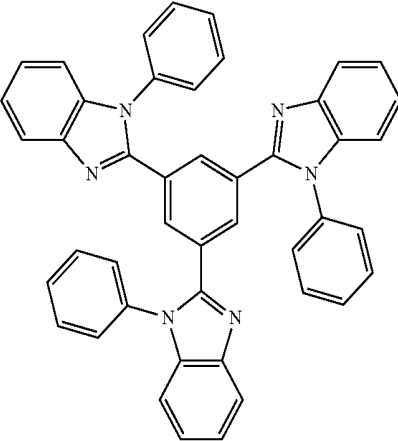
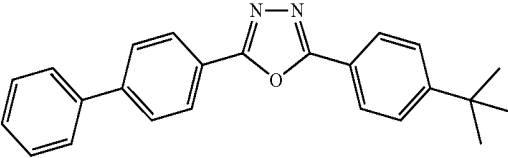
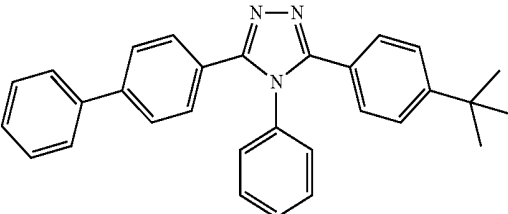
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Metal hydroxybenzoquinolates		Chem. Lett. 5, 905 (1993)
Bathocuprine compounds such as BCP, BPhen, etc		Appl. Phys. Lett. 91, 263503 (2007)
		Appl. Phys. Lett. 79, 449 (2001)
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole, imidazole, benzoimidazole)		Appl. Phys. Lett. 74, 865 (1999)
		Appl. Phys. Lett. 55, 1489 (1989)
		Jpn. J. Apply. Phys. 32, L917 (1993)

TABLE A-continued

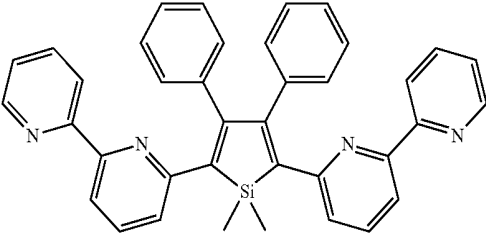
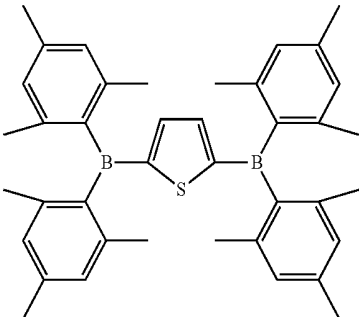
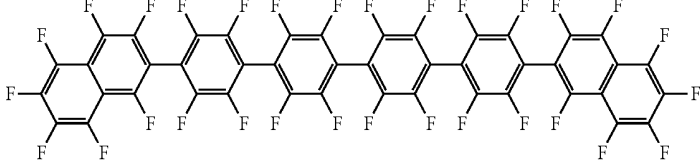
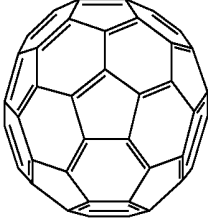
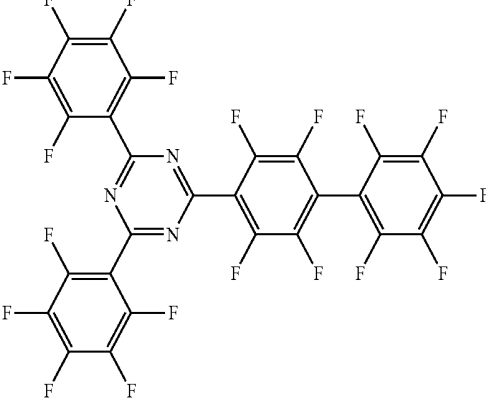
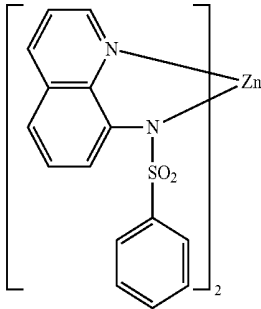
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Silole compounds		Org. Electron. 4, 113 (2003)
Arylborane compounds		J. Am. Chem. Soc. 120, 9714 (1998)
Fluorinated aromatic compounds		J. Am. Chem. Soc. 122, 1832 (2000)
Fullerene (e.g., C60)		US20090101870
Triazine complexes		US20040036077

TABLE A-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
Zn (N <sup>+</sup> N) complexes		U.S. Pat. No. 6,528,187

## EXPERIMENTAL

DFT calculations were performed for certain compounds and comparative compounds. The results are shown in table 1. Geometry optimization calculations were performed within the Gaussian 09 software package using the B3LYP hybrid functional and CEP-31g effective core potential basis set. The results are summarized in Table 1, below.

TABLE 1

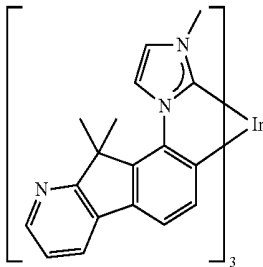
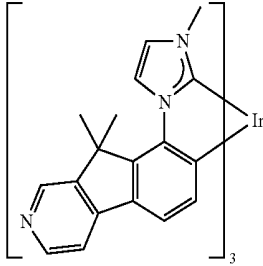
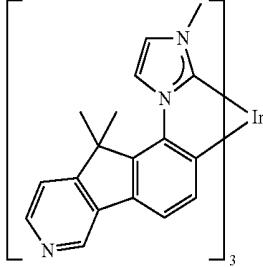
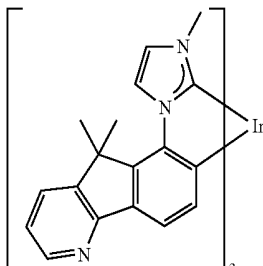
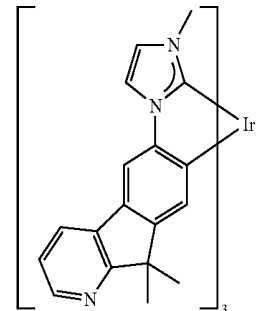
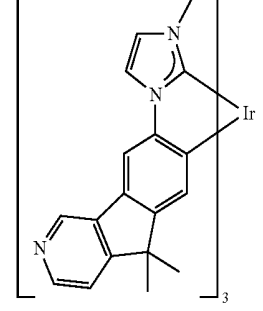
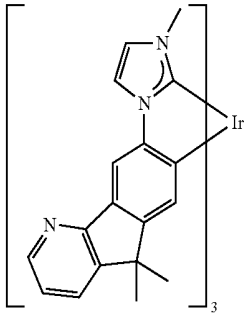
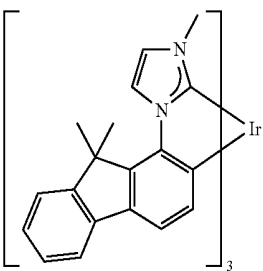
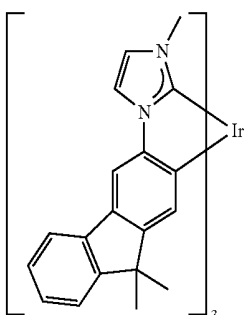
Calculated results of inventive compounds and comparative compounds containing idmiazole carbene ligands					
Compound	HOMO	LUMO	Gap	S1	T1
	-5.09	-1.17	-3.92	361	475
Compound T1					
	-5.21	-1.25	-3.95	358	464
Compound T2					
	-5.13	-1.03	-4.09	352	463
Compound T3					

TABLE 1-continued

Calculated results of inventive compounds and comparative compounds containing idmiazole carbene ligands					
Compound	HOMO	LUMO	Gap	S1	T1
	-5.10	-1.17	-3.92	367	466
Compound T4					
	-5.05	-1.15	-3.89	383	472
Compound T5					
	-5.08	-1.04	-4.04	376	461
Compound T6					

255

TABLE 1-continued

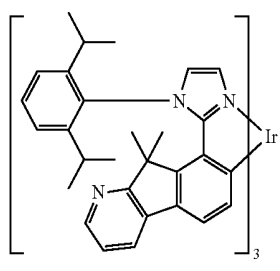
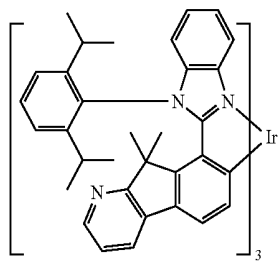
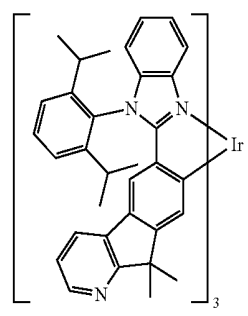
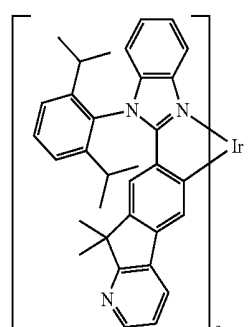
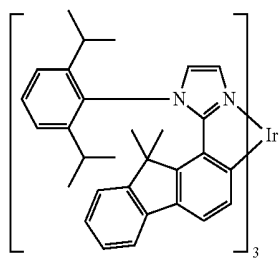
Calculated results of inventive compounds and comparative compounds containing imiazole carbene ligands					
Compound	HOMO	LUMO	Gap	S1	T1
	-5.06	-1.17	-3.89	380	463
Compound T7					
	-4.97	-0.78	-4.19	358	464
Comparative Compound 1					
	-4.92	-0.79	-4.13	376	461
Comparative Compound 2					

Compounds T1 to T7 of formula I are compared against Comparative Compounds 1 and 2. The difference is that the compounds of formula I have a nitrogen atom in the fluorene ring. When the carbon atom of Comparative Compounds 1 and 2 is replaced with nitrogen, the calculated emission remains blue, with a slight red shift for some of the compound. One noticeable difference is the LUMO of the compounds of formula I. The comparative compounds have a LUMO level around -0.79 eV, while the LUMO level of the compounds of Formula I are significantly stabilized, all deeper than -1.0 eV. The stabilization of LUMO is believed to result in more stable phosphorescent emitters.

Table 2 below, summarizes the calculated values of imiazole containing complexes. Again, the compounds of formula I show similar emission wavelength. However, the LUMO level of compounds of formula I are more stabilized than the comparative compounds.

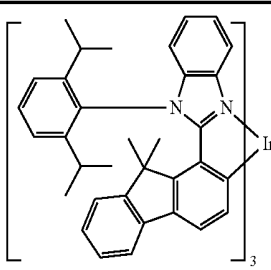
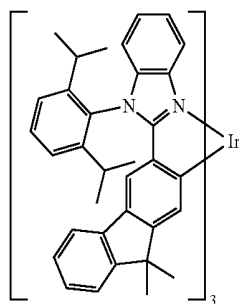
256

TABLE 2

Compound	HOMO	LUMO	Gap	S1	T1
	-4.93	-1.30	-3.63	440	522
Compound T8					
	-5.05	-1.76	-3.30	478	546
Compound T9					
	-5.06	-1.59	-3.47	464	502
Compound T10					
	-5.03	-1.86	-3.17	484	561
Compound T11					
	-4.80	-1.17	-3.64	447	519
Comparative Compound 3					

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TABLE 2-continued

Compound	HOMO	LUMO	Gap	S1	T1
	-4.93	-1.68	-3.24	487	551
Comparative Compound 4					
	-4.93	-1.51	-3.43	456	507
Comparative Compound 5					

258

TABLE 2-continued

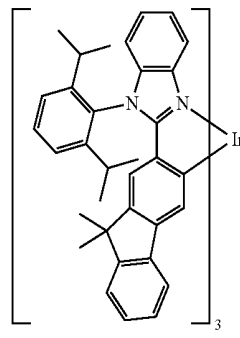
Compound	HOMO	LUMO	Gap	S1	T1
	-4.92	-1.68	-3.24	474	551
Comparative Compound 6					

Table 3, below, summarizes the calculation results of phenylpyridine containing homoleptic and heteroleptic iridium complexes. In this series, the calculated emission peak is slightly blue shifted, which results in more saturated color. In addition, the LUMO level of the compounds of formula I are more stabilized than that of the comparative compounds.

TABLE 3

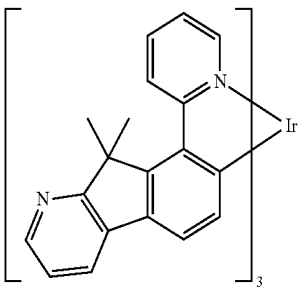
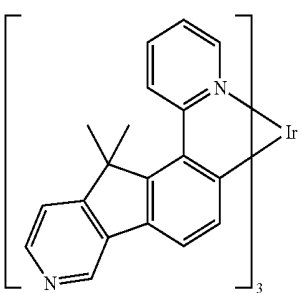
Compound	HOMO	LUMO	Gap	S1	T1
	-5.18	-1.75	-3.43	454	519
Compound T12					
	-5.22	-1.79	-3.43	454	516
Compound T13					

TABLE 3-continued

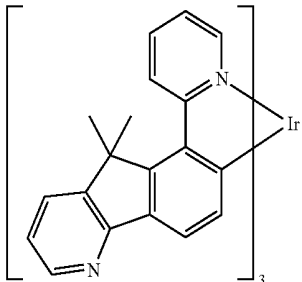
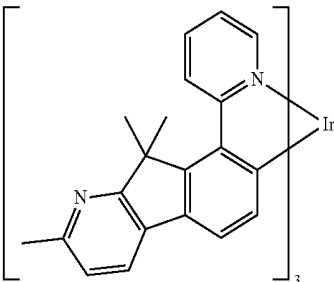
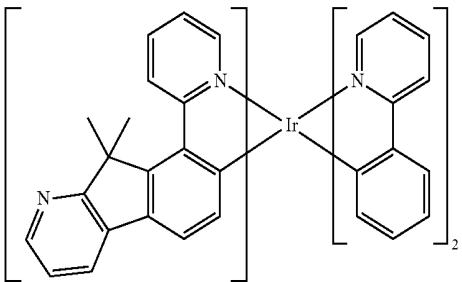
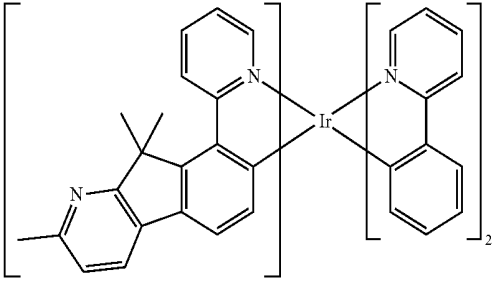
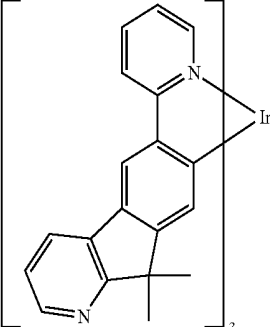
Compound	HOMO	LUMO	Gap	S1	T1
 Compound T14	-5.19	-1.75	-3.44	453	516
 Compound T15	-5.11	-1.72	-3.39	459	523
 Compound 44	-5.17	-1.67	-3.50	452	521
 Compound 255	-5.12	-1.66	-3.47	456	524
 Compound T16	-5.18	-1.68	-3.50	460	506

TABLE 3-continued

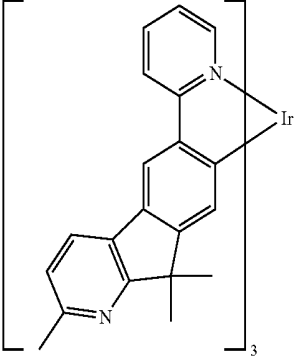
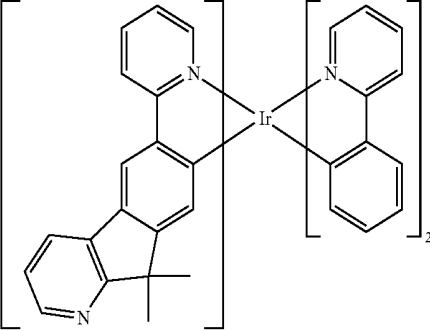
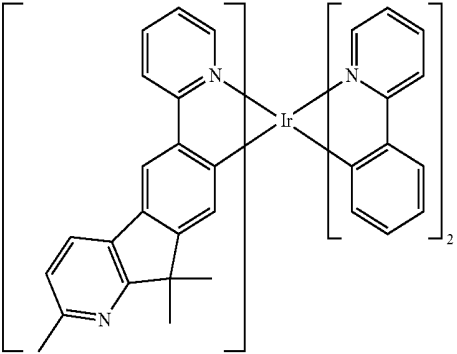
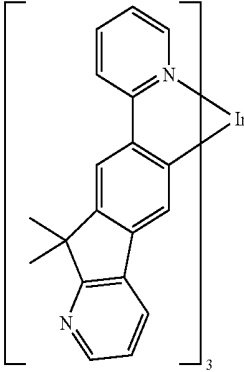
Compound	HOMO	LUMO	Gap	S1	T1
 <p>Compound T17</p>	-5.11	-1.65	-3.47	461	519
 <p>Compound 84</p>	-5.18	-1.63	-3.55	462	505
 <p>Compound 295</p>	-5.13	-1.62	-3.52	462	508
 <p>Compound T18</p>	-5.20	-1.91	-3.29	467	555

TABLE 3-continued

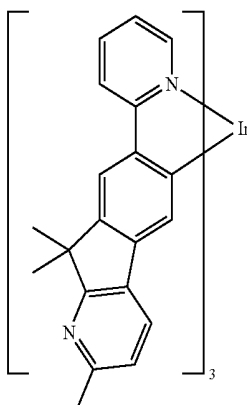
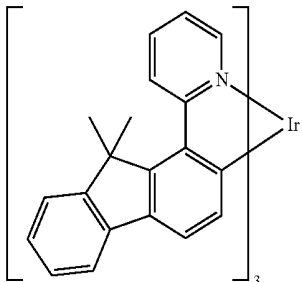
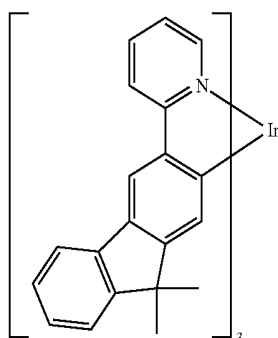
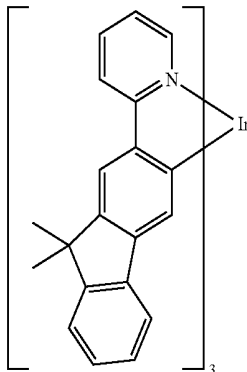
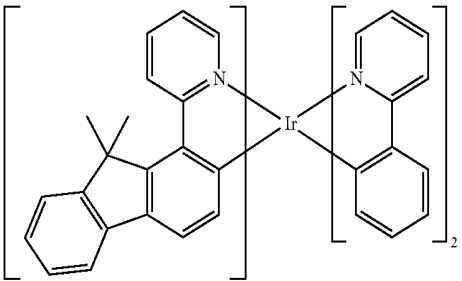
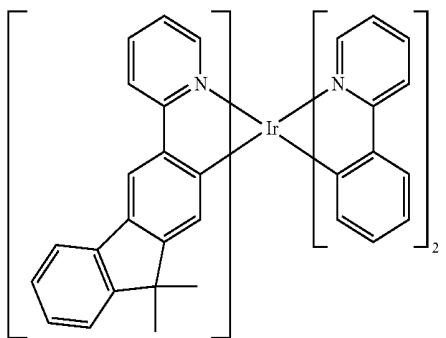
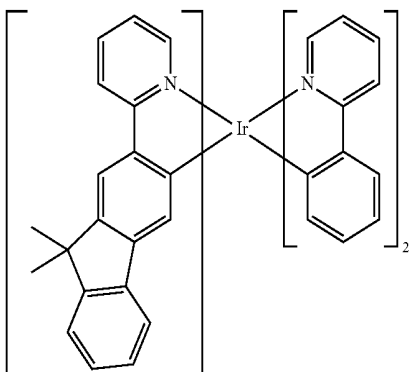
Compound	HOMO	LUMO	Gap	S1	T1
 <p>Compound T19</p>	-5.15	-1.84	-3.31	464	555
 <p>Comparative Compound 7</p>	-5.04	-1.60	-3.36	464	525
 <p>Comparative Compound 8</p>	-5.04	-1.60	-3.45	452	523
 <p>Comparative Compound 9</p>	-5.08	-1.74	-3.34	462	550

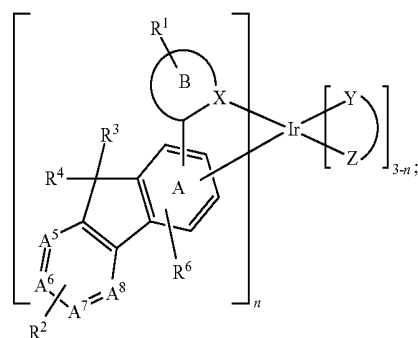
TABLE 3-continued

Compound	HOMO	LUMO	Gap	S1	T1
 Comparative Compound 10	-5.08	-1.60	-3.44	457	524
 Comparative Compound 11	-5.09	-1.60	-3.49	453	510
 Comparative Compound 12	-5.15	-1.69	-3.46	448	547

It is understood that the various embodiments described herein are by way of example only, and are not intended to limit the scope of the invention. For example, many of the materials and structures described herein may be substituted with other materials and structures without deviating from the spirit of the invention. The present invention as claimed may therefore include variations from the particular examples and preferred embodiments described herein, as will be apparent to one of skill in the art. It is understood that various theories as to why the invention works are not intended to be limiting.

We claim:

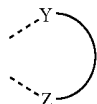
1. A compound having the formula  $\text{Ir}(\text{L}_A)_n(\text{L}_B)_{3-n}$ , having the structure:



wherein  $A^5$ ,  $A^6$ ,  $A^7$ , and  $A^8$  comprise carbon or nitrogen; wherein at least one of  $A^5$ ,  $A^6$ ,  $A^7$ , and  $A^8$  is nitrogen;

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wherein ring B is bonded to ring A through a C—C bond;  
 wherein R<sup>1</sup>, R<sup>2</sup> and R<sup>6</sup> independently represent from  
 mono-substitution to the possible maximum number of  
 substitution, or no substitution;  
 wherein any adjacent substitutions in R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, and R<sup>4</sup>  
 are optionally linked together to form a ring;  
 wherein X is a neutral donor;  
 wherein



is a monoanionic bidentate ligand;

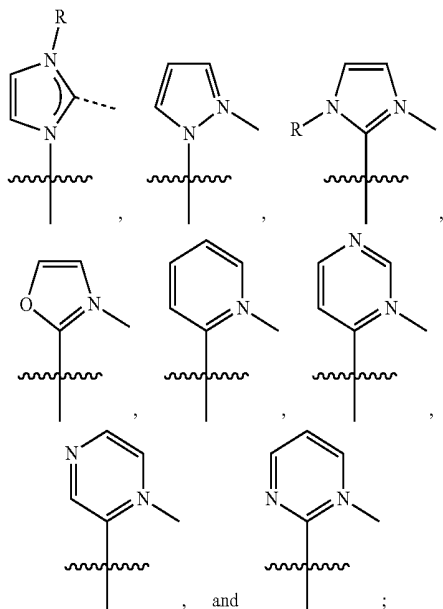
wherein R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, and R<sup>6</sup> are independently selected  
 from the group consisting of hydrogen, deuterium,  
 halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy,  
 aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl,  
 alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic  
 acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl,  
 sulfonyl, phosphino, and combinations thereof; and  
 wherein n is an integer from 1 to 3.

2. The compound of claim 1, wherein n is 1.

3. The compound of claim 1, wherein X is selected from  
 the group consisting of N, P, and C.

4. The compound of claim 1, wherein only one of A<sup>5</sup> to  
 A<sup>8</sup> is nitrogen.

5. The compound of claim 1, wherein ring B is selected  
 from the group consisting of:



wherein the wave line indicates the bond to ring A, and the  
 dashed line represents the bond to Ir; and  
 wherein R is selected from the group consisting of hydro-  
 gen, deuterium, alkyl, cycloalkyl, heteroalkyl, arylal-  
 kyl, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl,  
 aryl, heteroaryl, and combinations thereof.

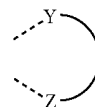
6. The compound of claim 1, wherein R<sup>3</sup>, and R<sup>4</sup> are alkyl.

7. The compound of claim 1, wherein R<sup>3</sup>, and R<sup>4</sup> are  
 linked together to form a ring.

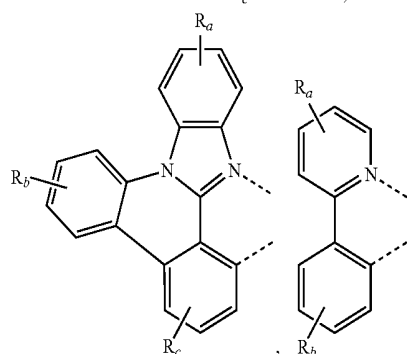
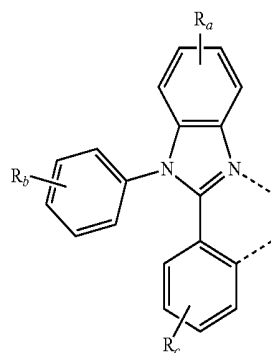
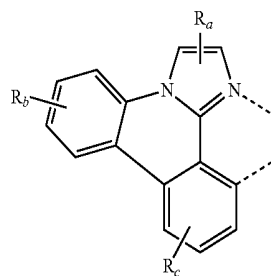
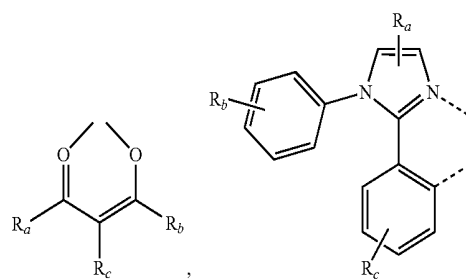
8. The compound of claim 1, wherein R<sup>2</sup> is selected from  
 the group consisting of hydrogen, deuterium, alkyl,  
 cycloalkyl, and combinations thereof.

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9. The compound of claim 1, wherein

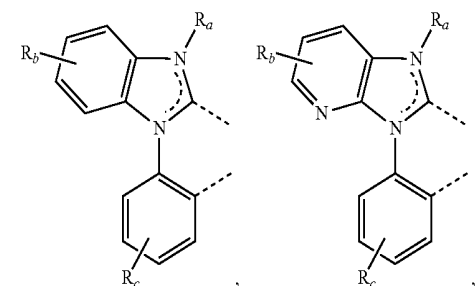
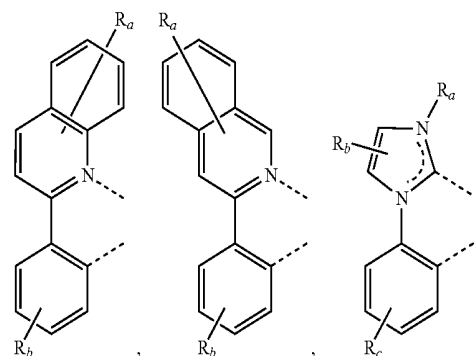
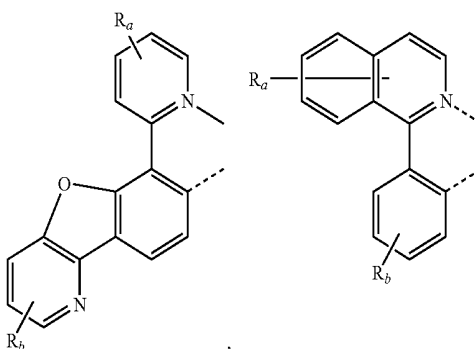
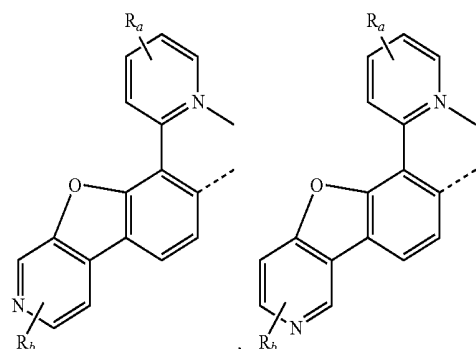
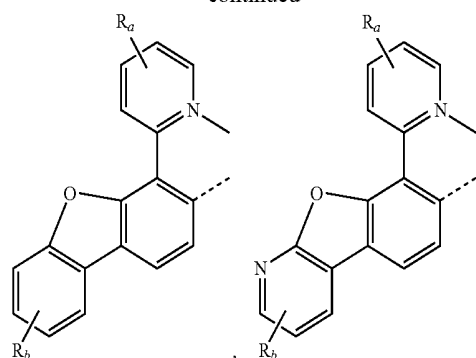


is selected from the group consisting of:



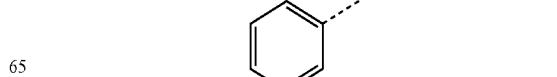
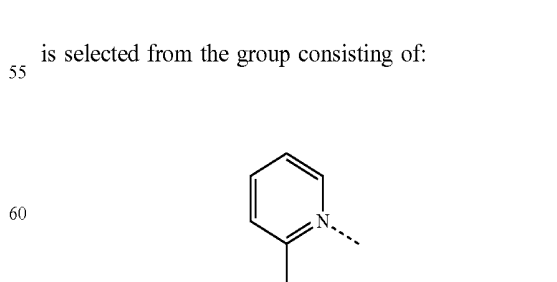
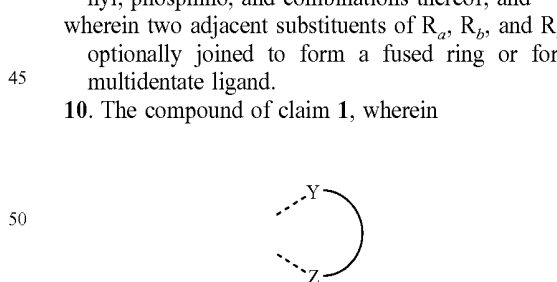
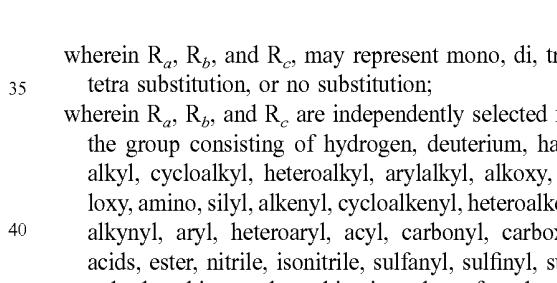
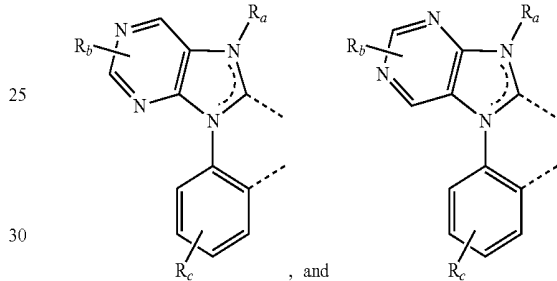
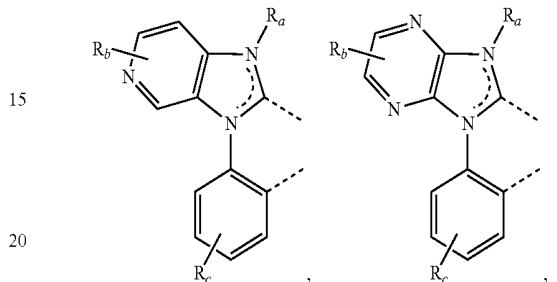
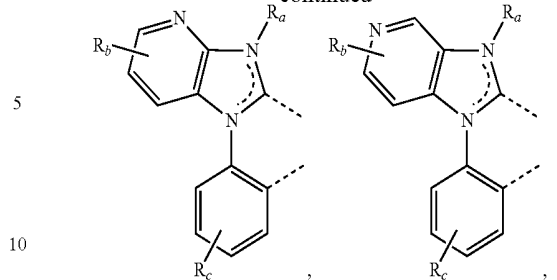
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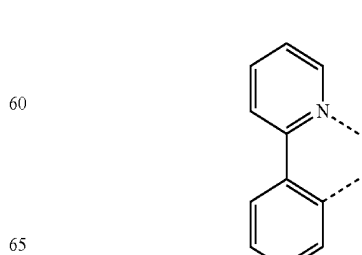
wherein  $R_a$ ,  $R_b$ , and  $R_c$ , may represent mono, di, tri, or tetra substitution, or no substitution;

wherein  $R_a$ ,  $R_b$ , and  $R_c$  are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and wherein two adjacent substituents of  $R_a$ ,  $R_b$ , and  $R_c$  are optionally joined to form a fused ring or form a multidentate ligand.

10. The compound of claim 1, wherein



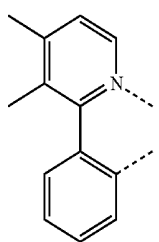
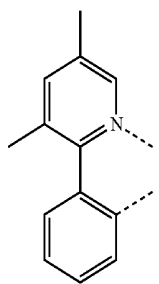
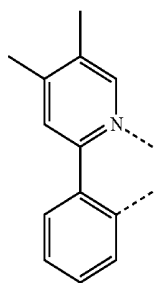
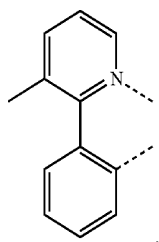
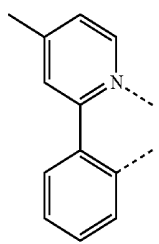
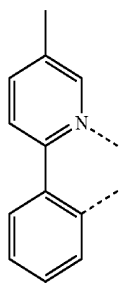
is selected from the group consisting of:



L<sub>B1</sub>

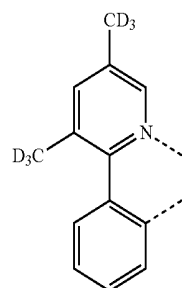
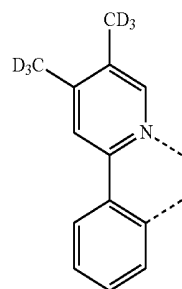
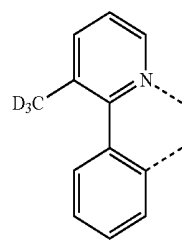
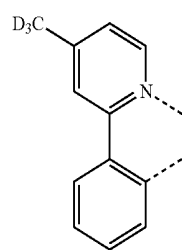
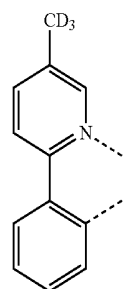
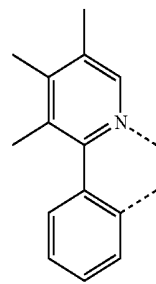
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272

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L<sub>B2</sub>

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L<sub>B3</sub>

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L<sub>B4</sub>

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L<sub>B5</sub>

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L<sub>B6</sub>

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L<sub>B8</sub>

L<sub>B9</sub>

L<sub>B10</sub>

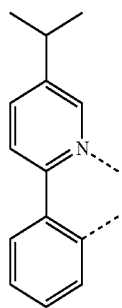
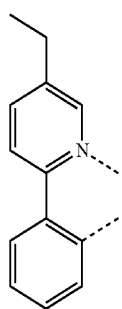
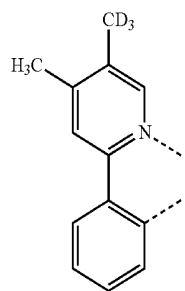
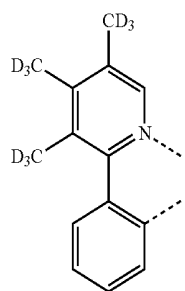
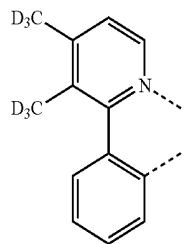
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L<sub>B13</sub>

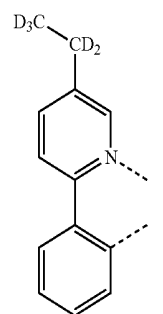
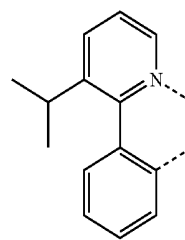
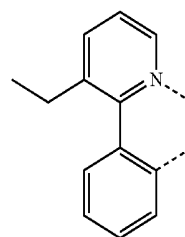
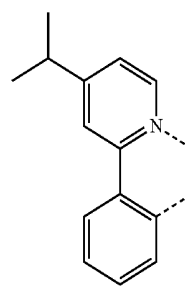
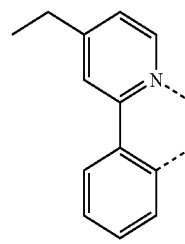
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274

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L<sub>B14</sub>

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L<sub>B15</sub>

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L<sub>B16</sub>

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L<sub>B18</sub>

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L<sub>B19</sub>

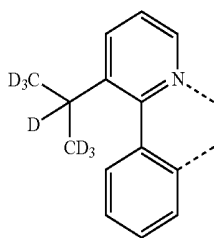
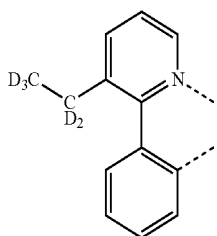
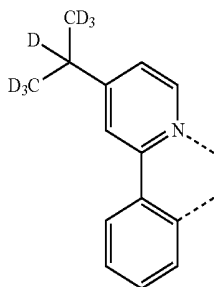
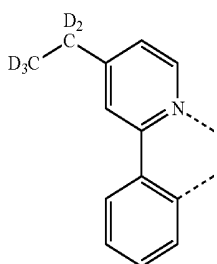
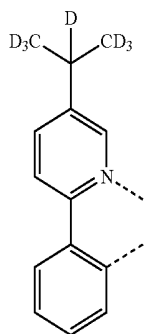
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L<sub>B22</sub>

L<sub>B23</sub>

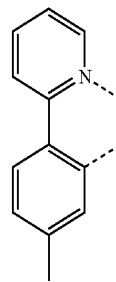
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**276**  
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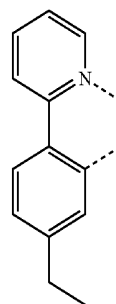
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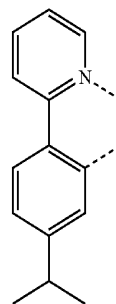
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L<sub>B25</sub>

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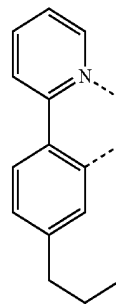
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L<sub>B26</sub>

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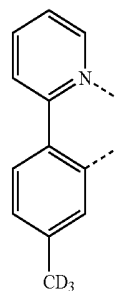


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L<sub>B28</sub>

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L<sub>B30</sub>

L<sub>B31</sub>

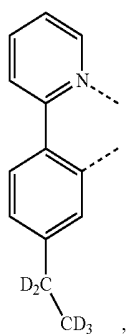
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L<sub>B33</sub>

L<sub>B34</sub>

277

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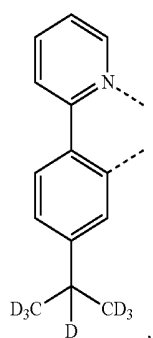


L<sub>B35</sub>

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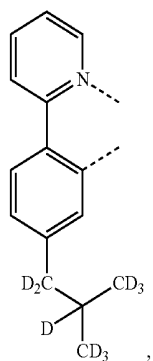
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L<sub>B36</sub>

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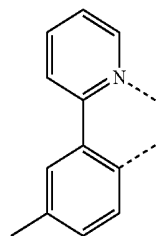
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L<sub>B37</sub>

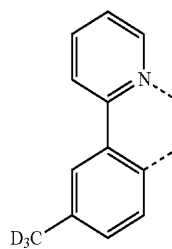
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L<sub>B38</sub>

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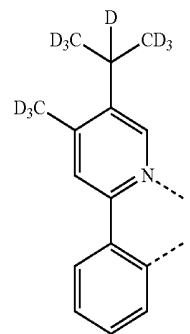
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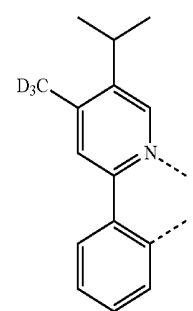
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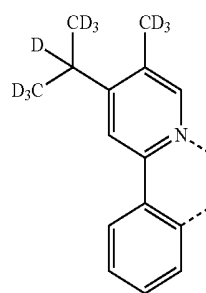
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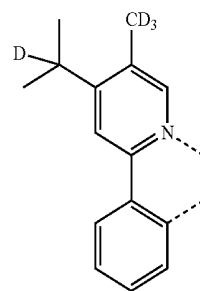
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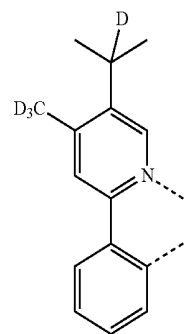
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L<sub>B42</sub>



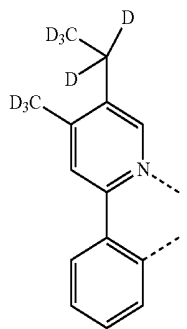
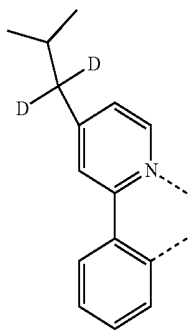
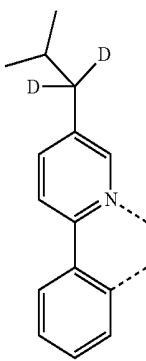
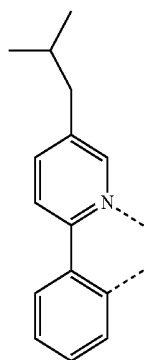
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L<sub>B44</sub>

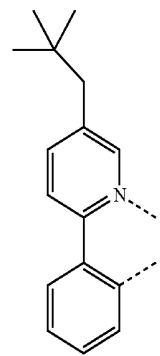
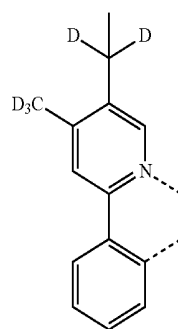
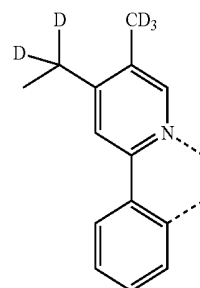
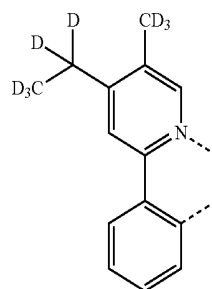
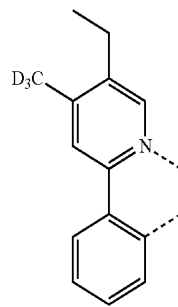
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L<sub>B45</sub>

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L<sub>B47</sub>

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L<sub>B48</sub>

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L<sub>B49</sub>

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L<sub>B50</sub>

L<sub>B51</sub>

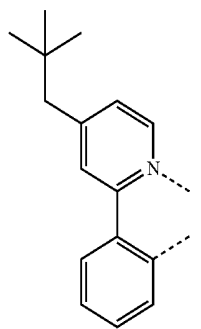
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L<sub>B53</sub>

L<sub>B54</sub>

**281**

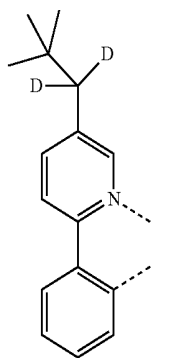
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L<sub>B55</sub>

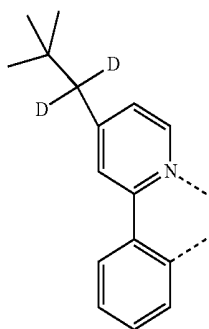
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L<sub>B56</sub>



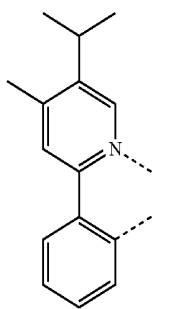
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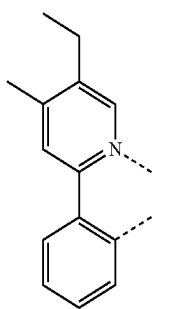
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L<sub>B58</sub>



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L<sub>B59</sub>

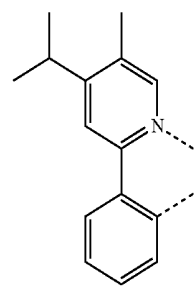


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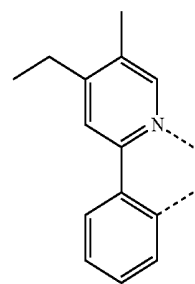
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**282**

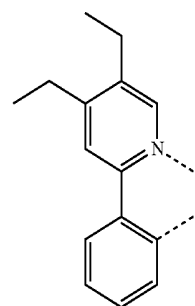
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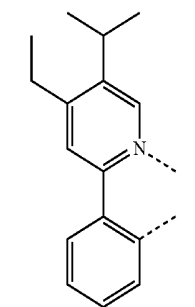
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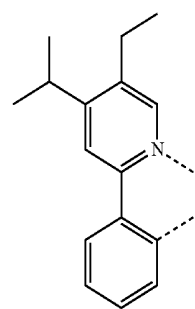
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L<sub>B62</sub>



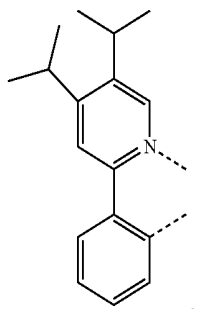
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L<sub>B64</sub>

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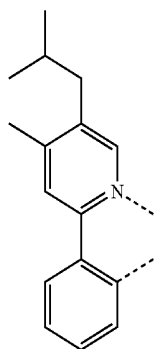
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L<sub>B66</sub>

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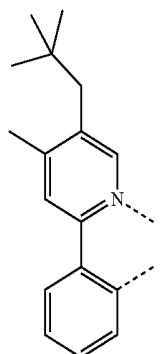


L<sub>B67</sub>

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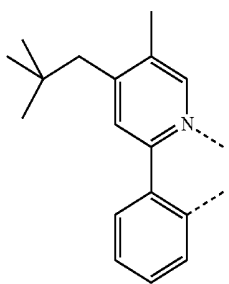
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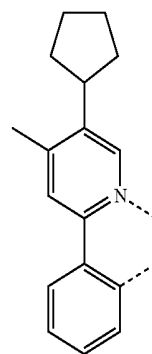
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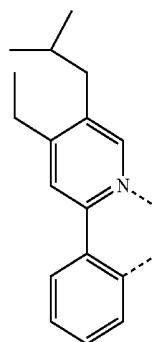


**284**

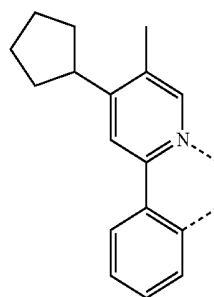
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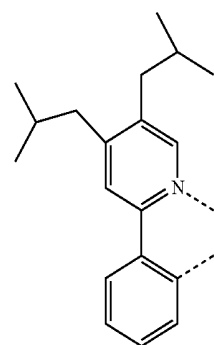
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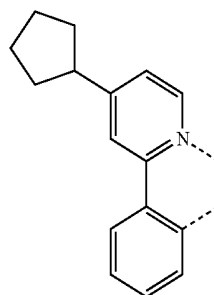
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L<sub>B72</sub>



L<sub>B73</sub>



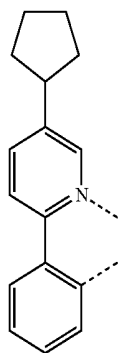
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**285**

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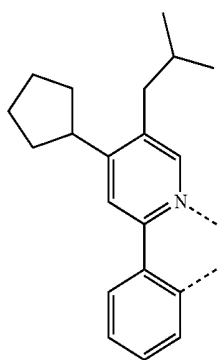


L<sub>B75</sub>

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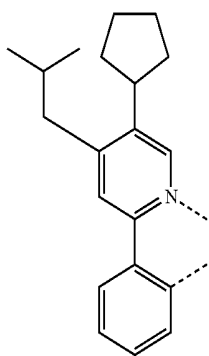


L<sub>B76</sub>

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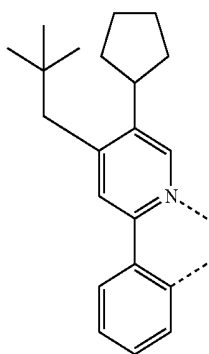
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L<sub>B77</sub>

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L<sub>B78</sub>

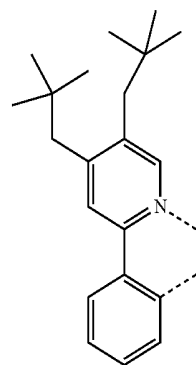
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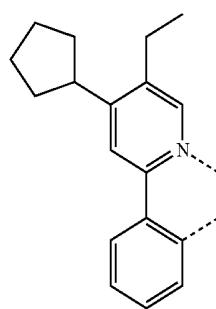
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**286**

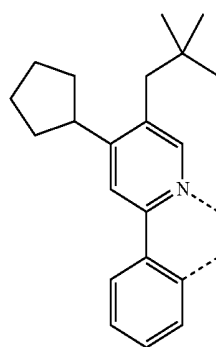
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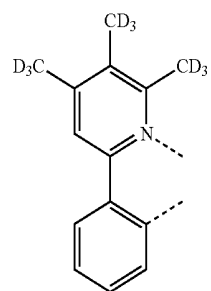
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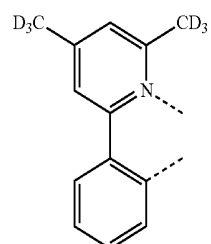
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L<sub>B81</sub>



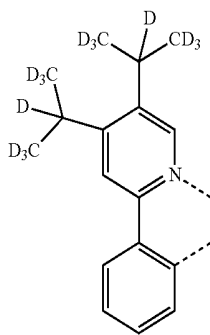
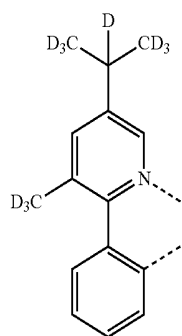
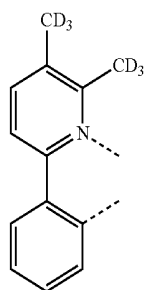
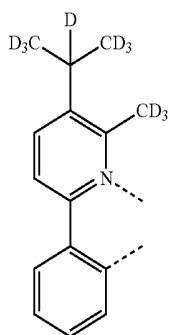
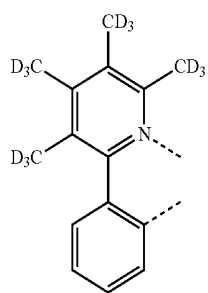
L<sub>B82</sub>



L<sub>B83</sub>

**287**

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**288**

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L<sub>B84</sub>

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L<sub>B85</sub>

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L<sub>B88</sub>

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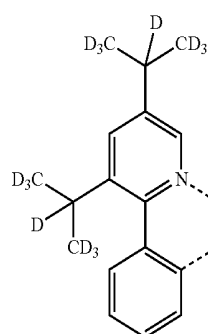
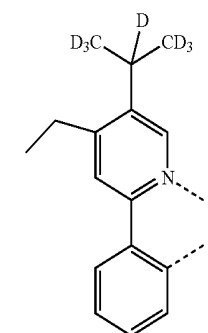
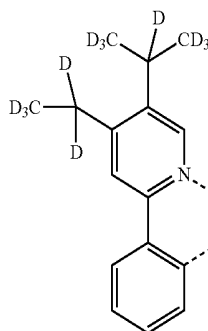
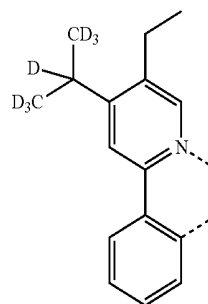
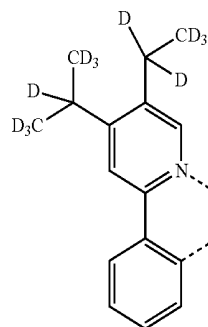
L<sub>B89</sub>

L<sub>B90</sub>

L<sub>B91</sub>

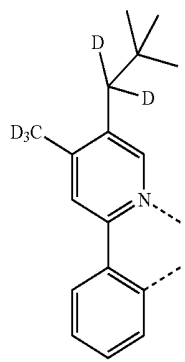
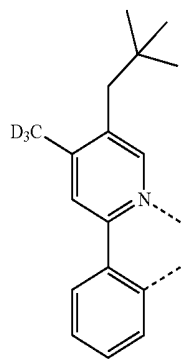
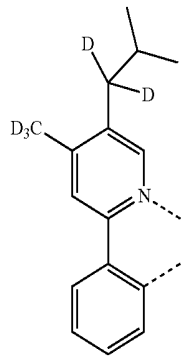
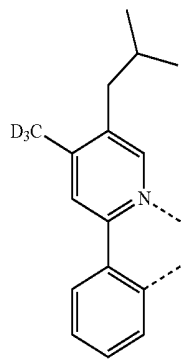
L<sub>B92</sub>

L<sub>B93</sub>



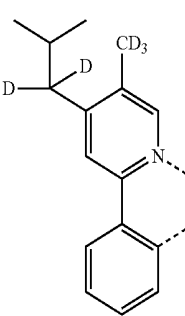
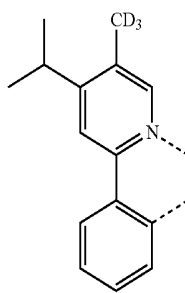
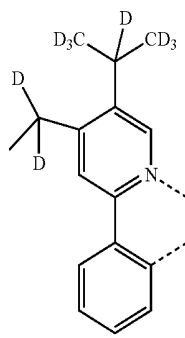
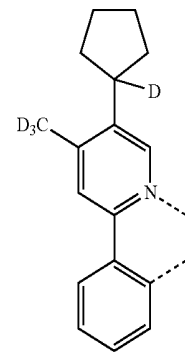
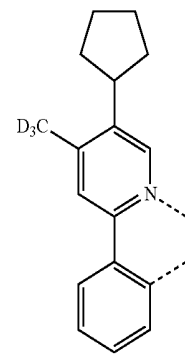
**289**

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**290**

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L<sub>B94</sub>

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L<sub>B95</sub>

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L<sub>B96</sub>

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L<sub>B97</sub>

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L<sub>B98</sub>

L<sub>B99</sub>

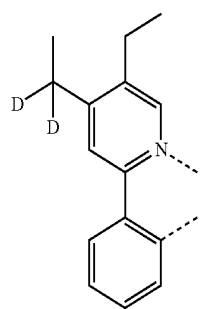
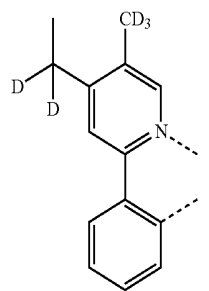
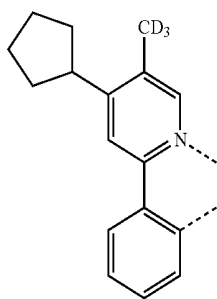
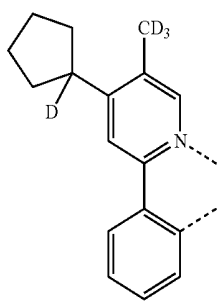
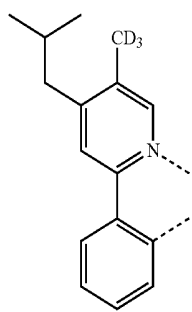
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L<sub>B101</sub>

L<sub>B102</sub>

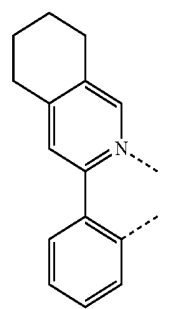
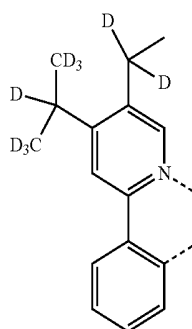
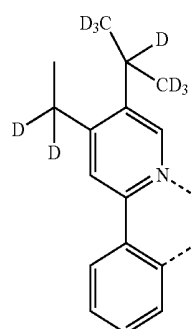
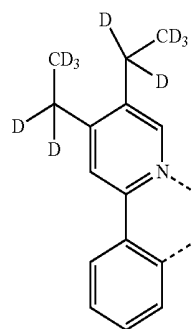
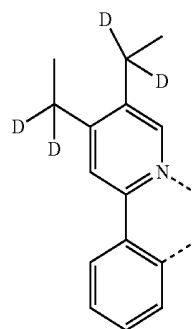
**291**

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**292**

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L<sub>B103</sub>

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L<sub>B104</sub>

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L<sub>B105</sub>

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L<sub>B106</sub>

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L<sub>B107</sub>

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L<sub>B108</sub>

L<sub>B109</sub>

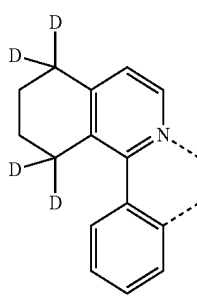
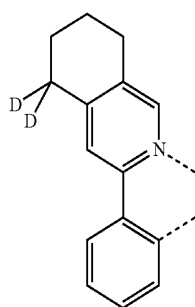
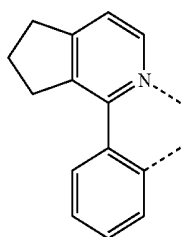
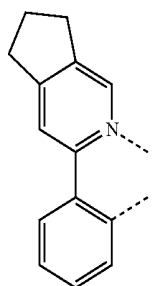
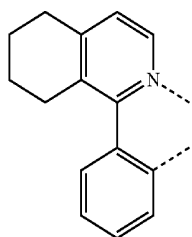
L<sub>B110</sub>

L<sub>B111</sub>

L<sub>B112</sub>

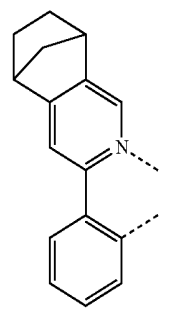
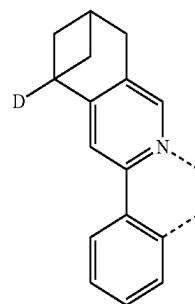
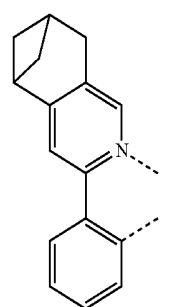
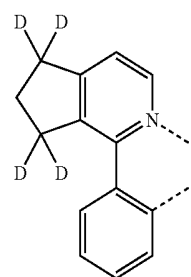
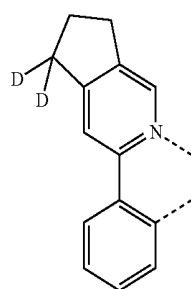
293

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294

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L<sub>B113</sub>

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L<sub>B114</sub>

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L<sub>B115</sub>

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L<sub>B116</sub>

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L<sub>B117</sub>

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L<sub>B118</sub>

L<sub>B119</sub>

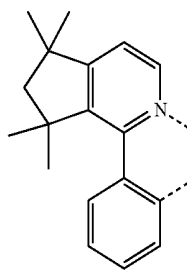
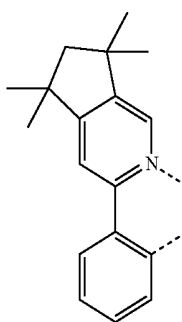
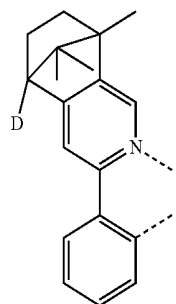
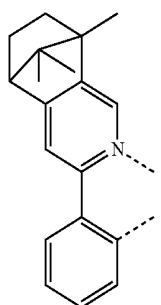
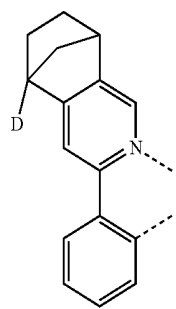
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L<sub>B121</sub>

L<sub>B122</sub>

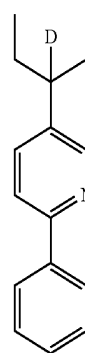
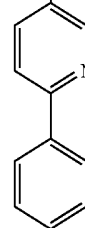
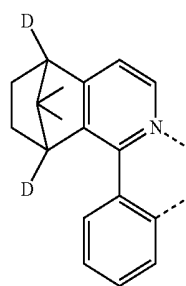
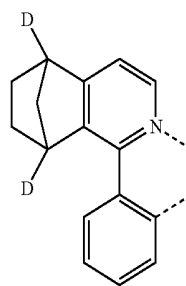
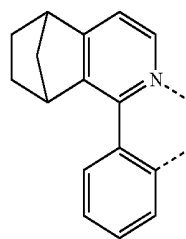
**295**

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**296**

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L<sub>B123</sub>

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L<sub>B124</sub>

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L<sub>B125</sub>

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L<sub>B126</sub>

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L<sub>B127</sub>

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L<sub>B128</sub>

L<sub>B129</sub>

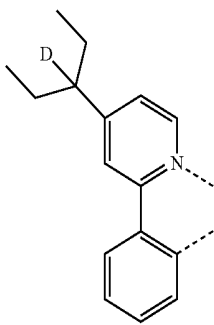
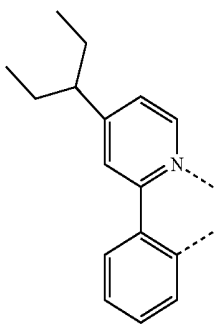
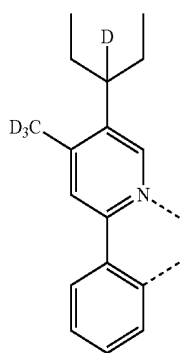
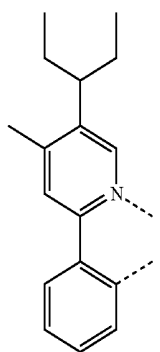
L<sub>B130</sub>

L<sub>B132</sub>

L<sub>B132</sub>

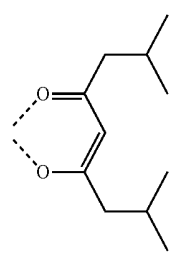
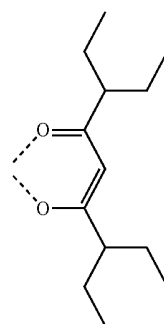
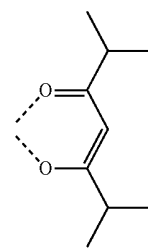
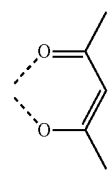
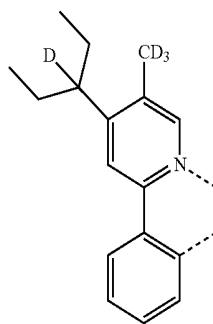
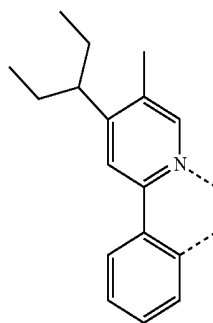
297

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298

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L<sub>B133</sub>

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L<sub>B134</sub>

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L<sub>B135</sub>

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L<sub>B136</sub>

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L<sub>B137</sub>

L<sub>B138</sub>

L<sub>B139</sub>

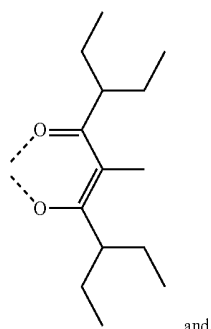
L<sub>B140</sub>

L<sub>B141</sub>

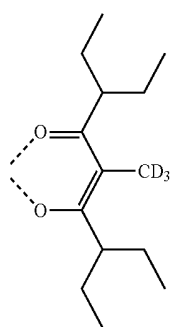
L<sub>B142</sub>

299

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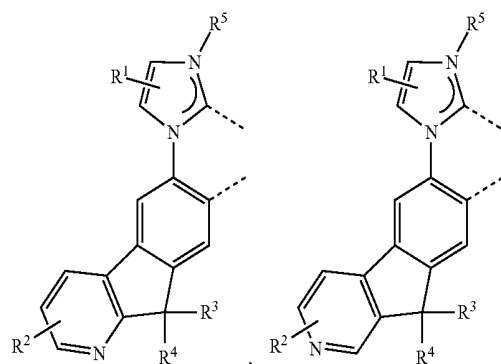
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LB143

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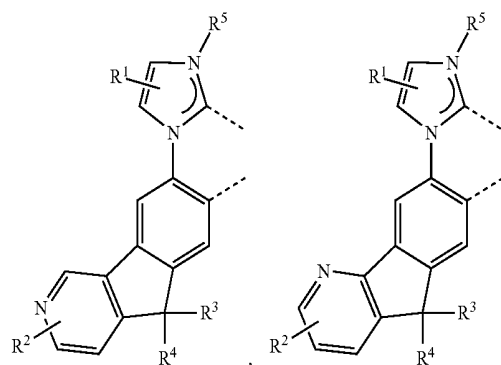


LB144

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11. The compound of claim 1, wherein L<sub>4</sub> is selected from the group consisting of:

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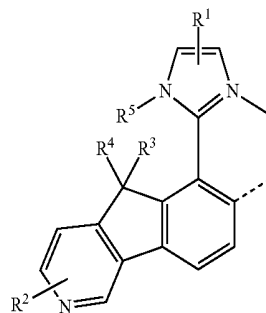
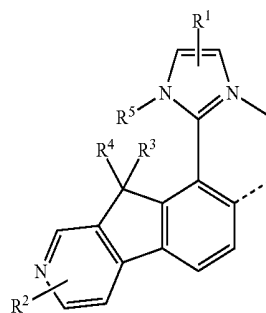
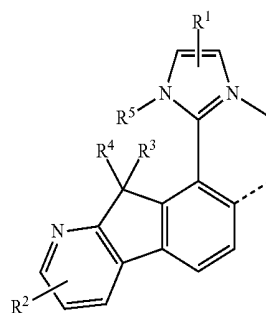
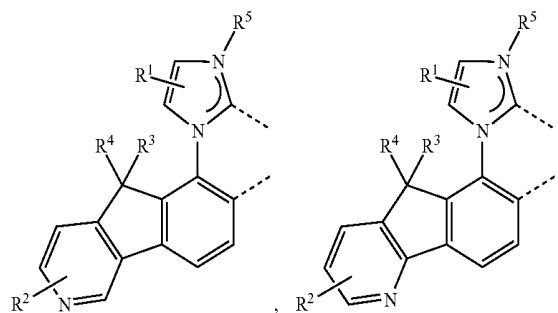
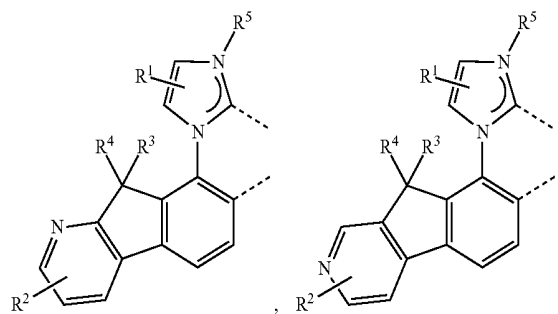
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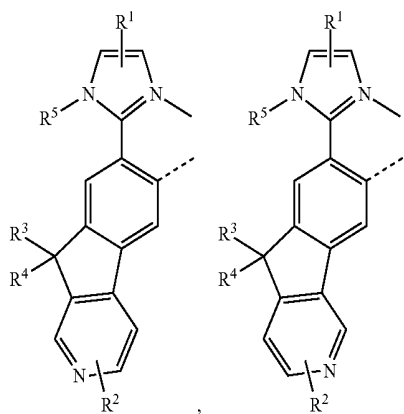
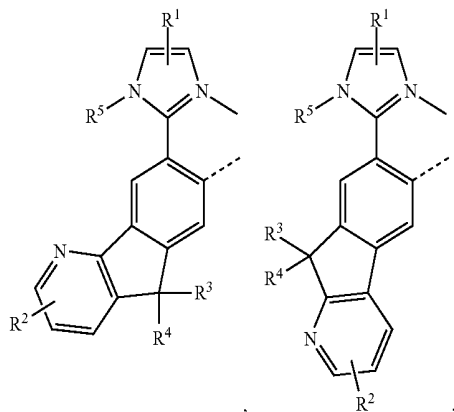
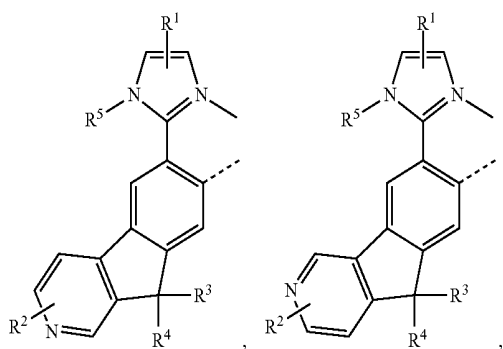
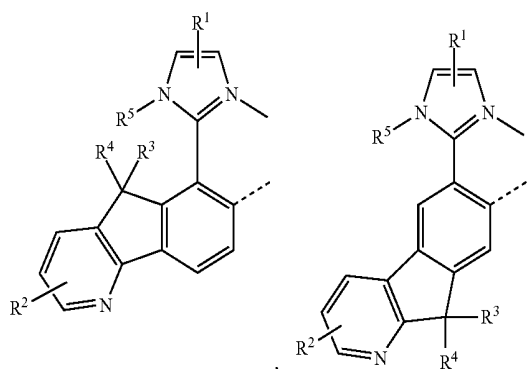
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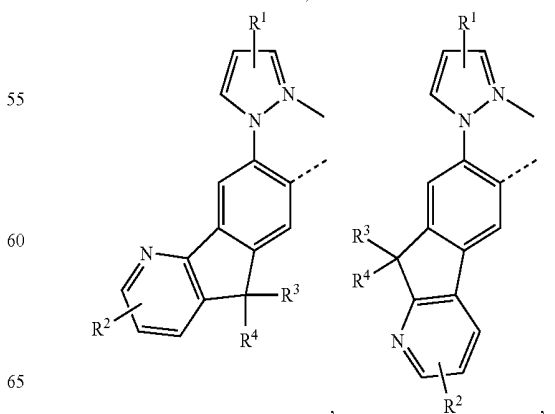
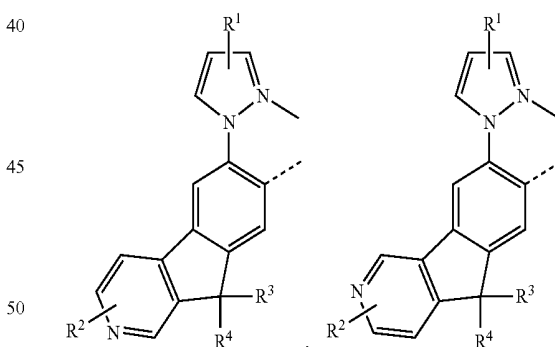
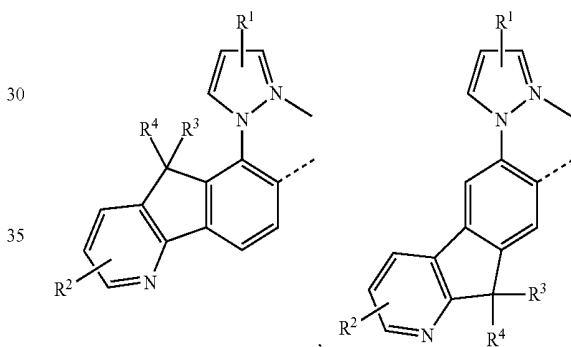
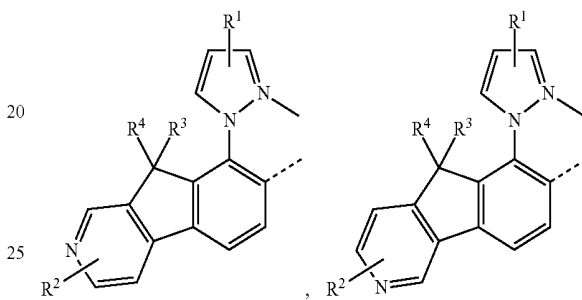
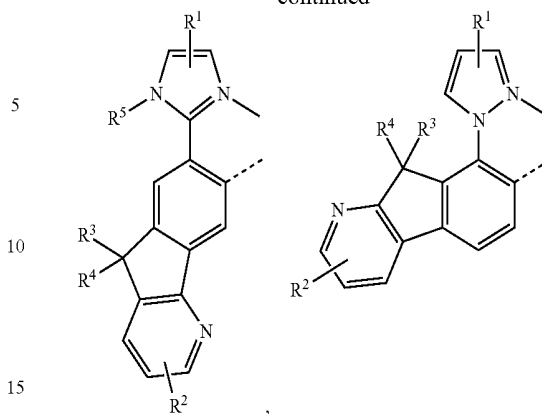
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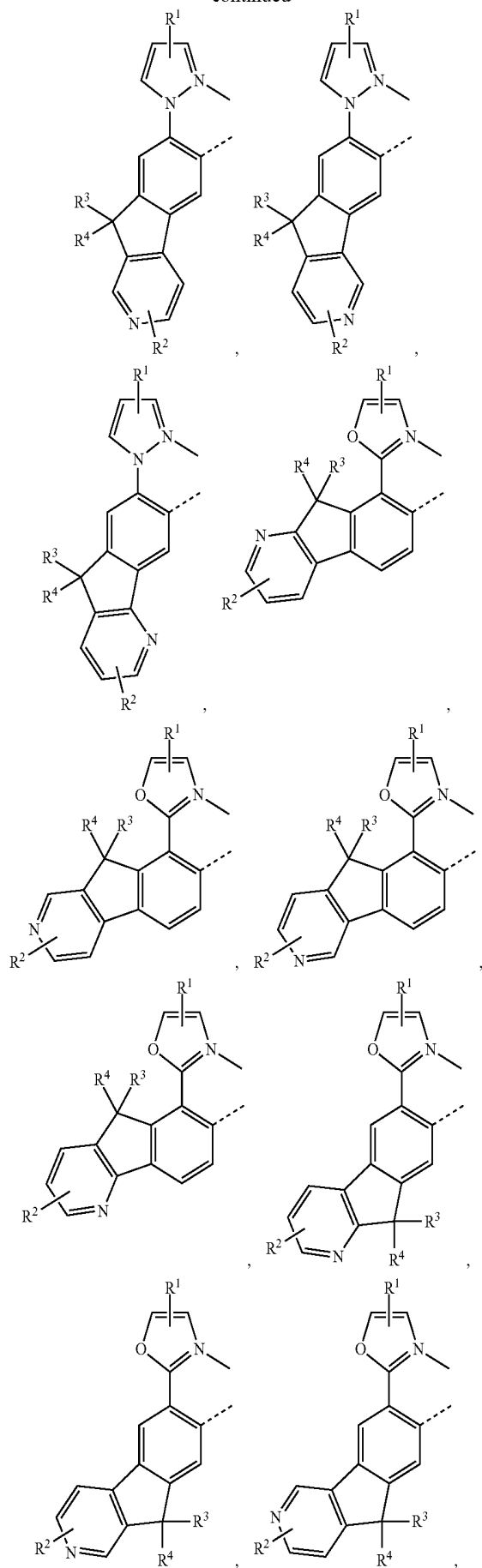
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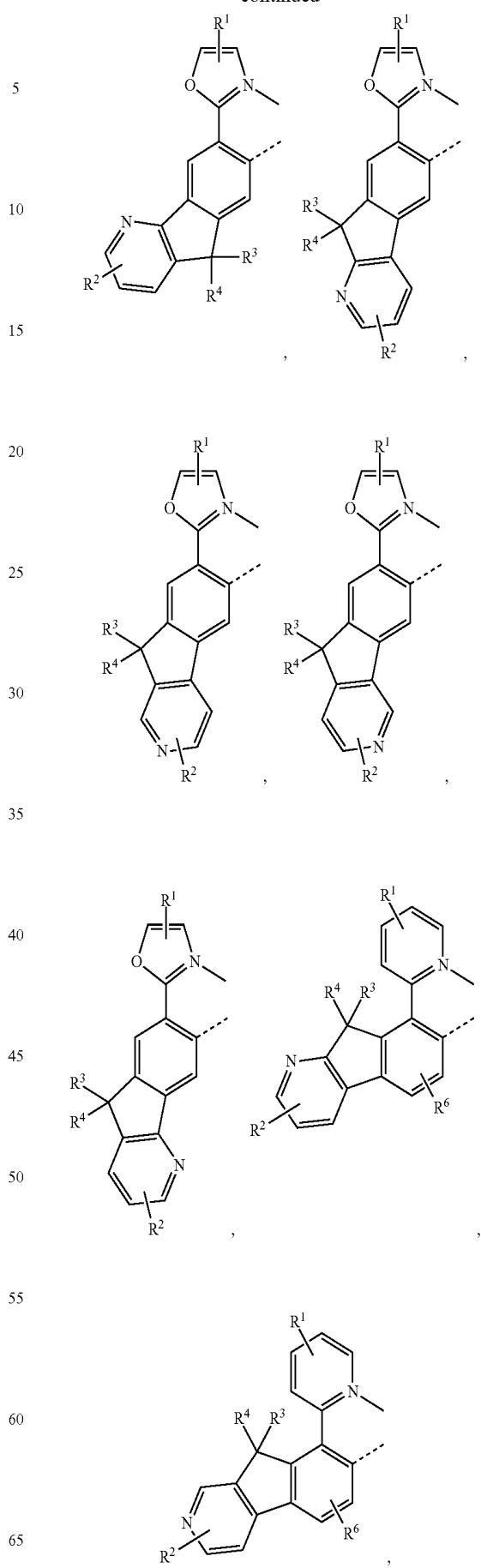
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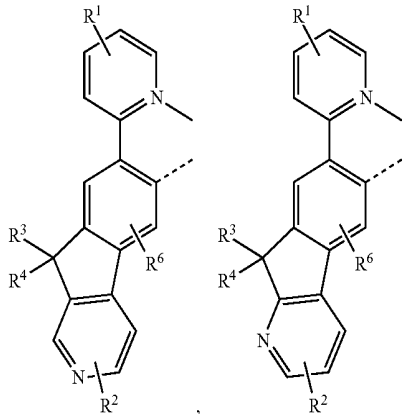
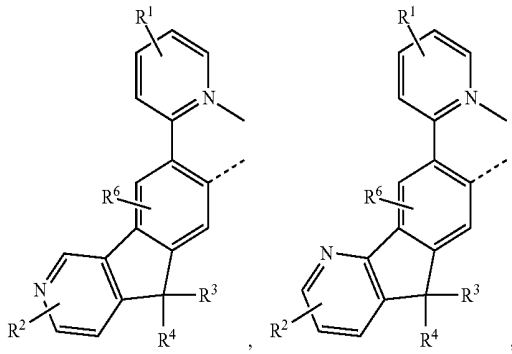
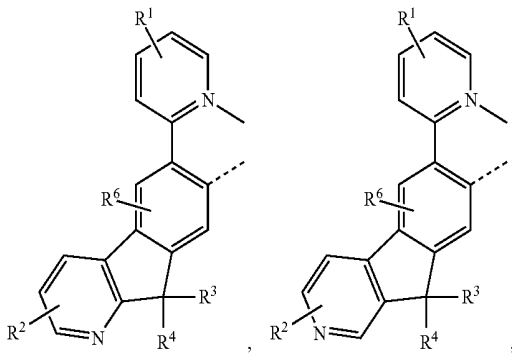
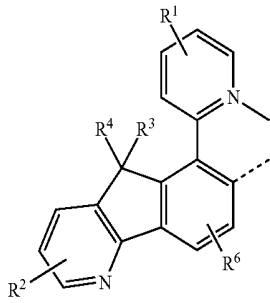
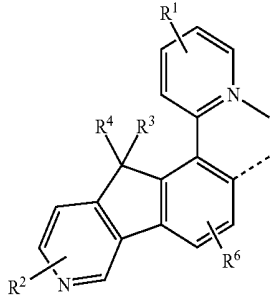
304

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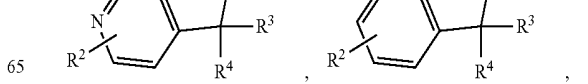
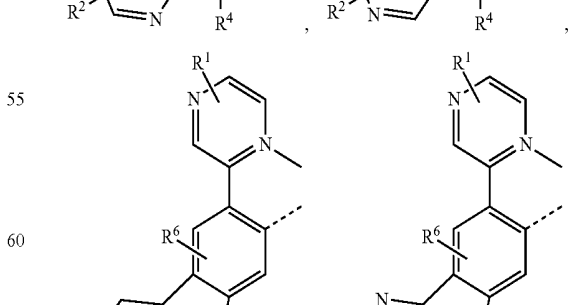
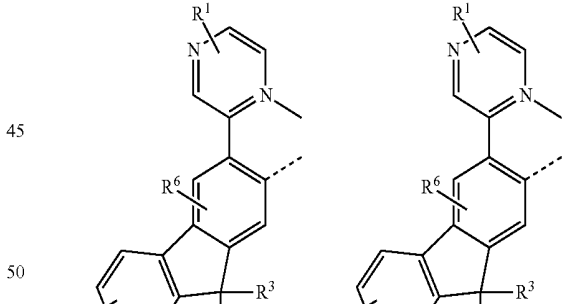
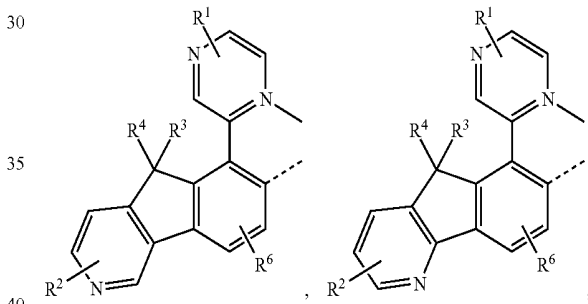
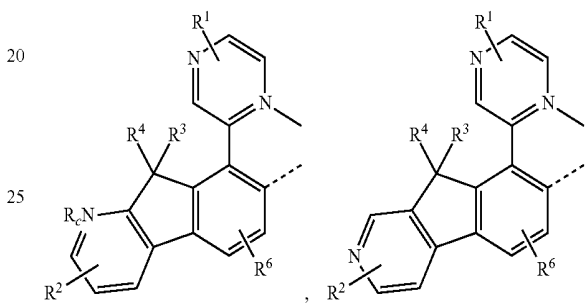
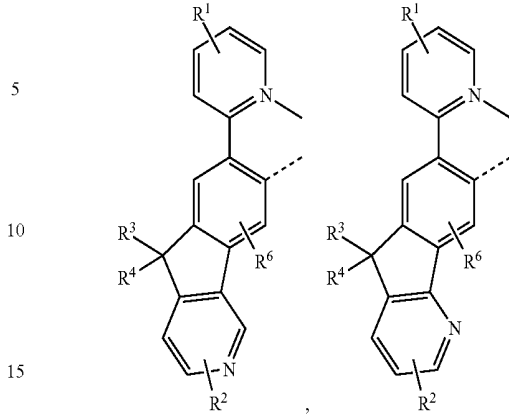
305

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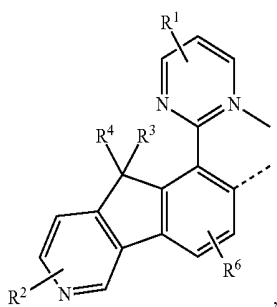
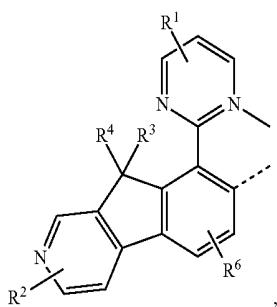
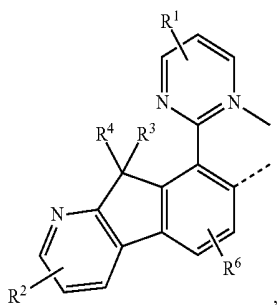
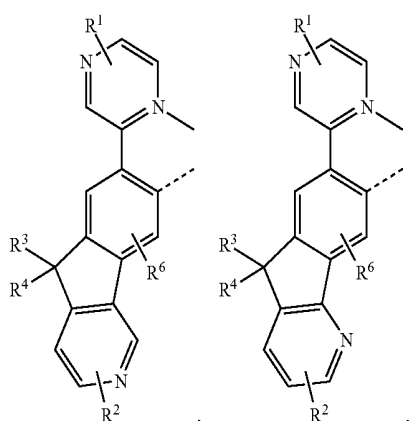
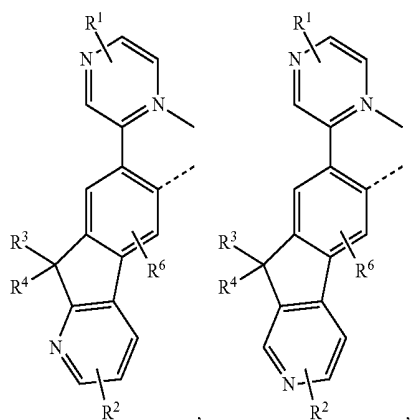
306

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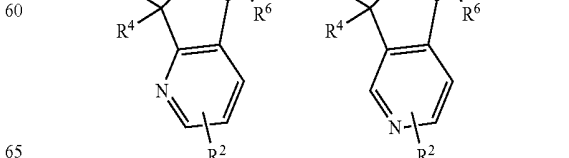
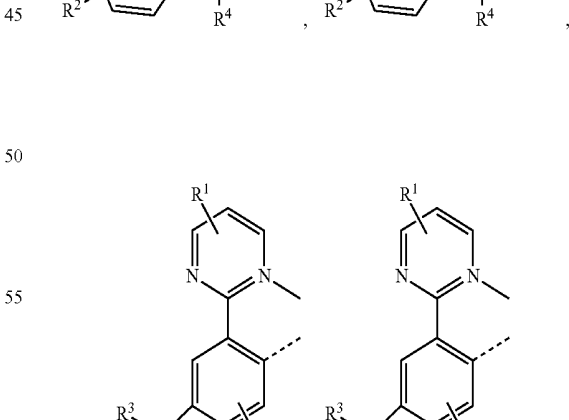
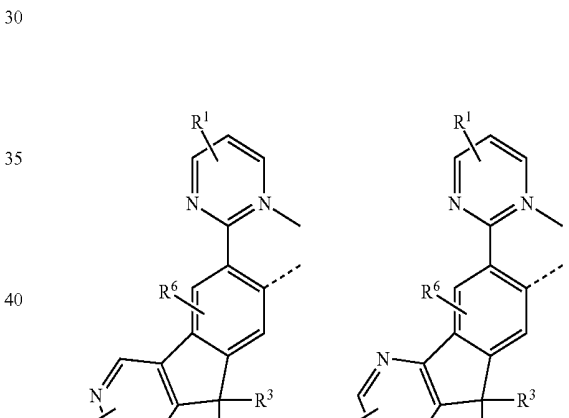
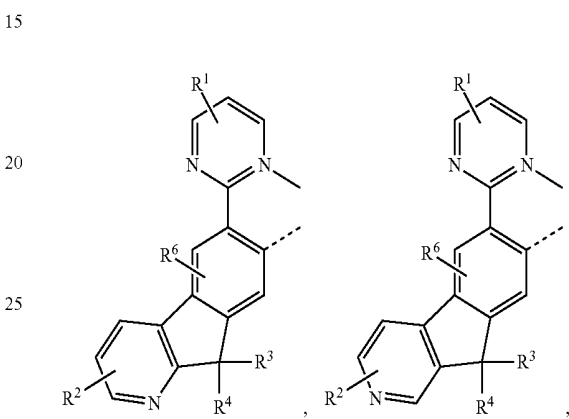
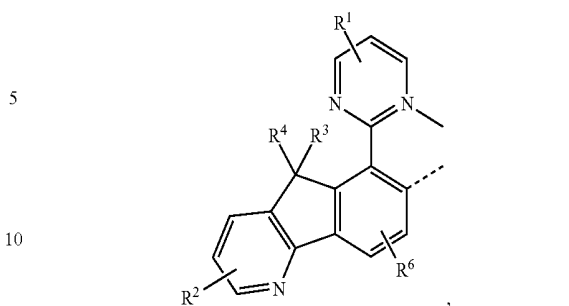
307

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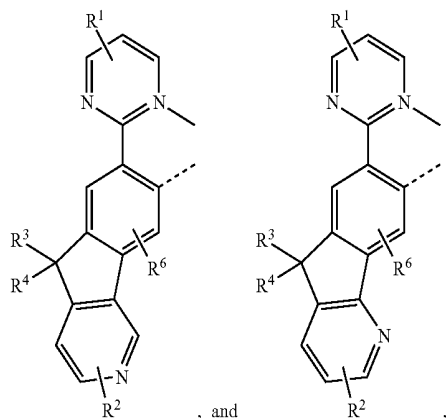
308

-continued



309

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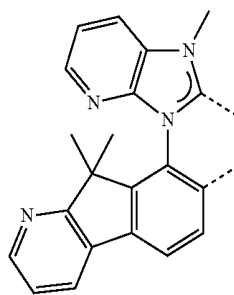
5

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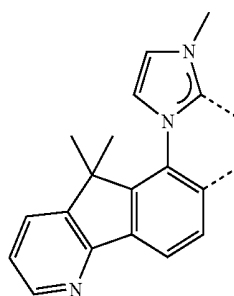
15

310

-continued



L<sub>44</sub>



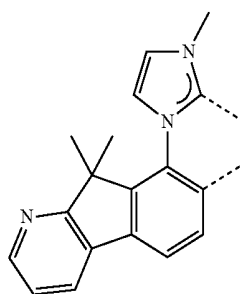
L<sub>45</sub>

wherein R<sup>5</sup> is selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

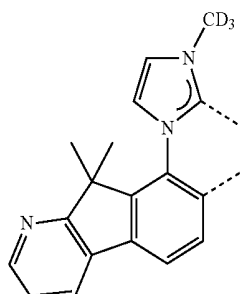
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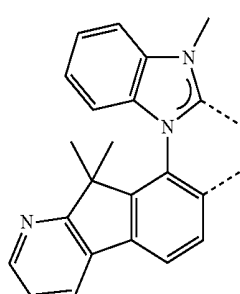
12. The compound of claim 1, wherein L<sub>4</sub> is selected from the group consisting of:



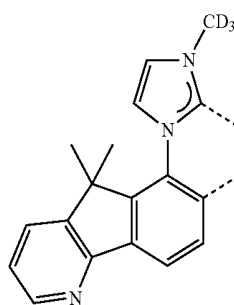
L<sub>41</sub>



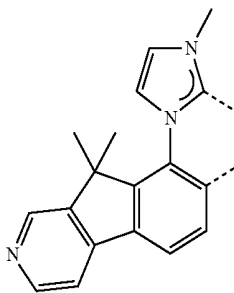
L<sub>42</sub>



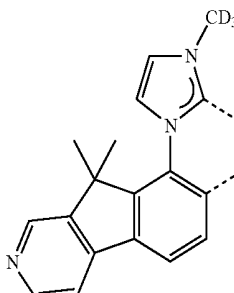
L<sub>43</sub>



L<sub>46</sub>



L<sub>47</sub>



L<sub>48</sub>

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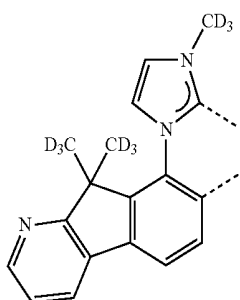
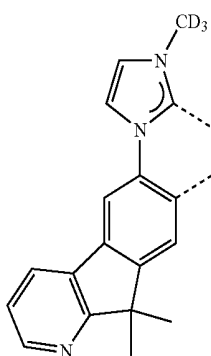
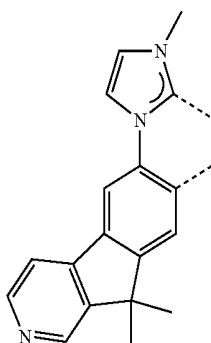
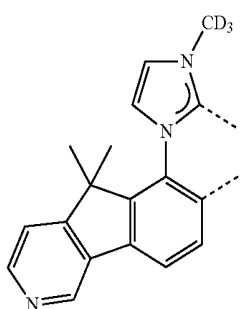
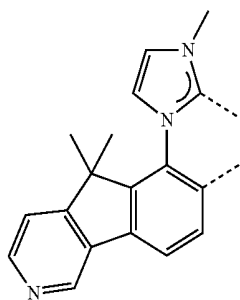
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311

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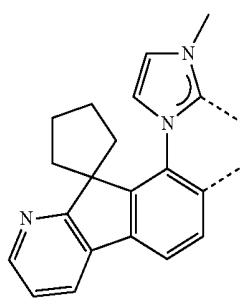


312

-continued

L<sub>49</sub>

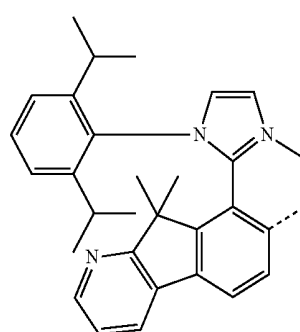
5



L<sub>414</sub>

L<sub>410</sub>

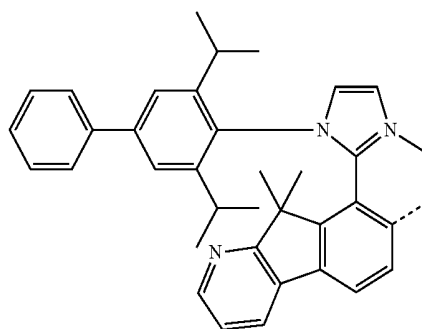
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L<sub>415</sub>

L<sub>411</sub>

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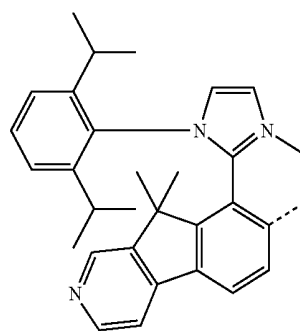


L<sub>416</sub>

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L<sub>412</sub>

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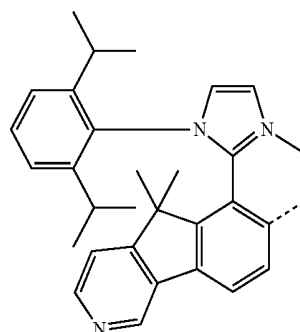
L<sub>417</sub>

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L<sub>413</sub>

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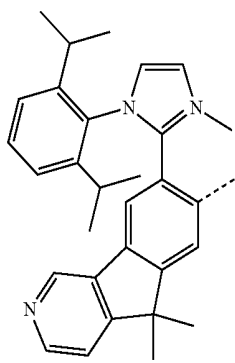
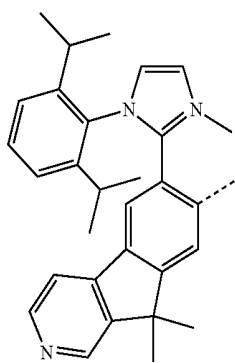
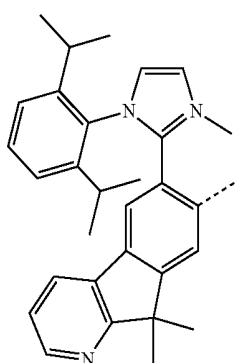
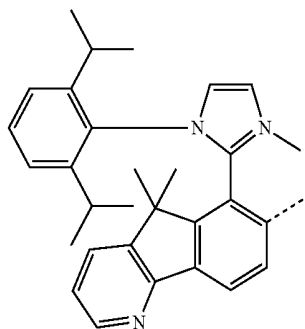
L<sub>418</sub>

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313

-continued



314

-continued

L<sub>419</sub>

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L<sub>420</sub>

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L<sub>421</sub>

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L<sub>422</sub>

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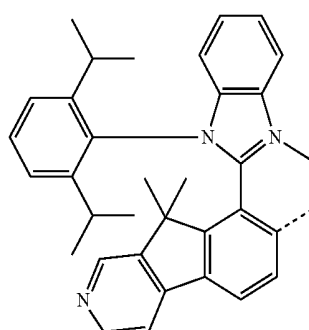
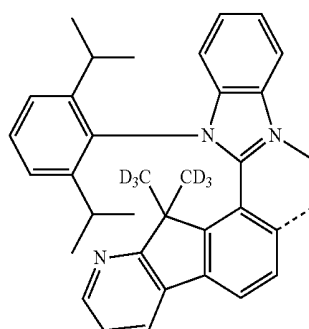
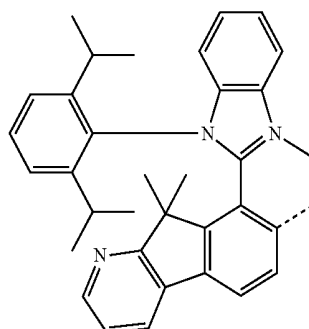
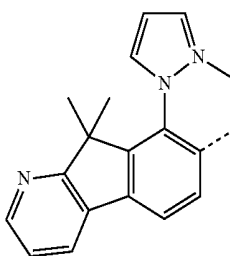
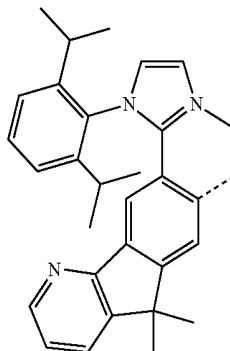
L<sub>423</sub>

L<sub>424</sub>

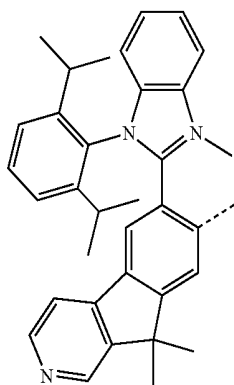
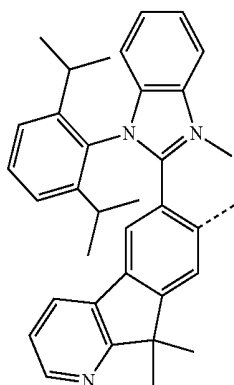
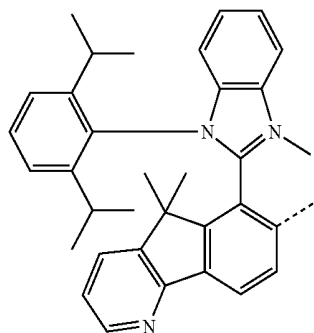
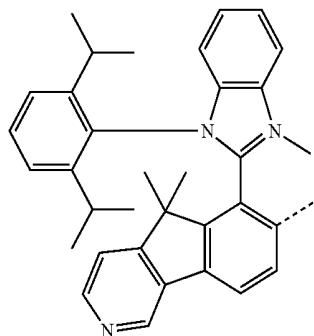
L<sub>425</sub>

L<sub>426</sub>

L<sub>427</sub>



**315**  
-continued



**316**  
-continued

L<sub>428</sub>

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L<sub>429</sub>

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L<sub>430</sub>

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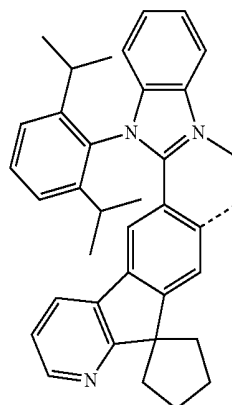
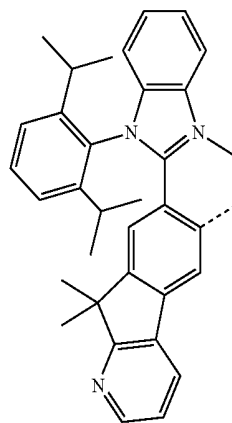
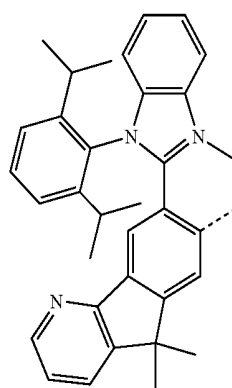
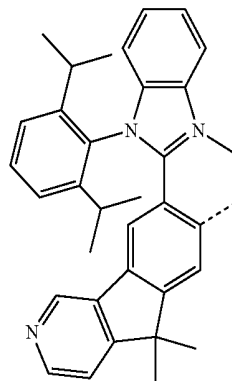
L<sub>431</sub>

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L<sub>432</sub>

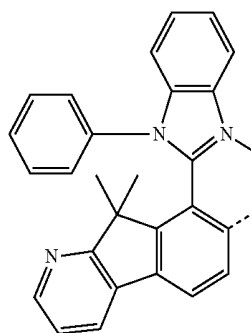
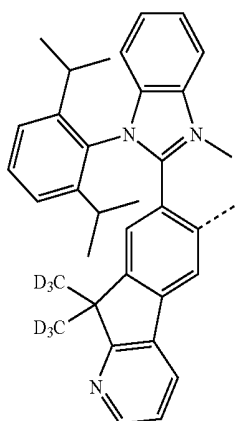
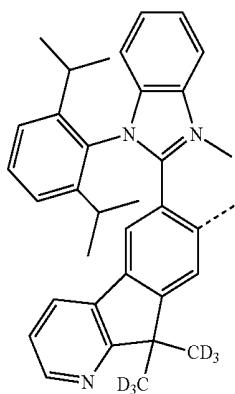
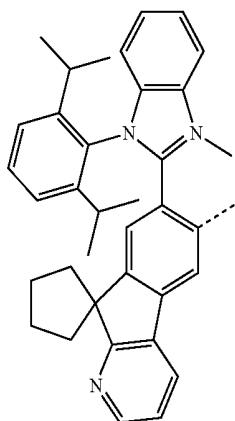


L<sub>433</sub>

L<sub>434</sub>

L<sub>435</sub>

**317**  
-continued



**318**  
-continued

L<sub>436</sub>

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L<sub>437</sub>

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L<sub>438</sub>

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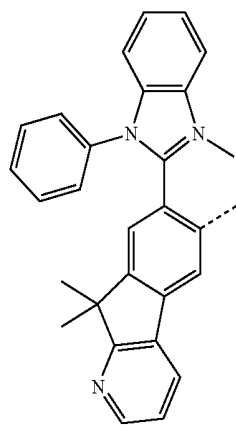
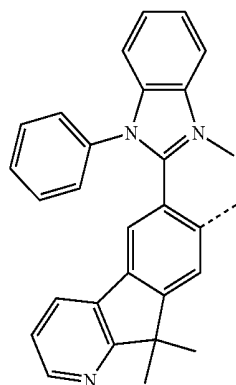
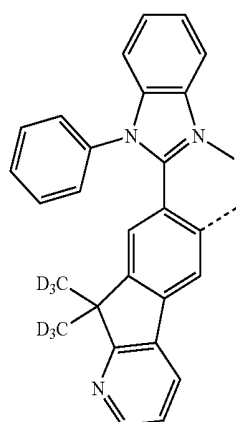
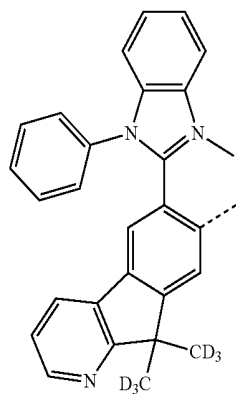
L<sub>439</sub>

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L<sub>440</sub>

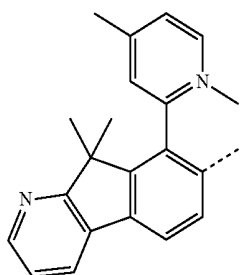
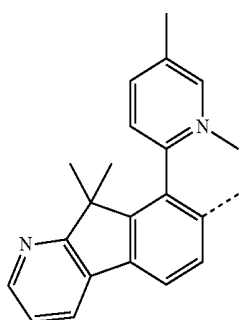
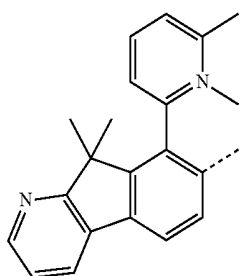
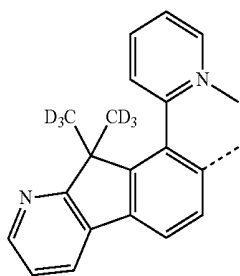
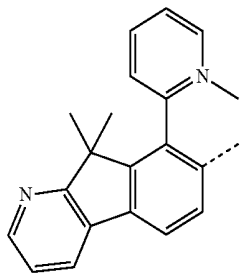


L<sub>441</sub>

L<sub>442</sub>

L<sub>443</sub>

**319**  
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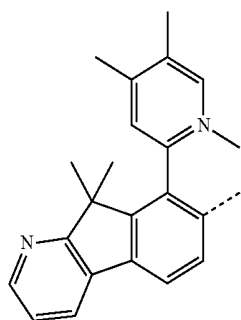


**320**  
-continued

L<sub>444</sub>

5

L<sub>449</sub>



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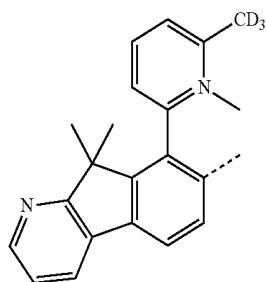
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L<sub>445</sub>

L<sub>450</sub>

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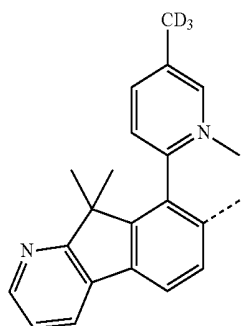
L<sub>446</sub>

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L<sub>451</sub>

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L<sub>447</sub>

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L<sub>452</sub>

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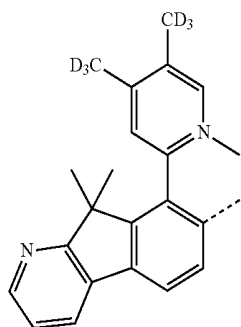
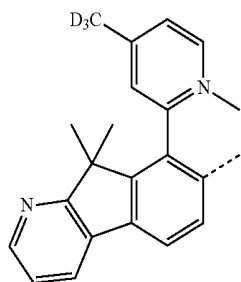
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L<sub>448</sub>

L<sub>453</sub>

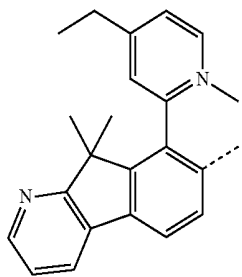
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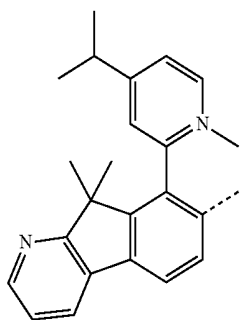
**321**

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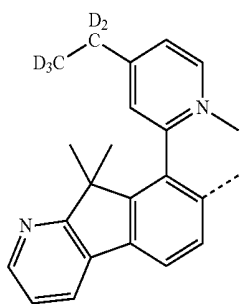
L<sub>454</sub>

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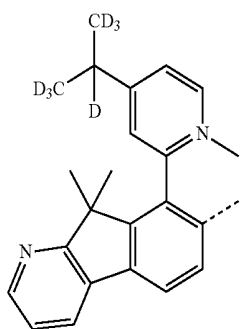
L<sub>455</sub>

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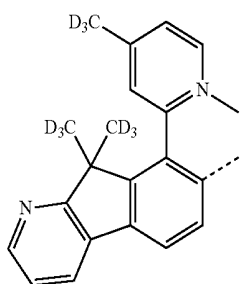
L<sub>456</sub>

30



L<sub>457</sub>

45



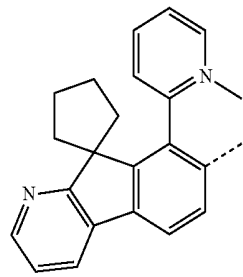
L<sub>458</sub>

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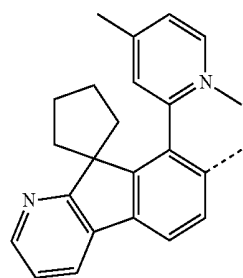
65

**322**

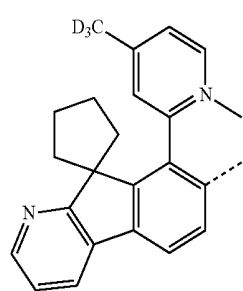
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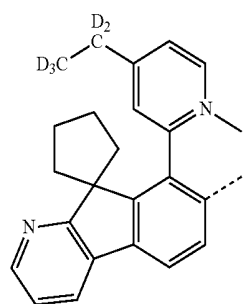
L<sub>459</sub>



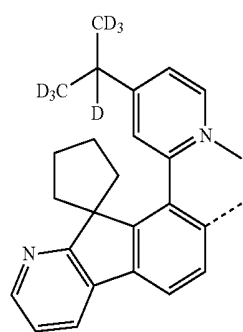
L<sub>460</sub>



L<sub>461</sub>



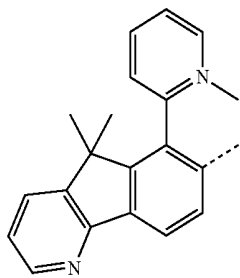
L<sub>462</sub>



L<sub>463</sub>

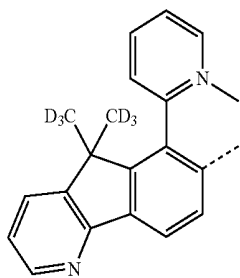
323

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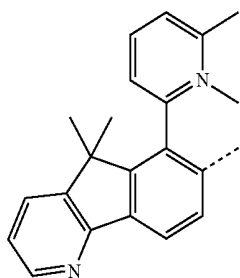
L<sub>464</sub>

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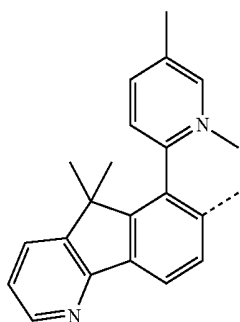
L<sub>465</sub>

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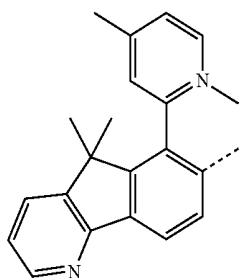
L<sub>466</sub>

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L<sub>467</sub>

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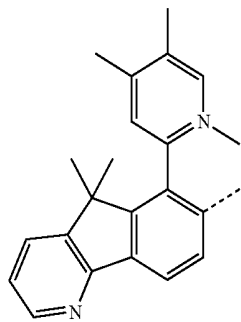
L<sub>468</sub>

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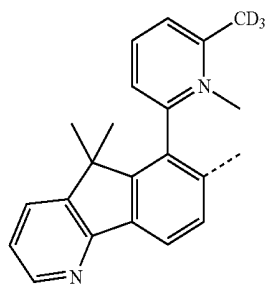
324

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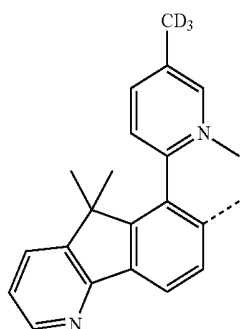
L<sub>469</sub>

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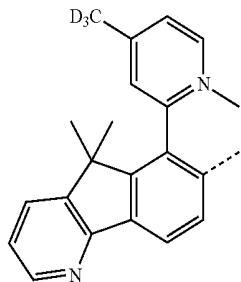
L<sub>470</sub>

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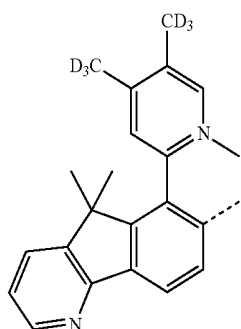
L<sub>471</sub>

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L<sub>472</sub>

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L<sub>473</sub>

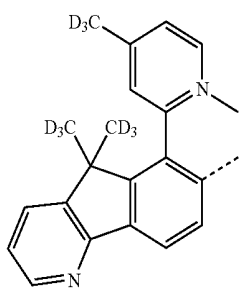
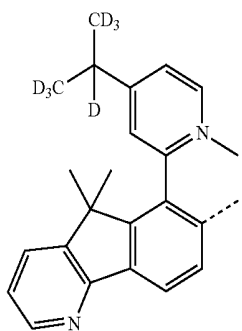
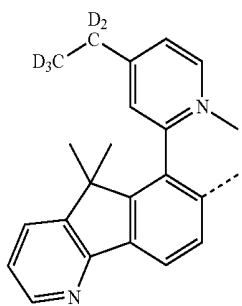
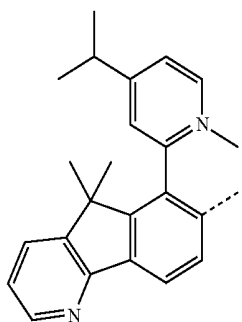
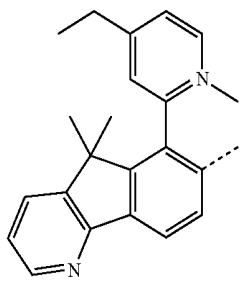
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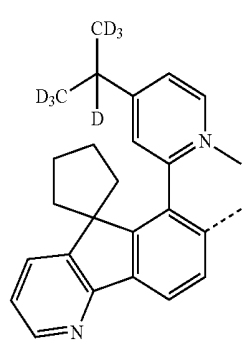
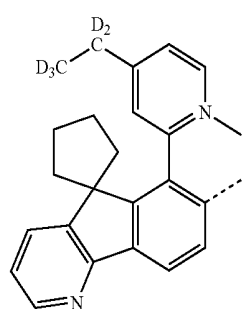
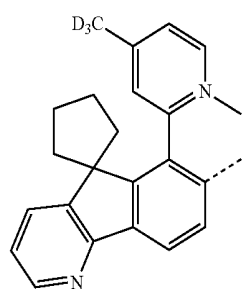
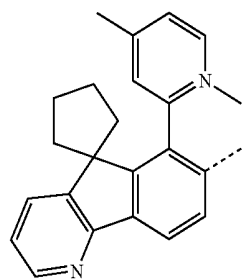
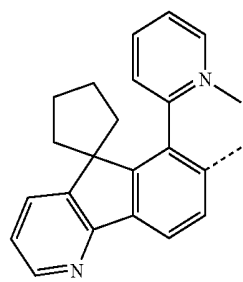
**325**

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**326**

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L<sub>474</sub>

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L<sub>475</sub> 15

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L<sub>476</sub> 30

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L<sub>477</sub> 45

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L<sub>478</sub> 60

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L<sub>479</sub>

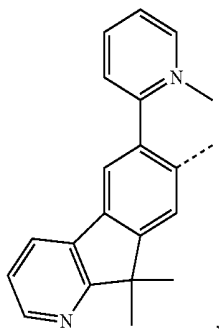
L<sub>480</sub>

L<sub>481</sub>

L<sub>482</sub>

L<sub>483</sub>

**327**  
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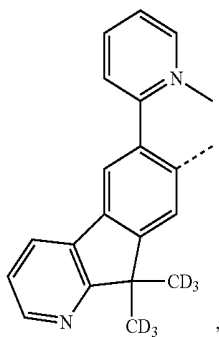


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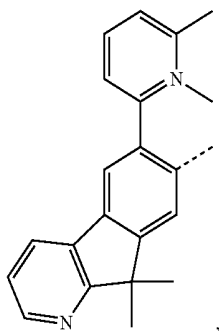


L<sub>485</sub>

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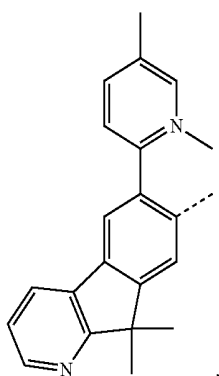


L<sub>486</sub>

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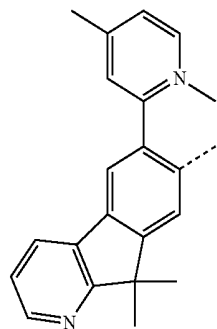
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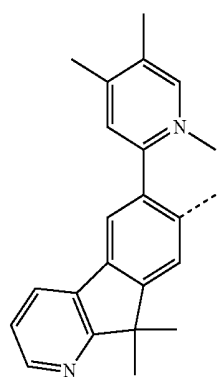
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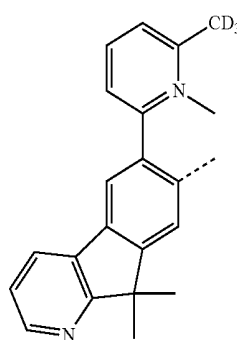
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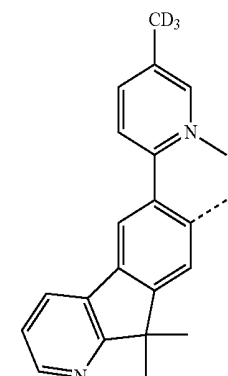
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L<sub>489</sub>



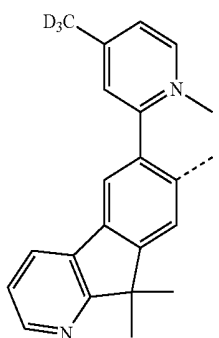
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L<sub>491</sub>

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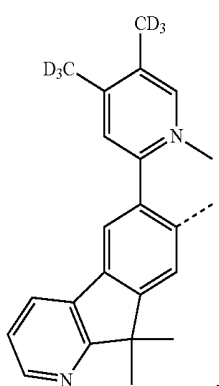


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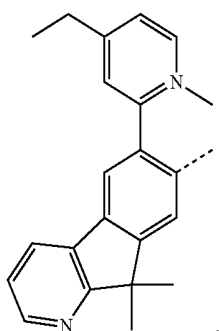


L<sub>493</sub>

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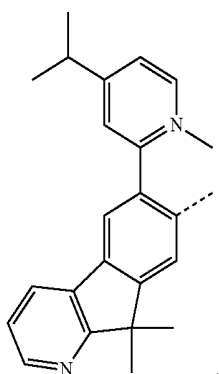
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L<sub>495</sub>

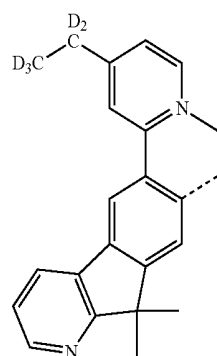
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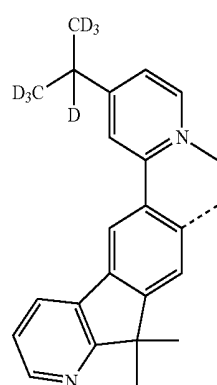
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**330**

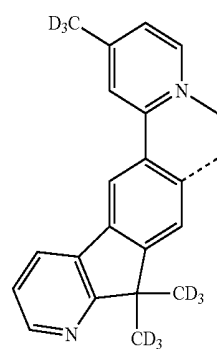
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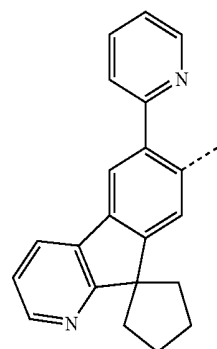
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L<sub>497</sub>



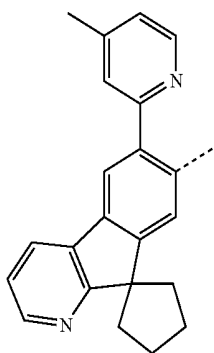
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L<sub>499</sub>

**331**

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L<sub>A100</sub>

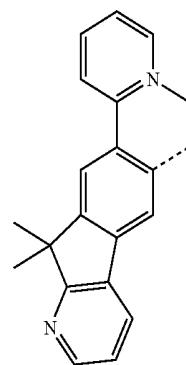
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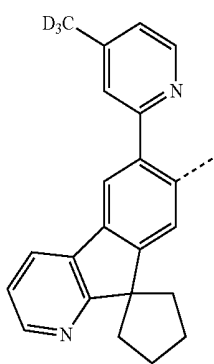
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**332**

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L<sub>A104</sub>

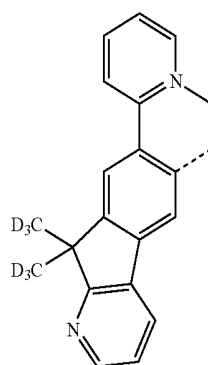


L<sub>A101</sub>

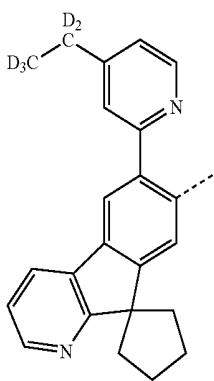
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L<sub>A105</sub>

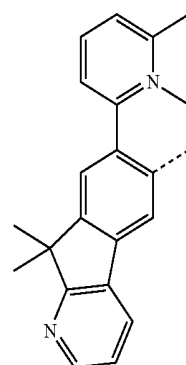


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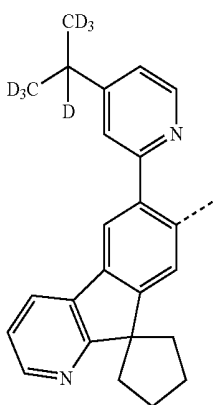
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L<sub>A106</sub>



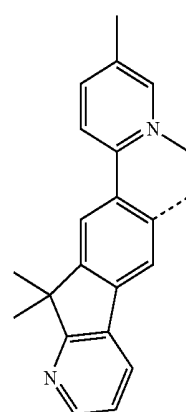
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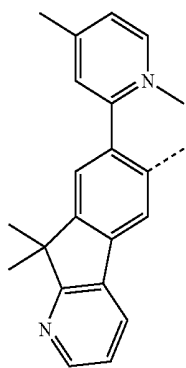
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L<sub>A107</sub>

333

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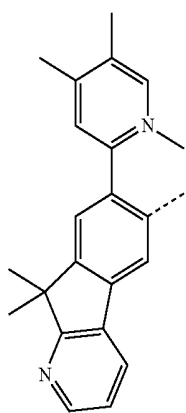


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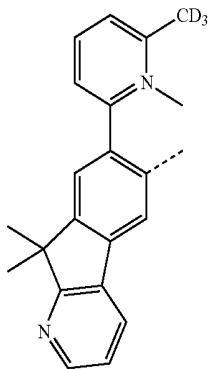


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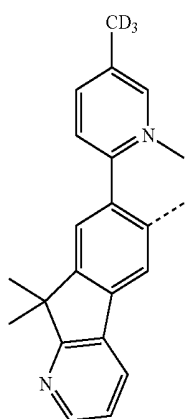


L<sub>A110</sub>

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L<sub>A111</sub>

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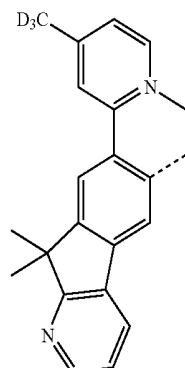
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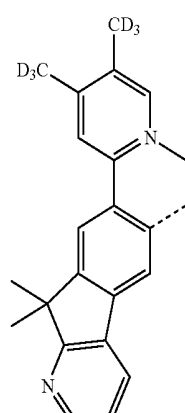
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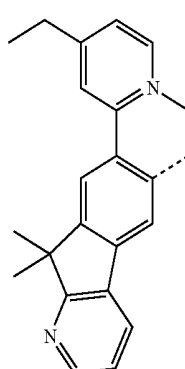
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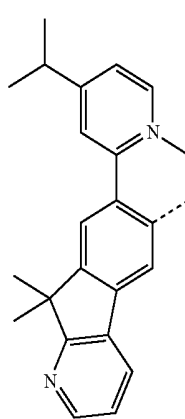
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L<sub>A113</sub>



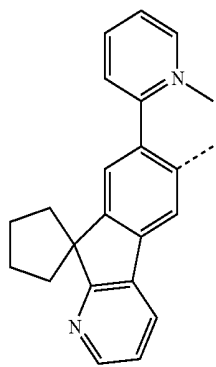
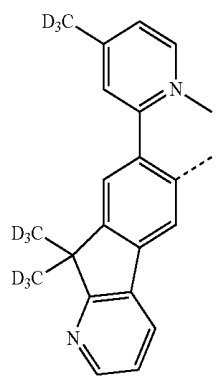
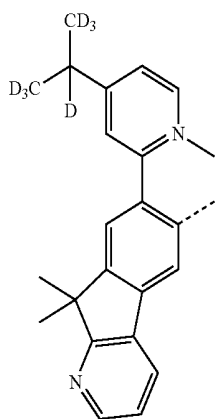
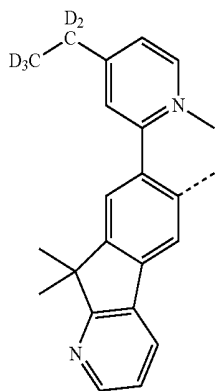
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L<sub>A115</sub>

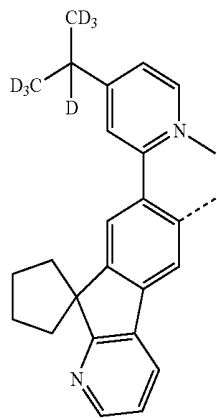
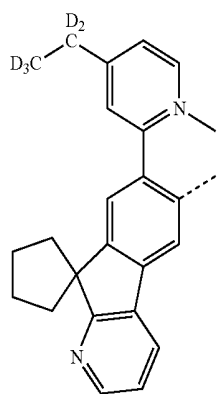
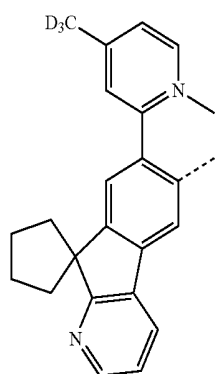
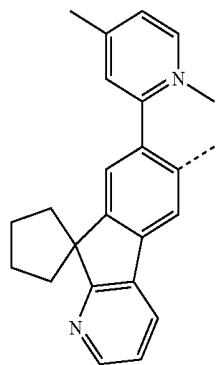
**335**

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**336**

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L<sub>A116</sub>

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L<sub>A117</sub>

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L<sub>A118</sub>

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L<sub>A119</sub>

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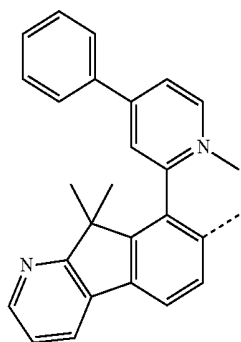
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L<sub>A122</sub>

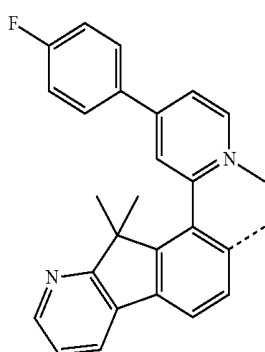
L<sub>A123</sub>

**337**  
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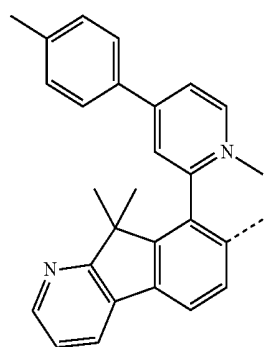
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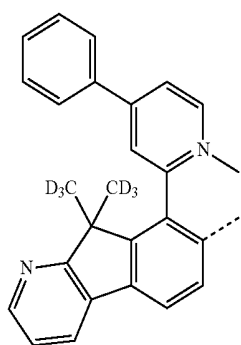
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L<sub>A126</sub>

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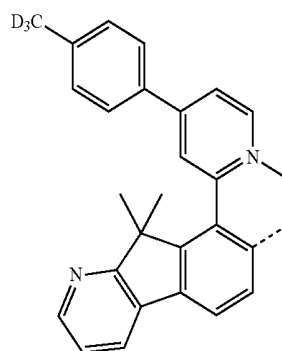
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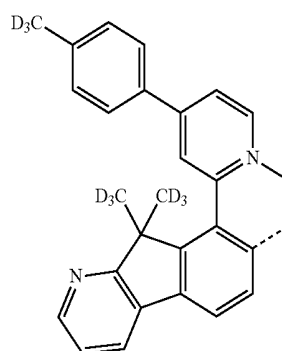
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L<sub>A128</sub>

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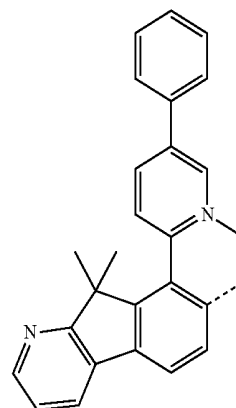
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L<sub>A129</sub>

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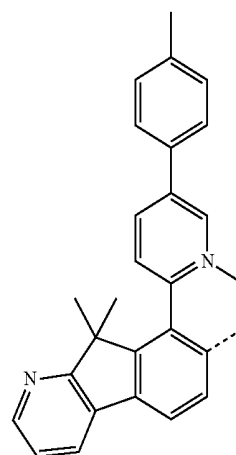


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L<sub>A131</sub>

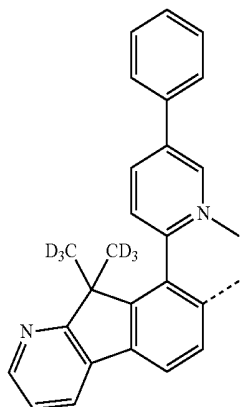
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**339**  
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L<sub>A132</sub>

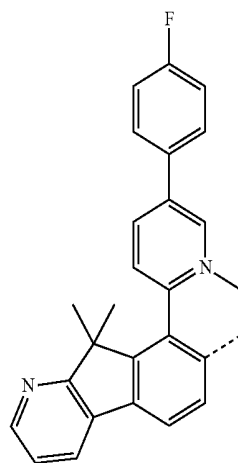
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**340**  
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L<sub>A135</sub>

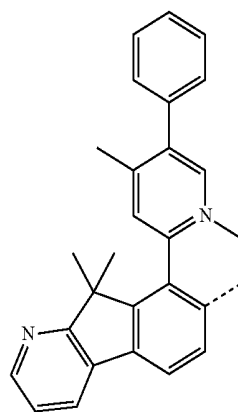
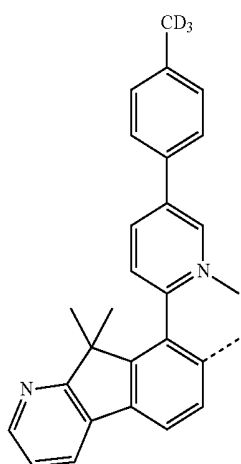
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L<sub>A136</sub>

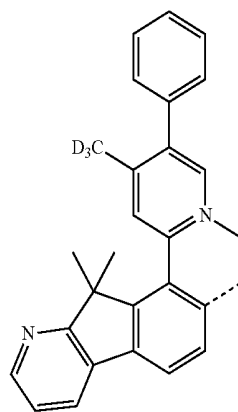
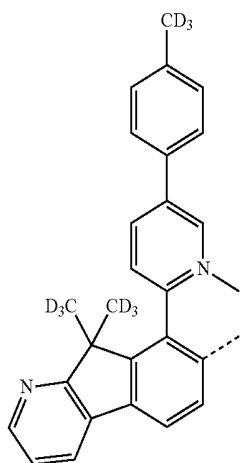
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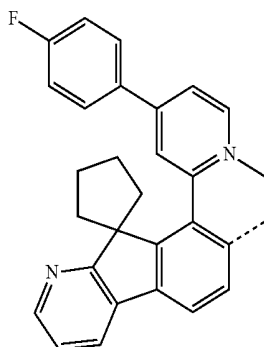
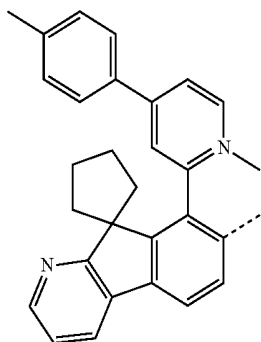
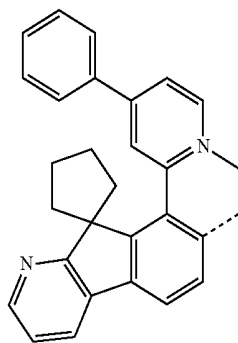
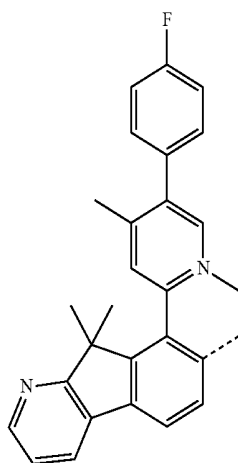
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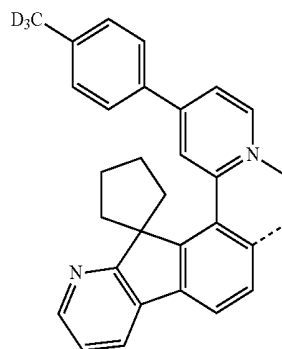
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**342**  
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L<sub>A138</sub>

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L<sub>A142</sub>

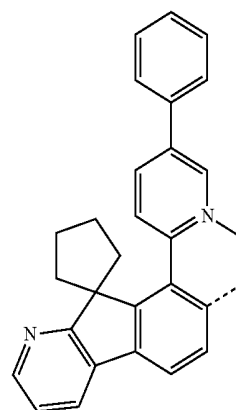
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L<sub>A139</sub>

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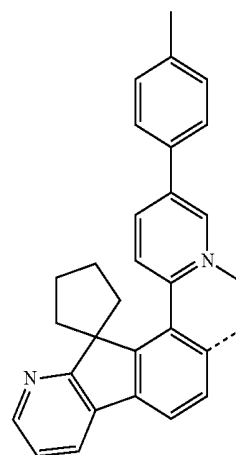
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L<sub>A140</sub>

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L<sub>A144</sub>

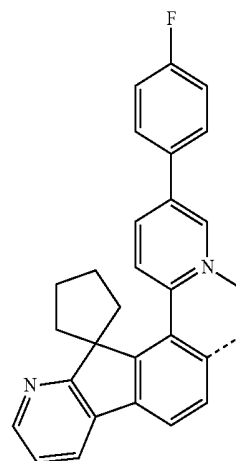
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L<sub>A141</sub>

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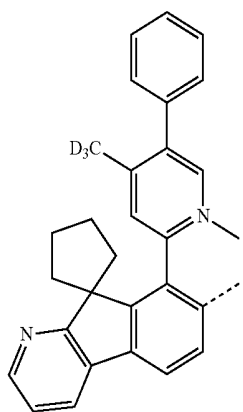
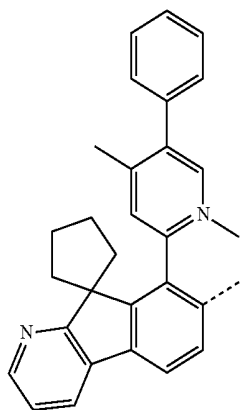
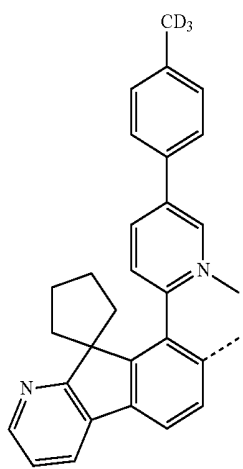
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L<sub>A145</sub>

**343**  
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**344**  
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L<sub>A146</sub>

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L<sub>A147</sub>

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L<sub>A148</sub>

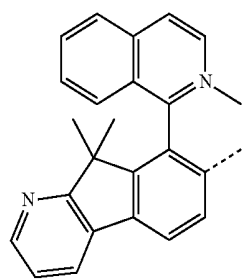
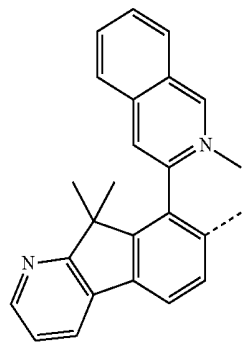
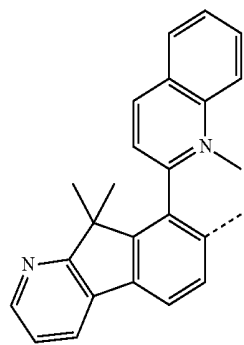
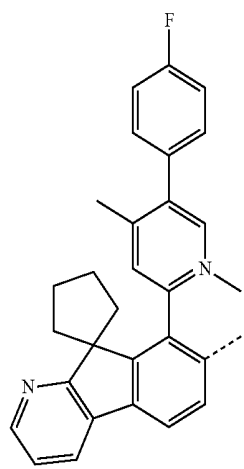
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L<sub>A149</sub>



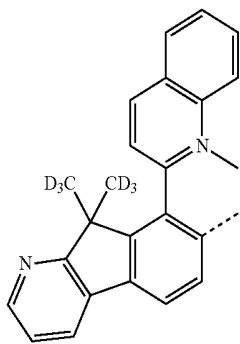
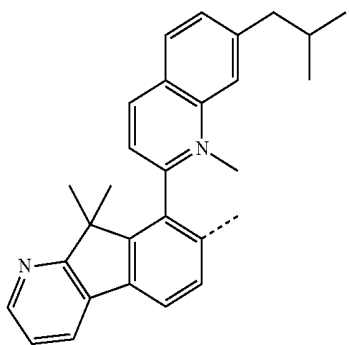
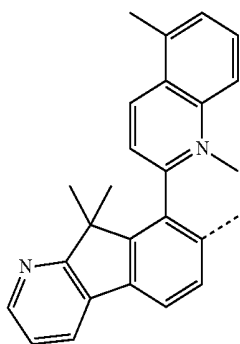
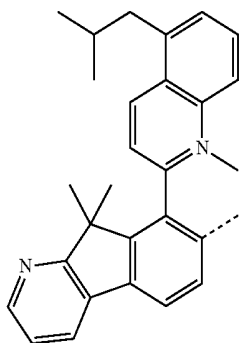
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L<sub>A151</sub>

L<sub>A152</sub>

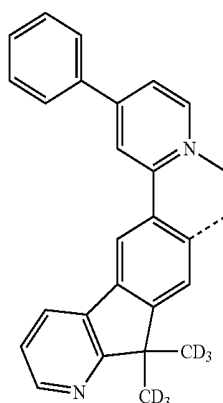
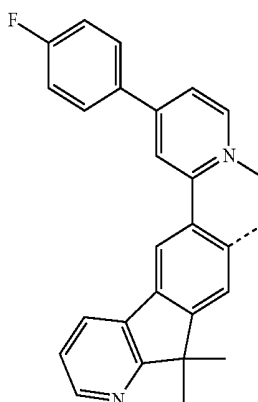
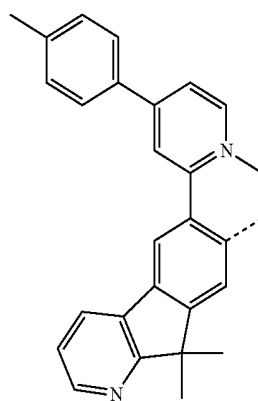
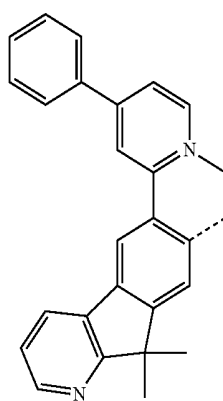
345

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L<sub>A153</sub>

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L<sub>A154</sub>

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L<sub>A155</sub>

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L<sub>A156</sub>

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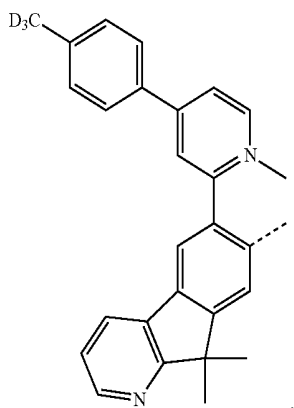
L<sub>A157</sub>

L<sub>A158</sub>

L<sub>A159</sub>

L<sub>A160</sub>

**347**  
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L<sub>A161</sub>

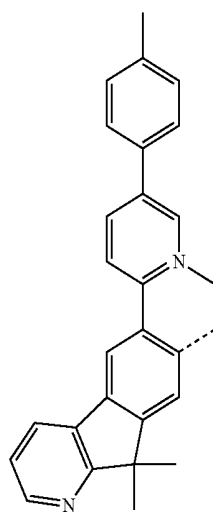
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**348**  
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L<sub>A164</sub>

L<sub>A162</sub>

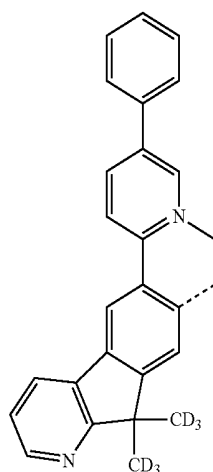
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L<sub>A165</sub>



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L<sub>A163</sub>

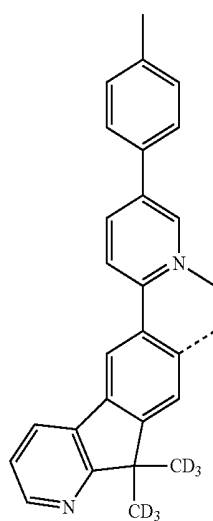
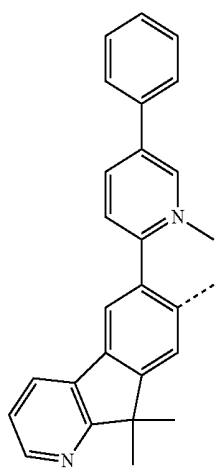
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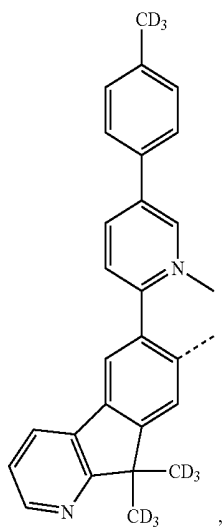
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L<sub>A166</sub>



**349**  
-continued



L<sub>A167</sub>

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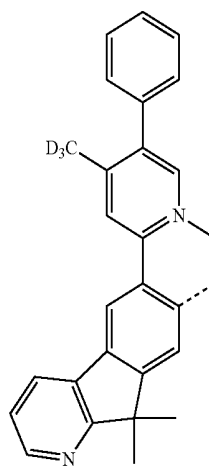
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**350**

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L<sub>A170</sub>

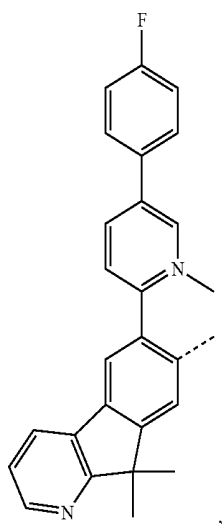
L<sub>A168</sub> 25

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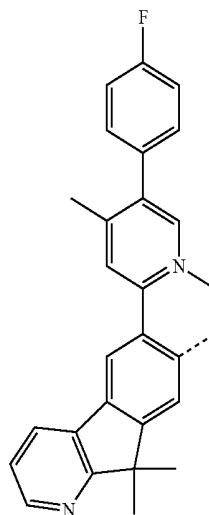
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L<sub>A171</sub>



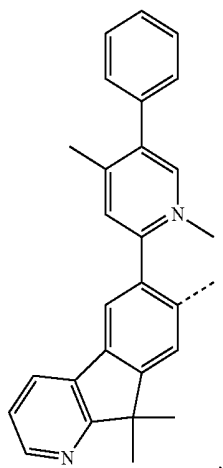
L<sub>A169</sub>

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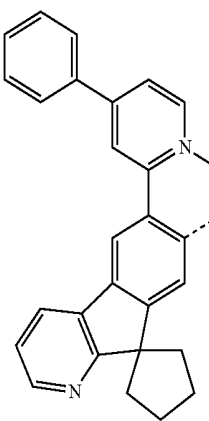
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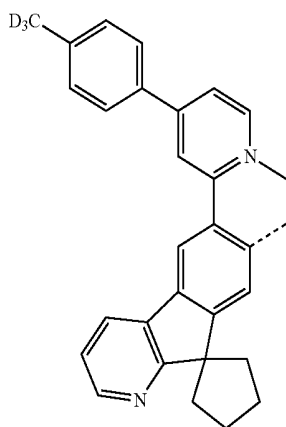
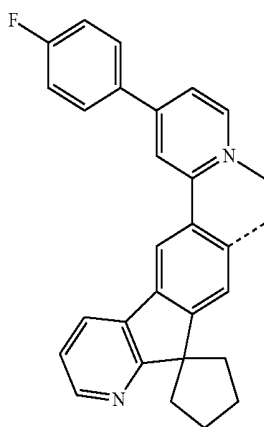
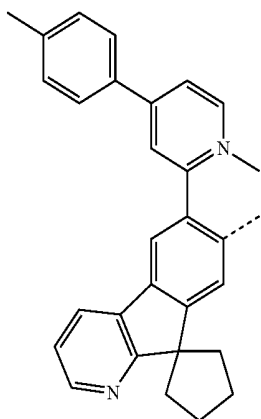
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L<sub>A172</sub>



**351**  
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**352**  
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L<sub>A173</sub>

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L<sub>A174</sub>

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L<sub>A175</sub>

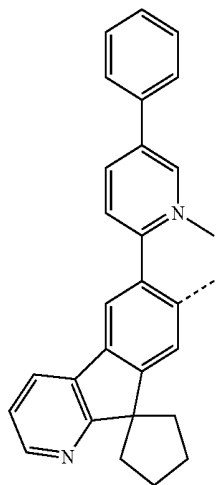
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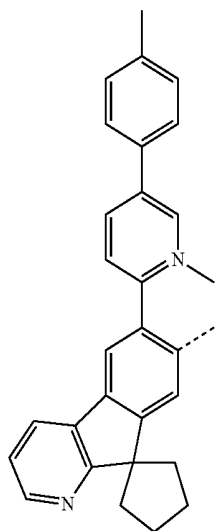
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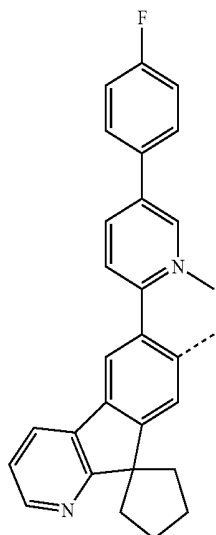
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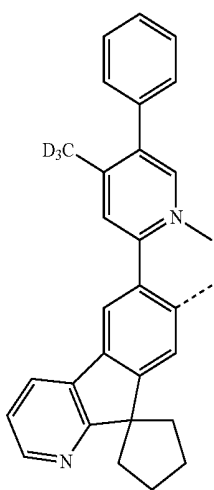
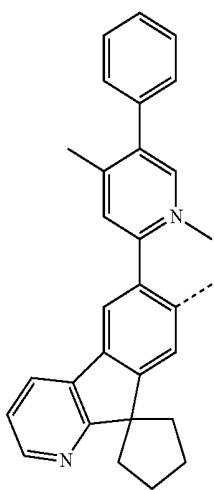
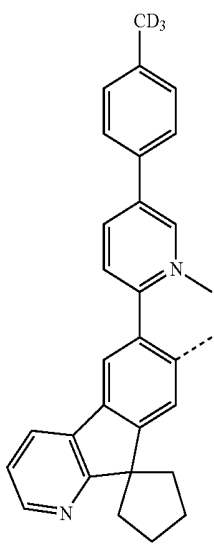
L<sub>A177</sub>



L<sub>A178</sub>



**353**  
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**354**  
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L<sub>A179</sub>

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L<sub>A180</sub>

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L<sub>A181</sub>

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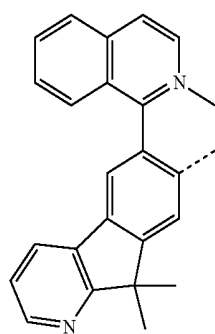
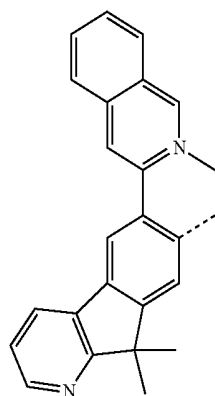
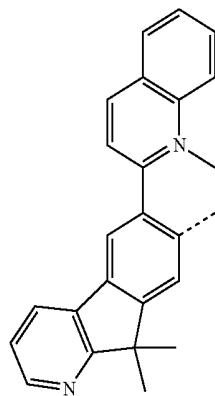
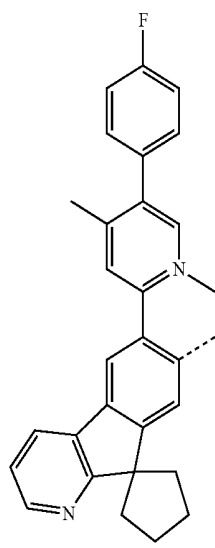
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L<sub>A182</sub>



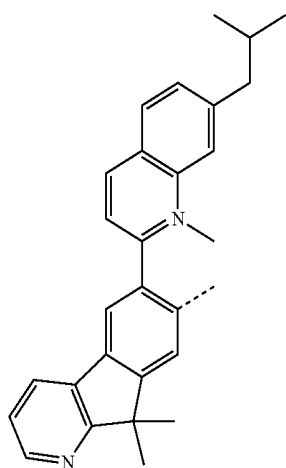
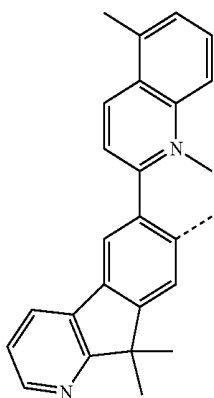
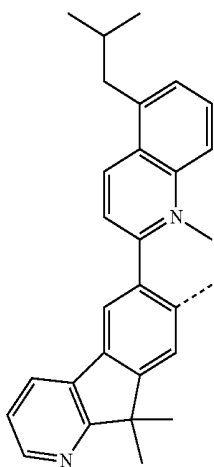
L<sub>A183</sub>

L<sub>A184</sub>

L<sub>A185</sub>

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L<sub>4186</sub>

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L<sub>4187</sub>

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L<sub>4188</sub>

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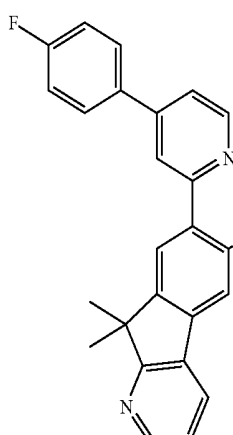
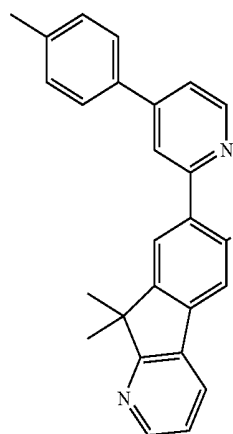
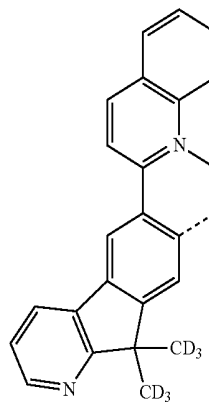
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L<sub>4189</sub>

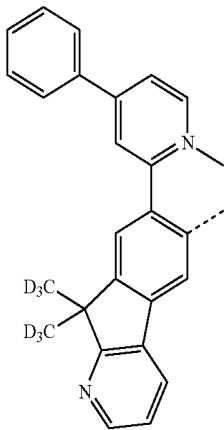
L<sub>4190</sub>

L<sub>4191</sub>

L<sub>4192</sub>



**357**  
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L<sub>A193</sub>

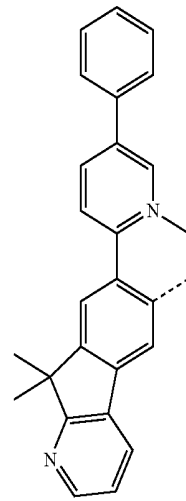
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**358**  
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L<sub>A196</sub>

L<sub>A194</sub>

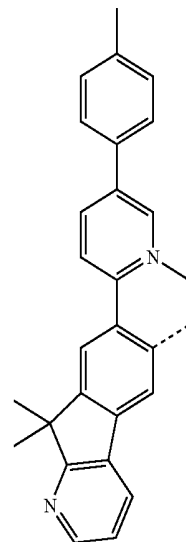
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L<sub>A197</sub>

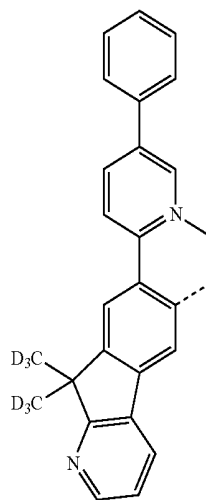
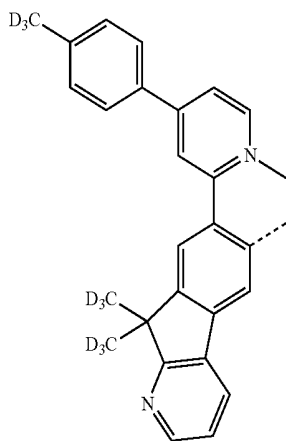
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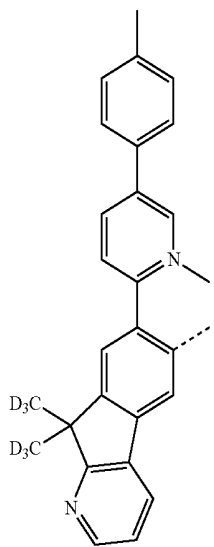
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L<sub>A198</sub>

**359**  
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L<sub>4199</sub>

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L<sub>4200</sub>

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L<sub>4201</sub>

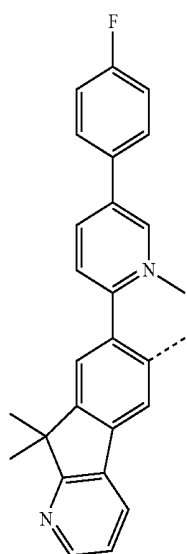
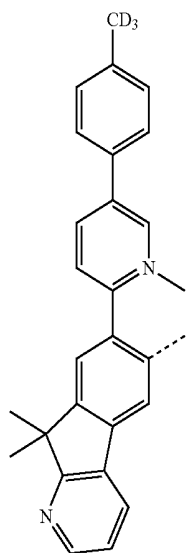
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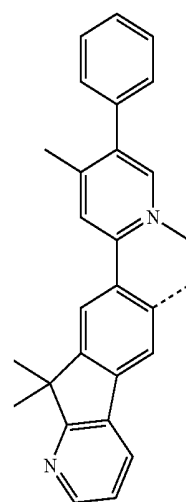
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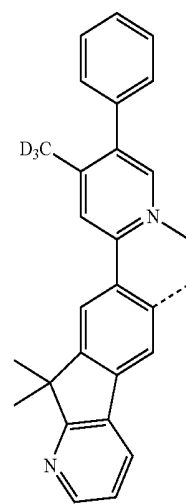
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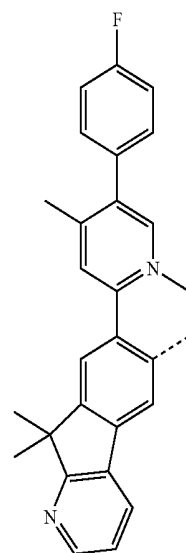
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L<sub>4202</sub>

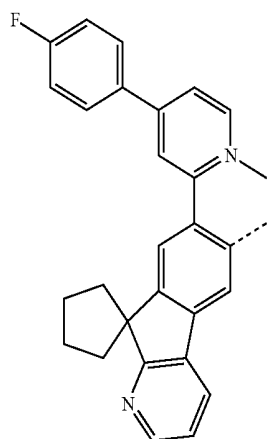
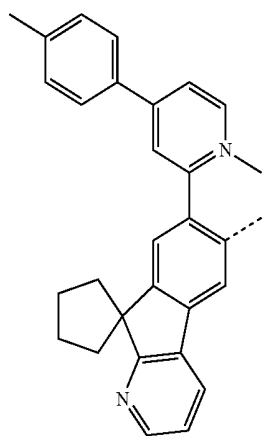
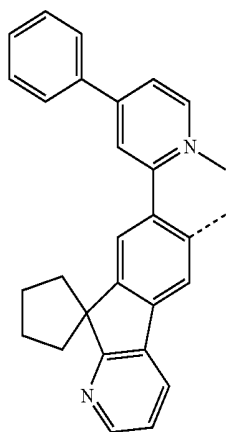


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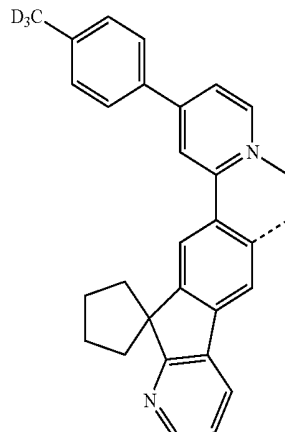


L<sub>4204</sub>

**361**  
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**362**  
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L<sub>4205</sub>

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L<sub>4206</sub>

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L<sub>4207</sub>

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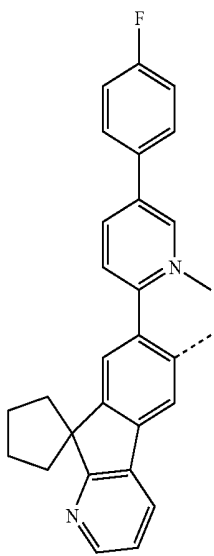
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L<sub>4208</sub>

L<sub>4209</sub>

L<sub>4210</sub>

**363**  
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L<sub>4211</sub>

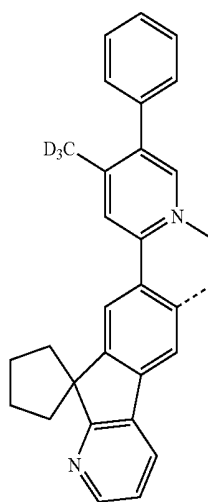
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**364**  
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L<sub>4214</sub>

L<sub>4212</sub> 25

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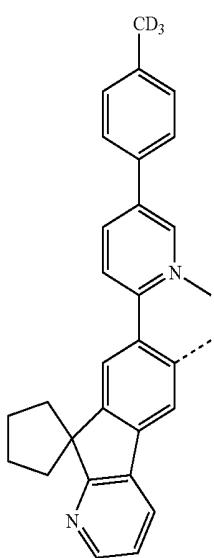
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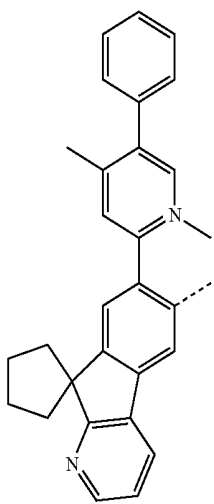
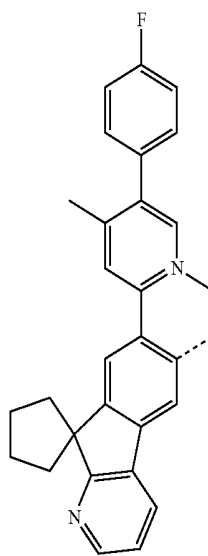
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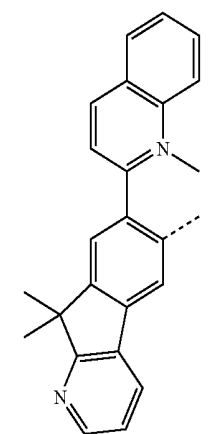
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L<sub>4215</sub>

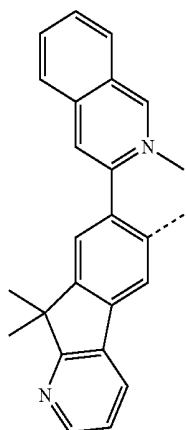


L<sub>4216</sub>



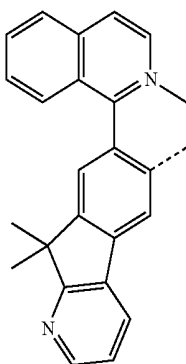
365

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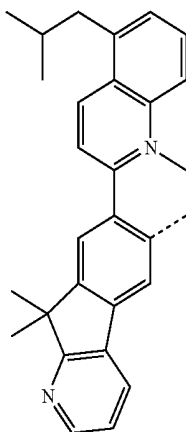
L<sub>4217</sub>

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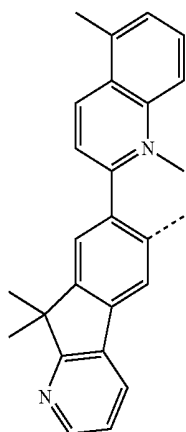
L<sub>4218</sub>

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L<sub>4219</sub>

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L<sub>4220</sub>

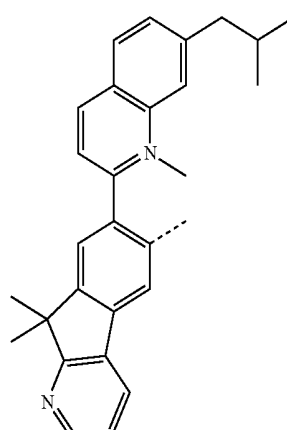
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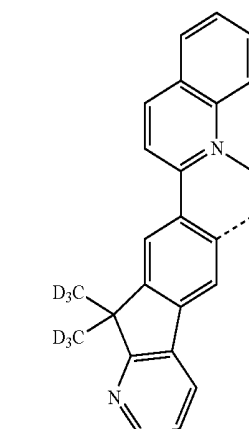
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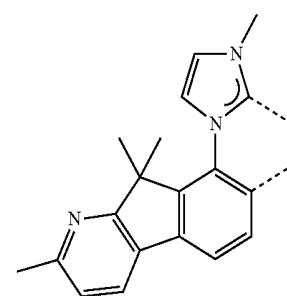
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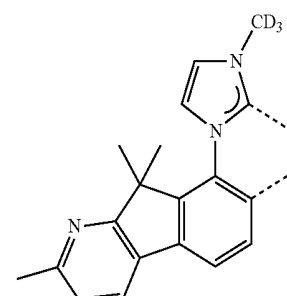
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L<sub>4222</sub>

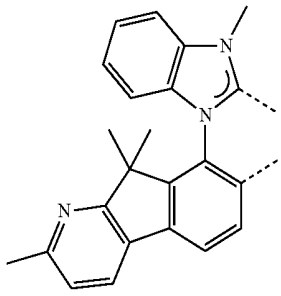


L<sub>4223</sub>



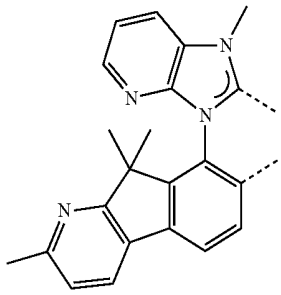
L<sub>4224</sub>

**367**  
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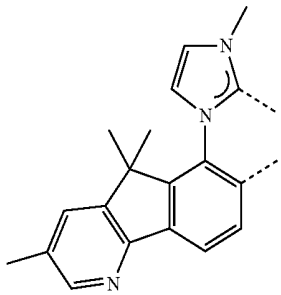
L<sub>4225</sub>

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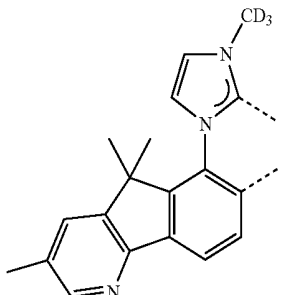
L<sub>4226</sub>

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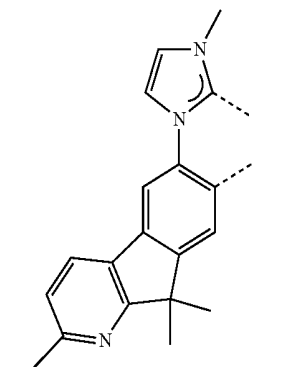
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L<sub>4228</sub>

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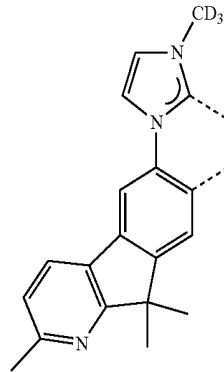
L<sub>4229</sub>

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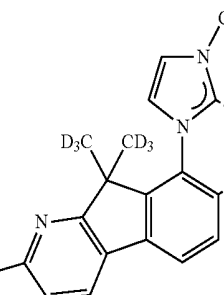
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**368**  
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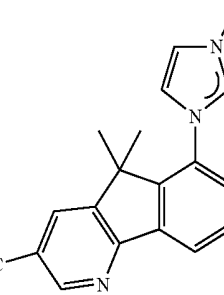
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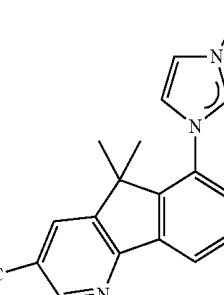
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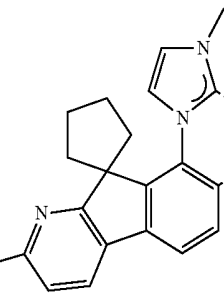
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L<sub>4233</sub>

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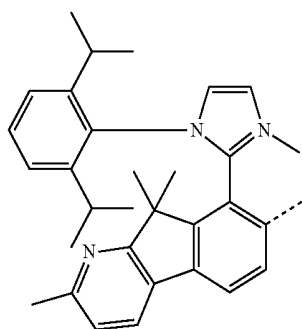


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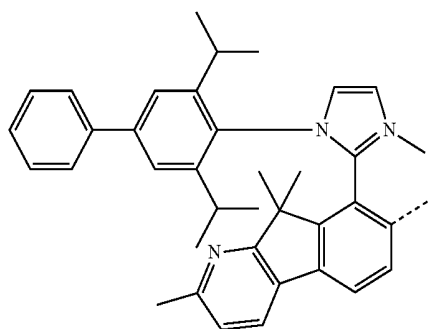
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**369**  
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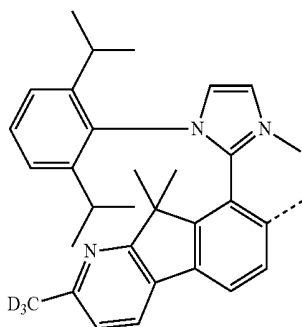
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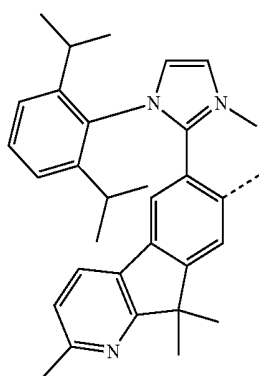
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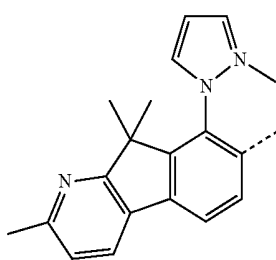
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L<sub>4238</sub>

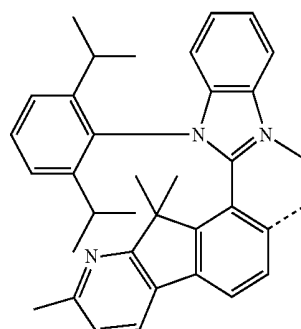
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L<sub>4239</sub>

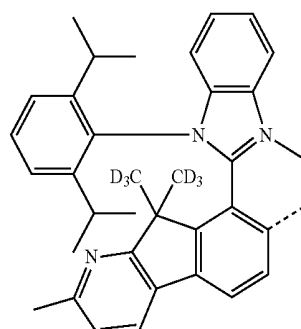
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**370**  
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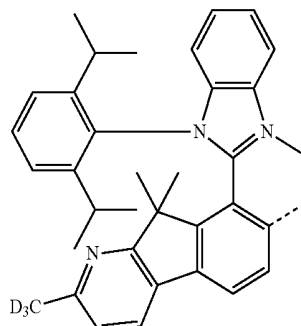
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L<sub>4241</sub>

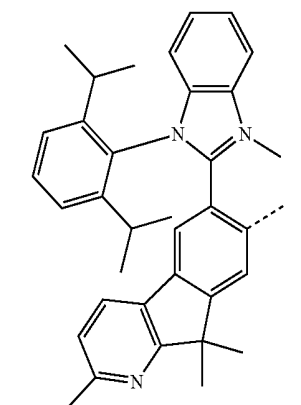
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L<sub>4242</sub>

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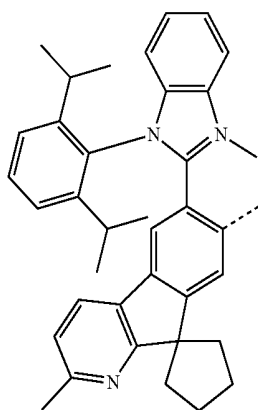
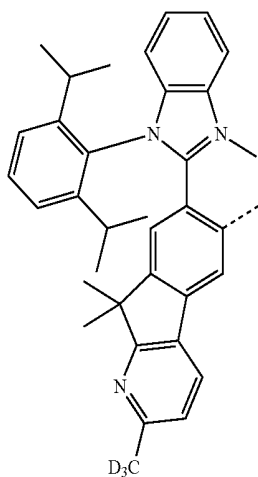
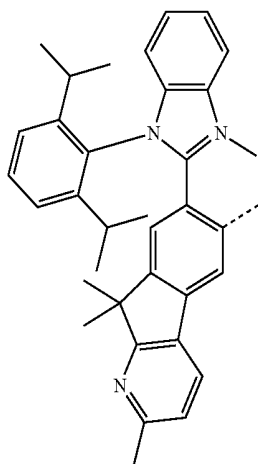
L<sub>4243</sub>

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**371**  
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**372**  
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L<sub>4244</sub>

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L<sub>4245</sub>

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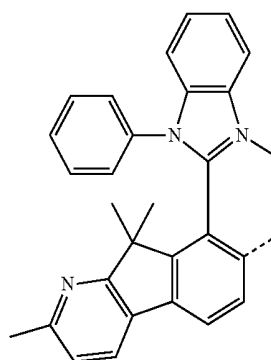
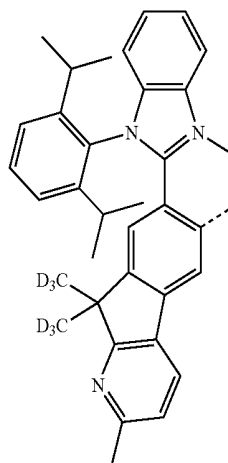
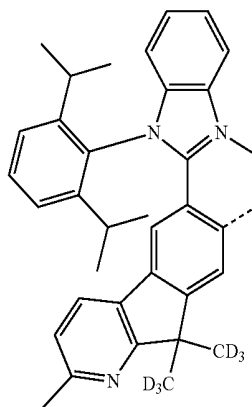
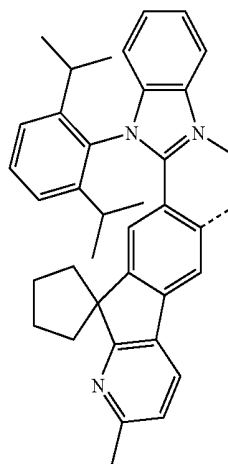
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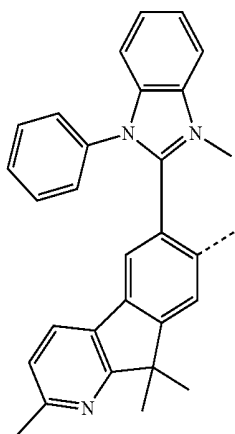
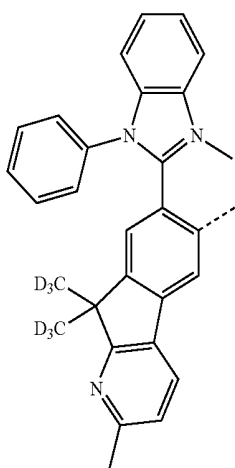
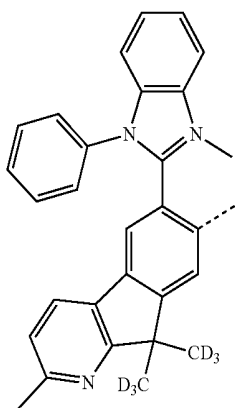
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L<sub>4248</sub>

L<sub>4249</sub>

L<sub>4250</sub>

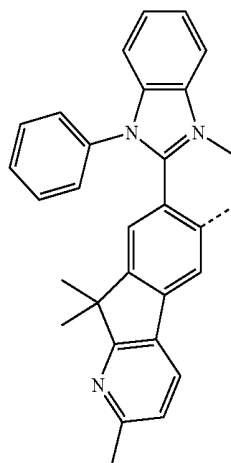
**373**  
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**374**  
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L<sub>A251</sub>

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L<sub>A254</sub>

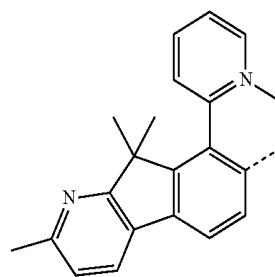
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L<sub>A252</sub>

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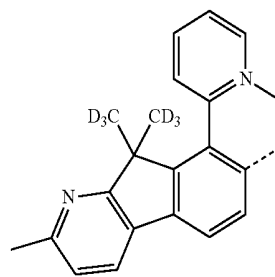
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L<sub>A256</sub>

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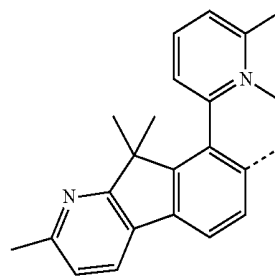


L<sub>A256</sub>

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L<sub>A253</sub>

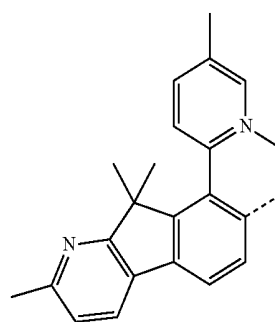
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L<sub>A257</sub>

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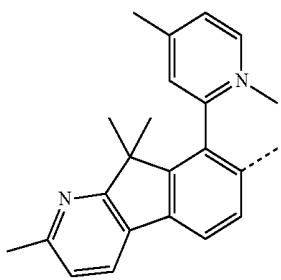
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L<sub>A258</sub>

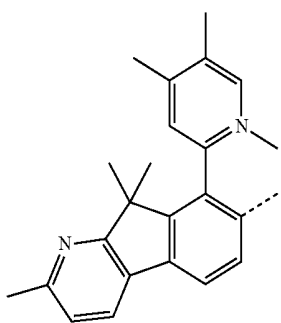
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**375**  
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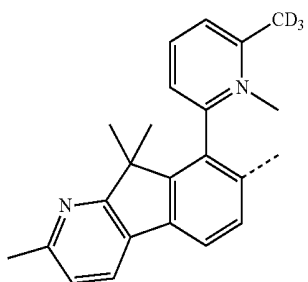
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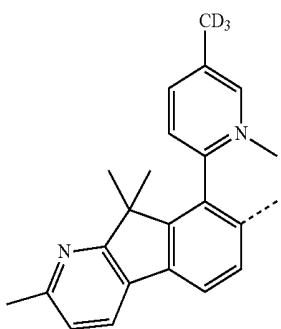
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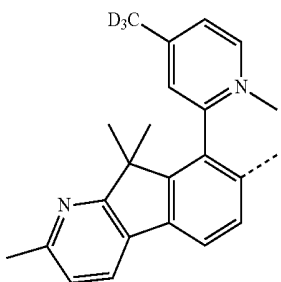
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L<sub>4262</sub>

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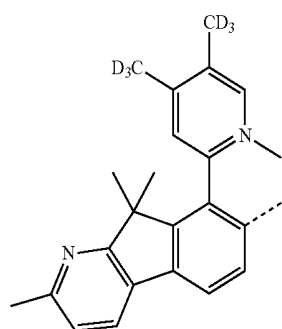


L<sub>4263</sub>

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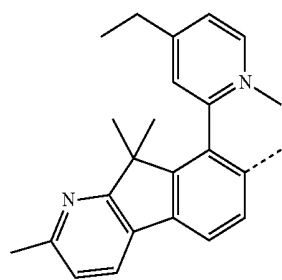
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**376**  
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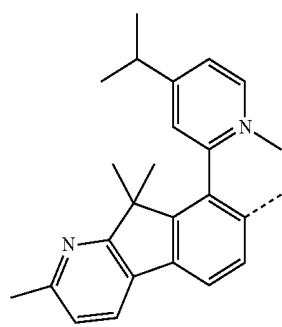
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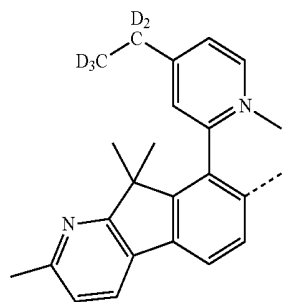
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L<sub>4266</sub>

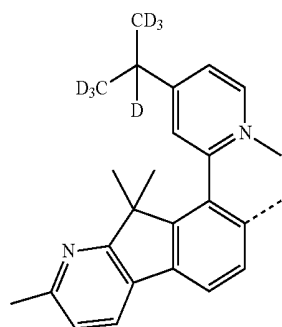
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L<sub>4267</sub>

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L<sub>4268</sub>

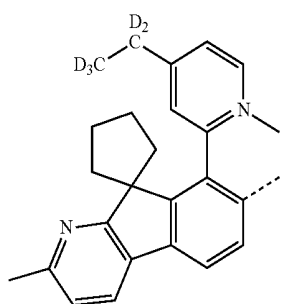
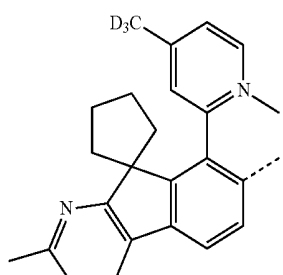
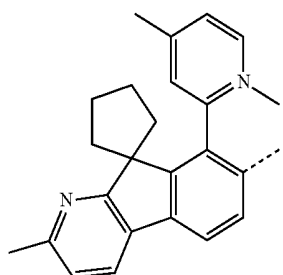
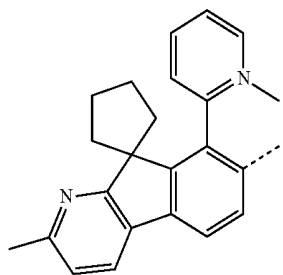
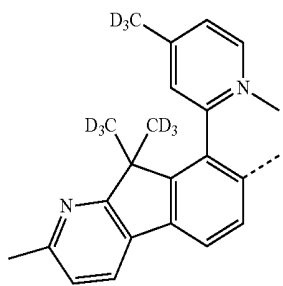
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**377**

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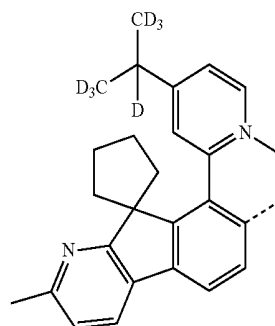


**378**

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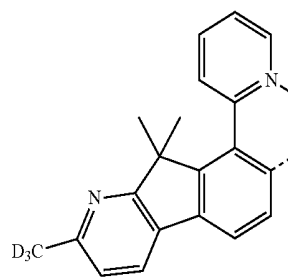
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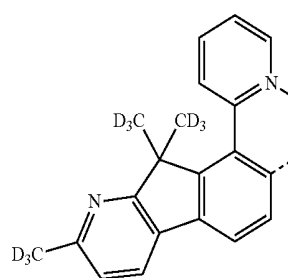
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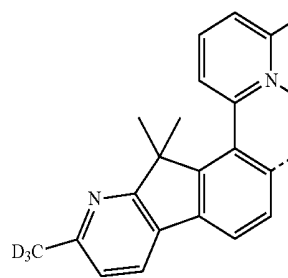
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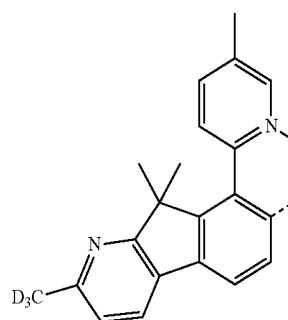
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L<sub>A273</sub>

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L<sub>A274</sub>

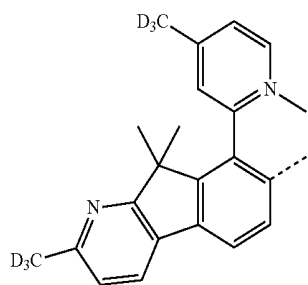
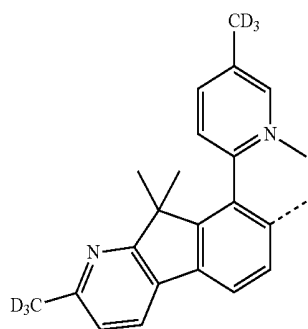
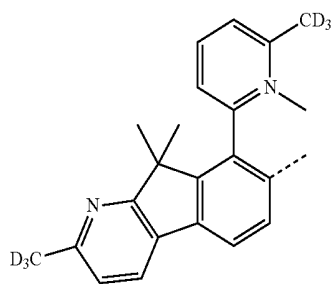
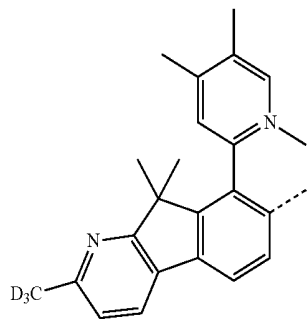
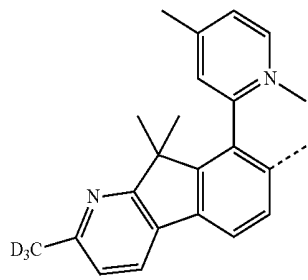
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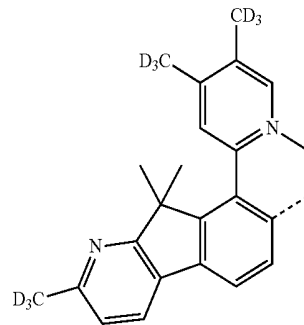
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**380**  
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L<sub>4279</sub>

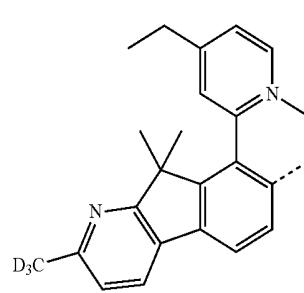
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L<sub>4284</sub>

L<sub>4280</sub>

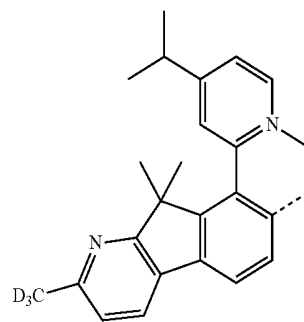
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L<sub>4285</sub>

L<sub>4281</sub>

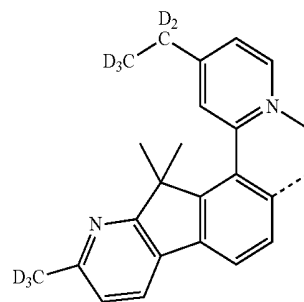
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L<sub>4286</sub>

L<sub>4282</sub>

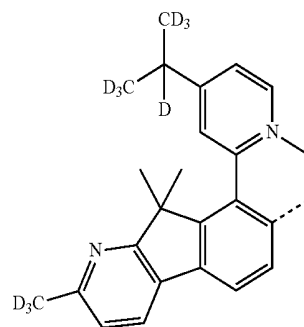
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L<sub>4287</sub>

L<sub>4283</sub>

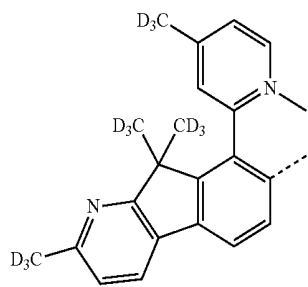
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L<sub>4288</sub>

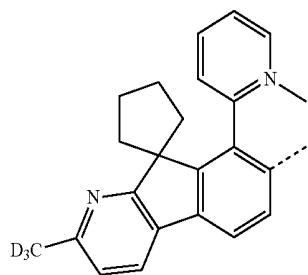
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**381**  
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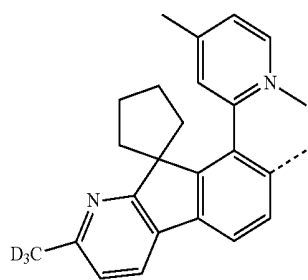
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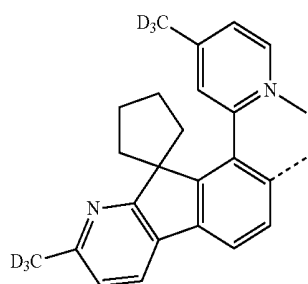
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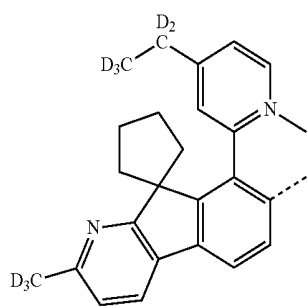
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L<sub>4292</sub>

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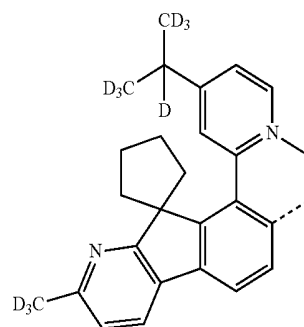


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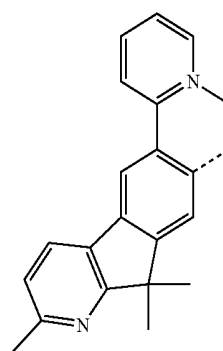
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**382**  
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L<sub>4294</sub>

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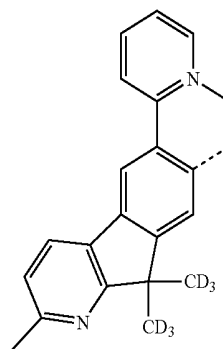
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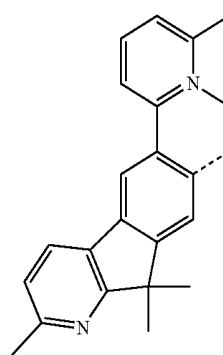


L<sub>4296</sub>

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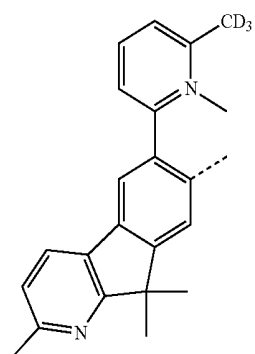
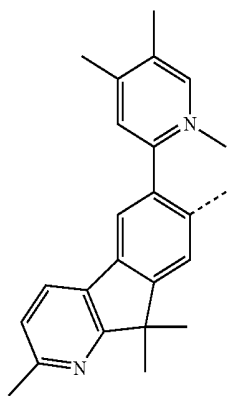
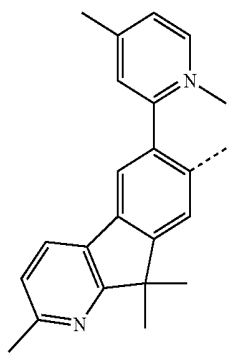
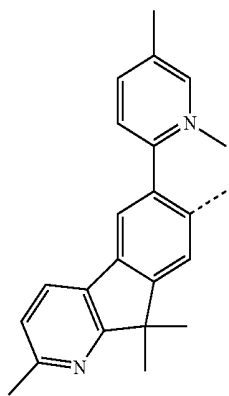
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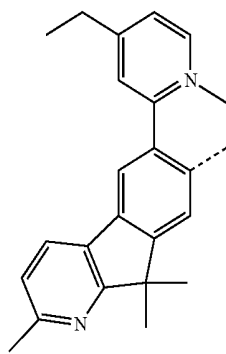
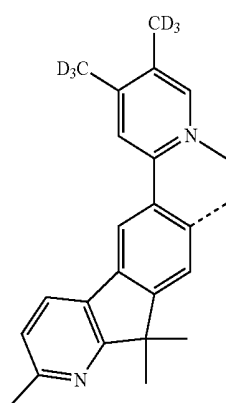
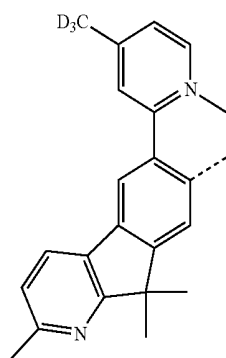
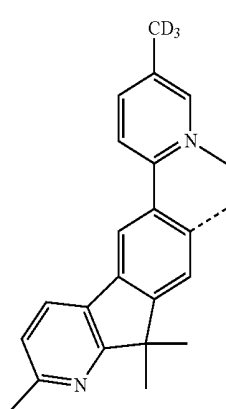
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**384**

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L<sub>4298</sub>

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L<sub>4299</sub>

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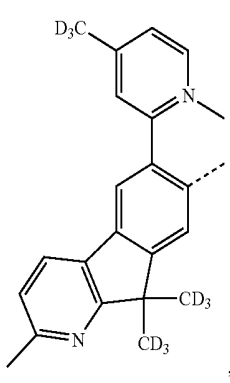
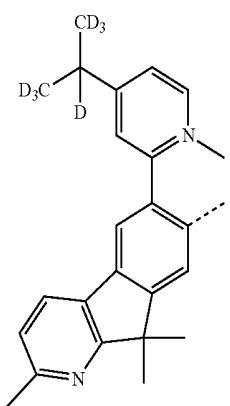
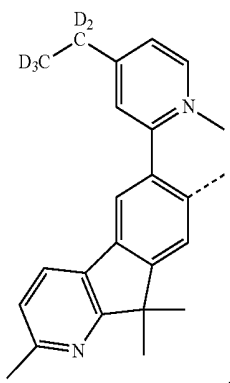
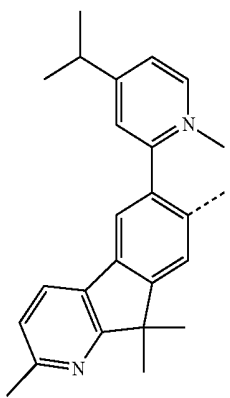
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L<sub>4305</sub>

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**386**

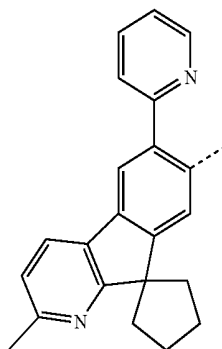
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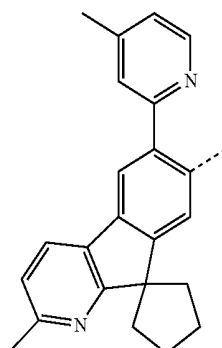


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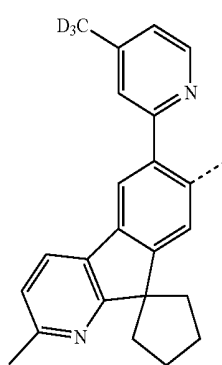
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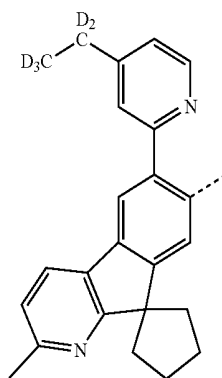


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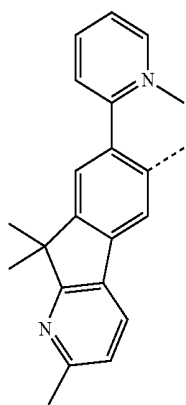
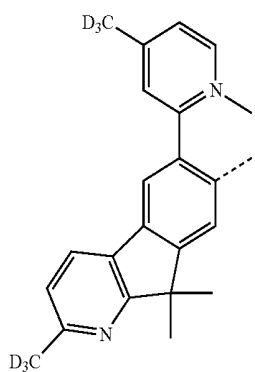
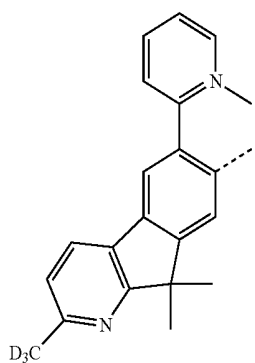
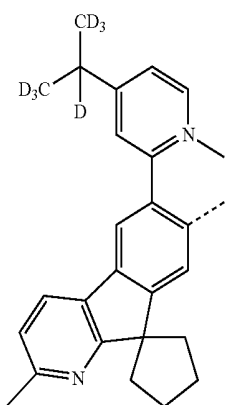
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L<sub>4313</sub>

**387**  
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**388**  
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L<sub>A314</sub>

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L<sub>A316</sub>

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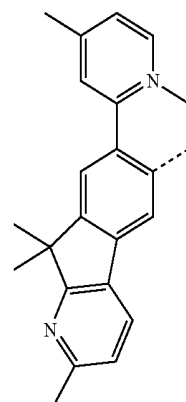
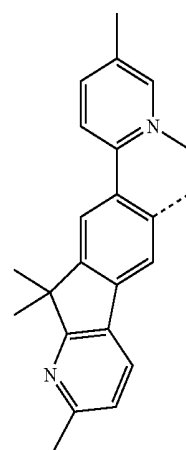
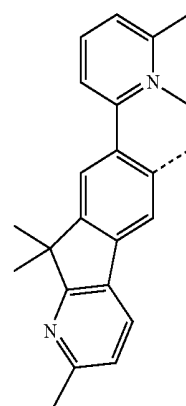
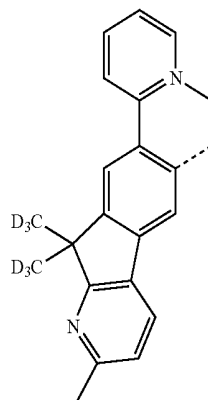
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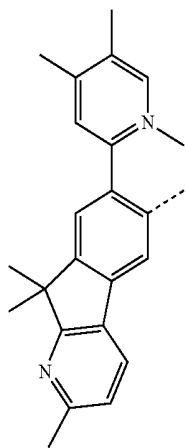
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L<sub>A321</sub>



**389**

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L<sub>4323</sub>

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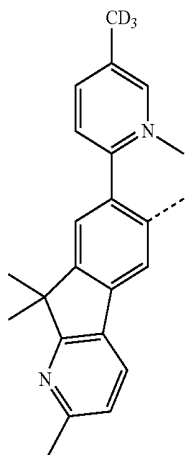
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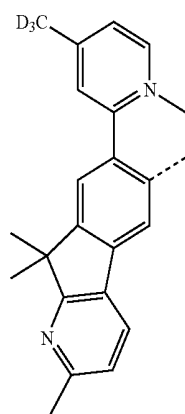
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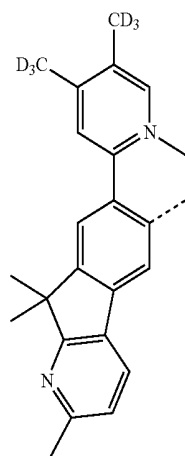


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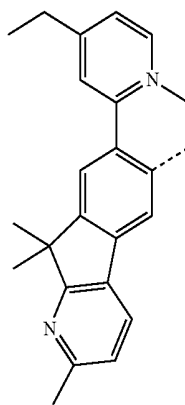
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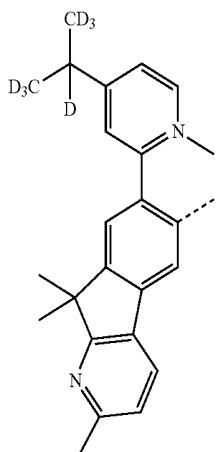
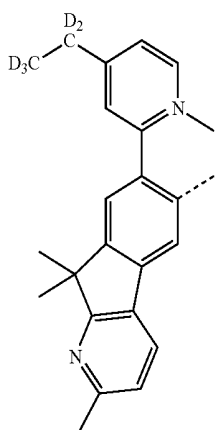
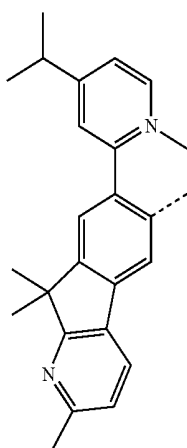
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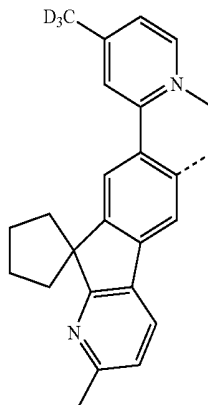
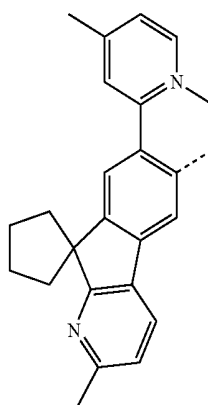
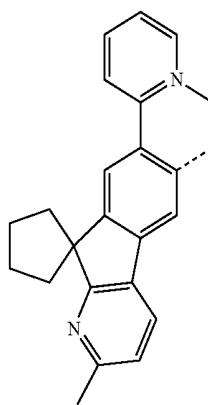
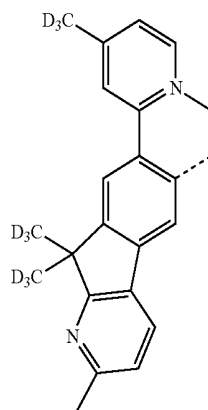
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**392**

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L<sub>4328</sub>

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L<sub>4329</sub>

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L<sub>4330</sub>

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L<sub>4331</sub>

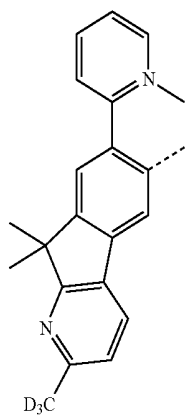
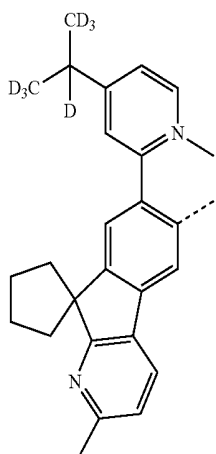
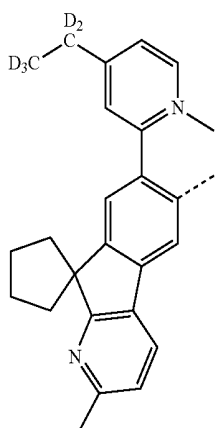
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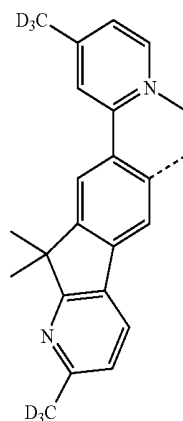


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L<sub>A338</sub>

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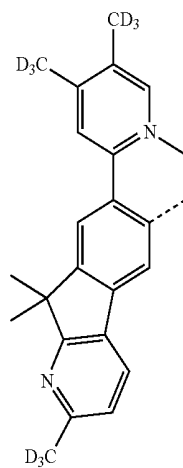
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L<sub>A336</sub>

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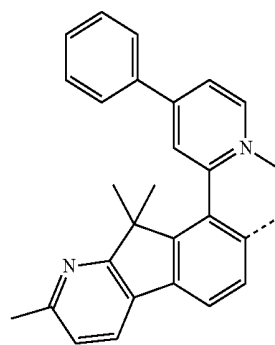
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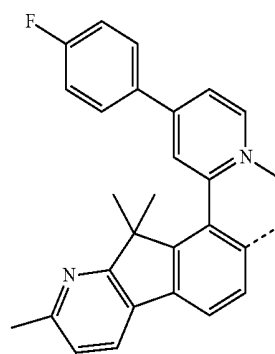


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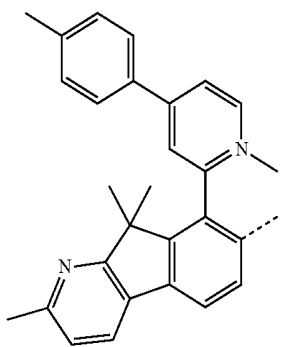
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L<sub>A341</sub>

**395**

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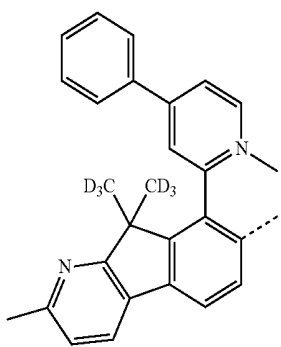


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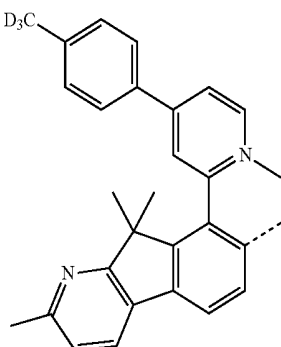
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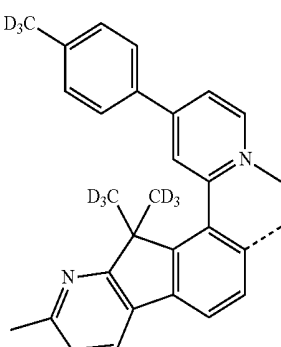
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L<sub>A344</sub>

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L<sub>A345</sub>

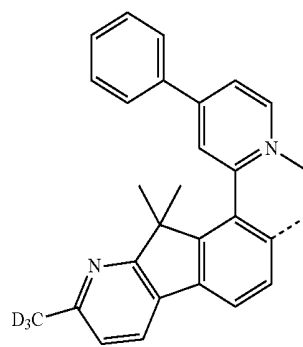
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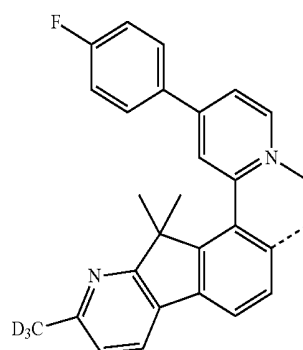
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**396**

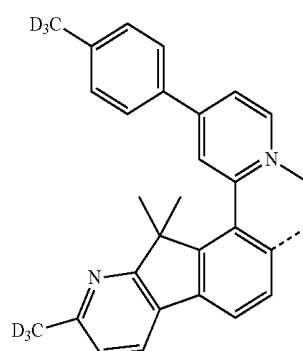
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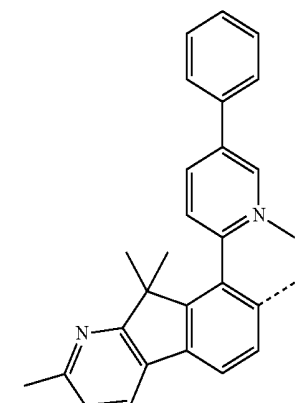
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L<sub>A347</sub>

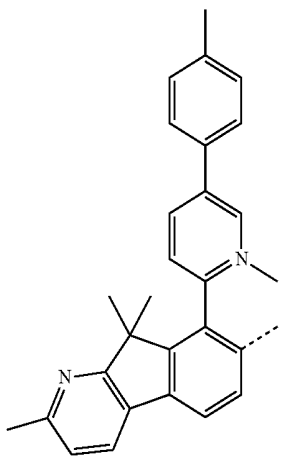


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L<sub>A349</sub>

**397**  
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L<sub>4350</sub>

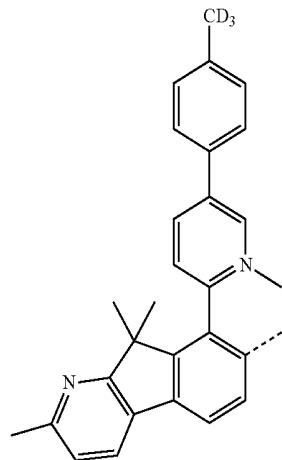
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**398**  
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L<sub>4353</sub>

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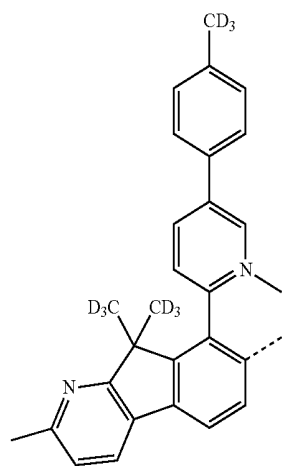
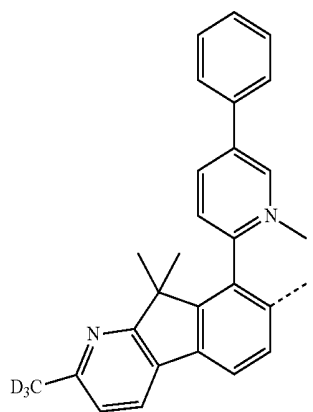
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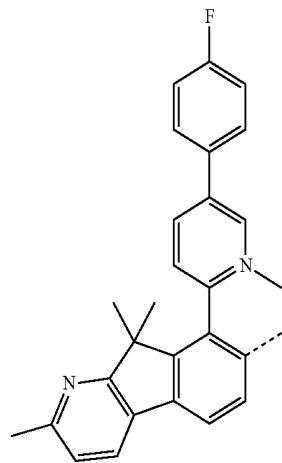
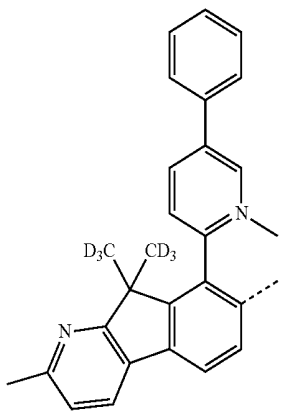
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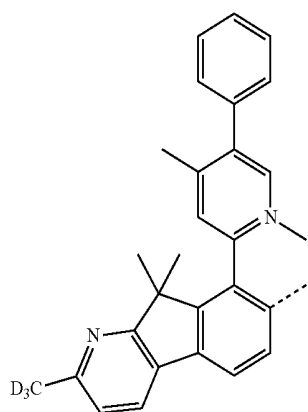
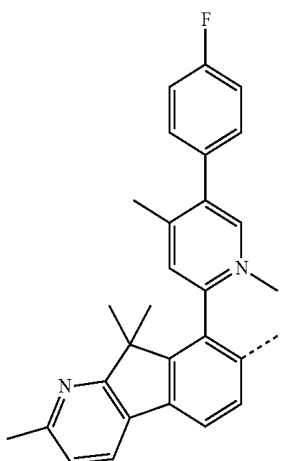
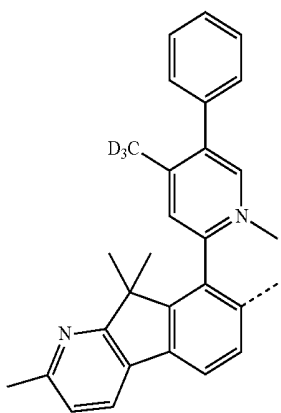
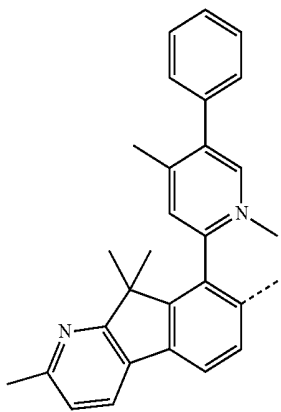
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L<sub>4355</sub>

**399**  
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L<sub>A356</sub>

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L<sub>A357</sub>

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L<sub>A358</sub>

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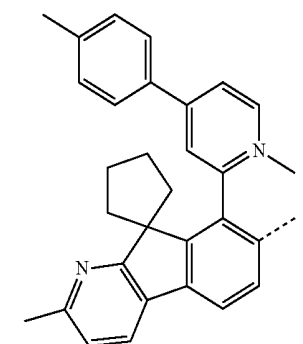
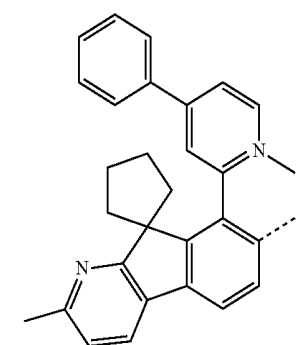
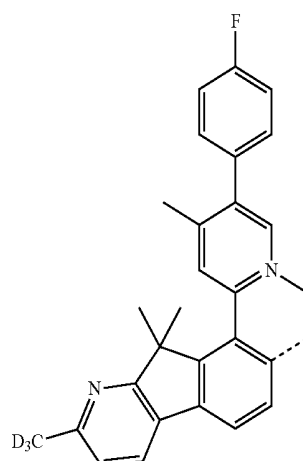
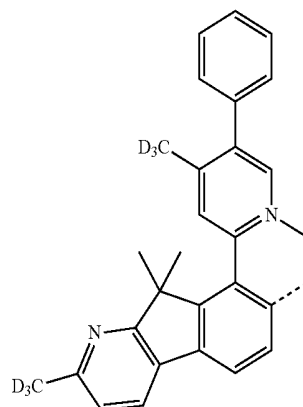
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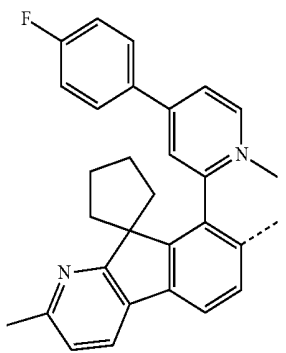
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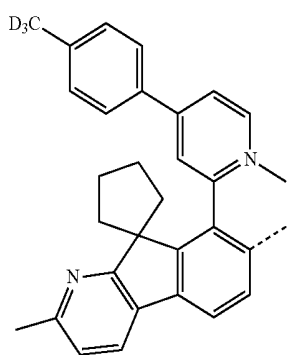
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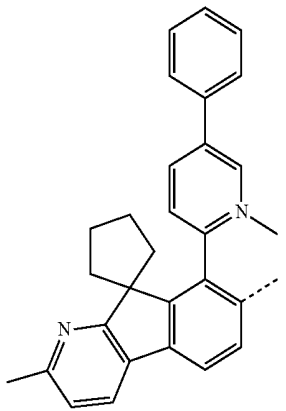
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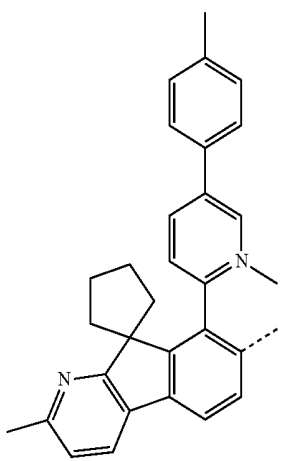
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L<sub>4366</sub>

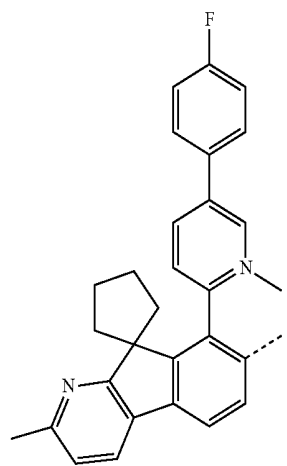
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L<sub>4367</sub>

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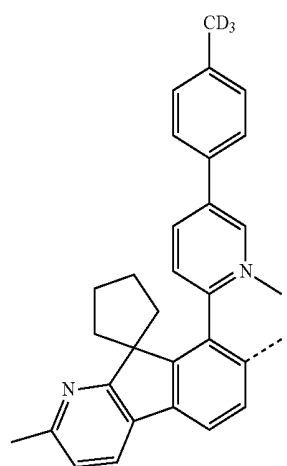
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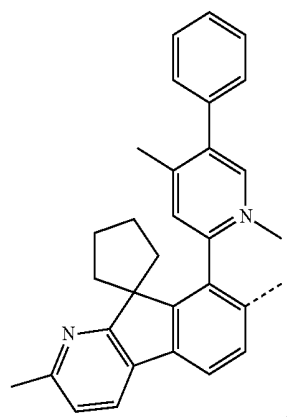
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L<sub>4370</sub>

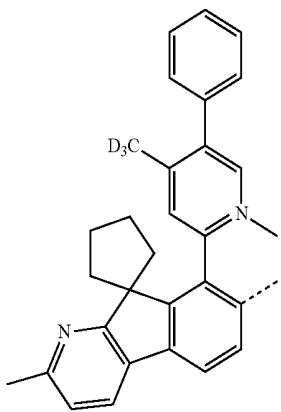
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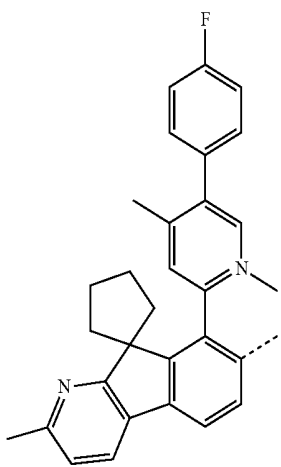
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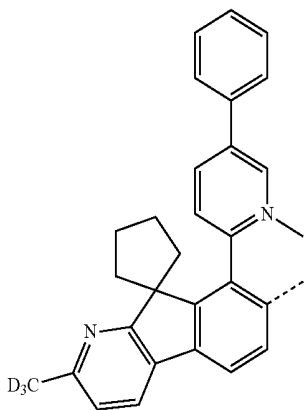
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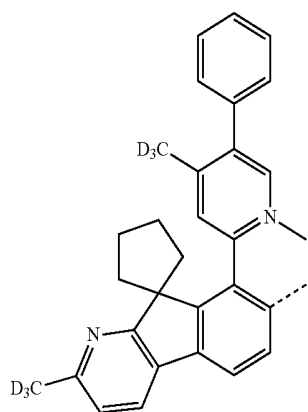
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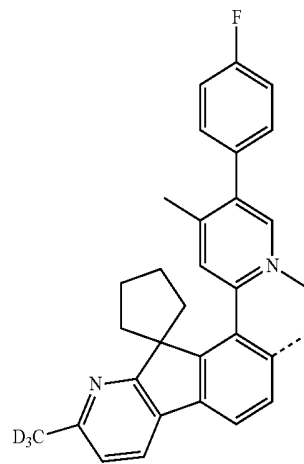


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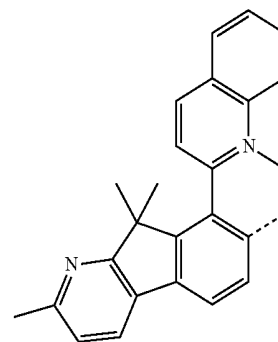
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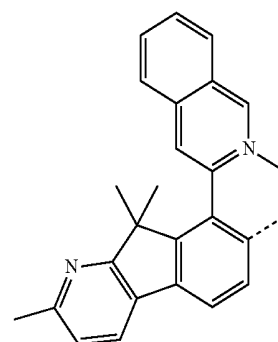
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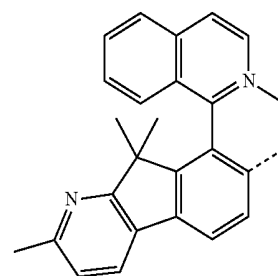
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L<sub>4377</sub>

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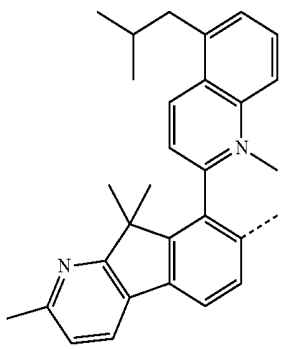
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L<sub>4379</sub>

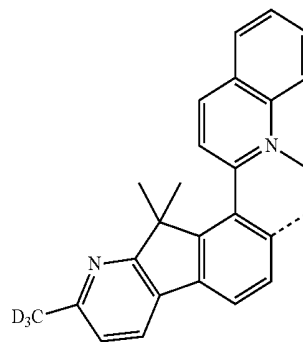
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406

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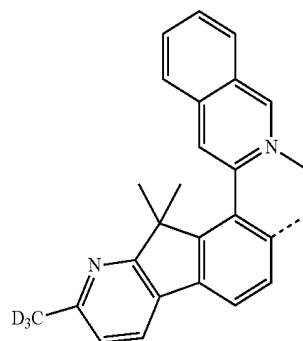
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L<sub>4380</sub>

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L<sub>4384</sub>

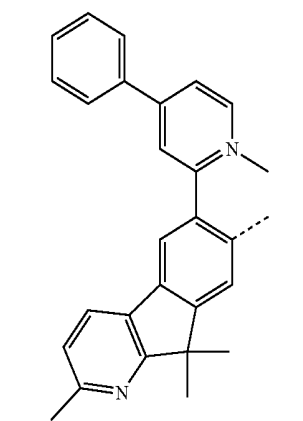
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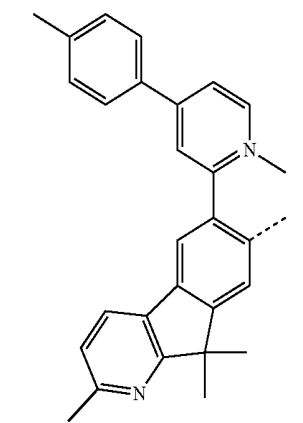
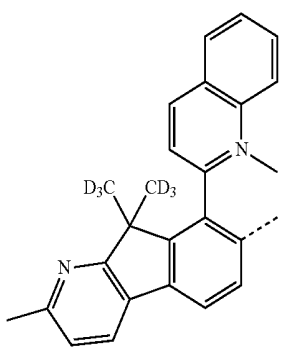
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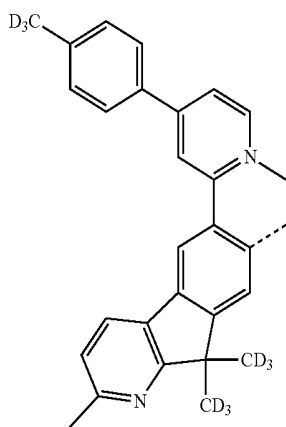
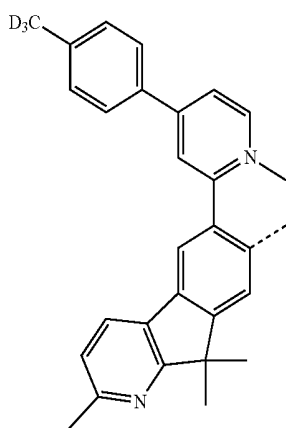
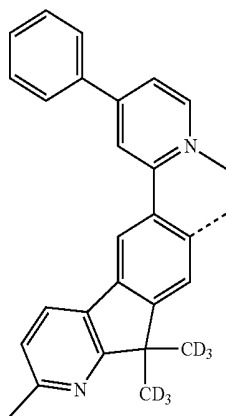
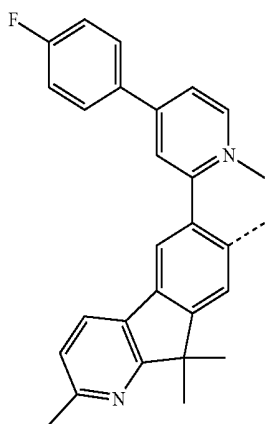
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L<sub>4386</sub>

**407**  
-continued



**408**  
-continued

L<sub>4387</sub>

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L<sub>4388</sub>

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L<sub>4389</sub>

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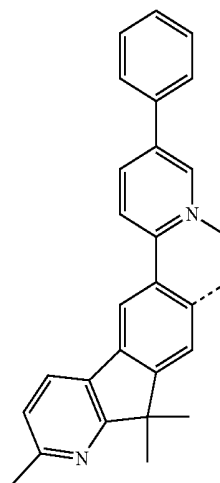
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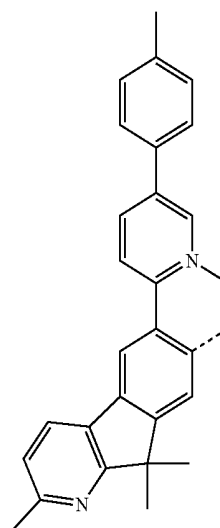
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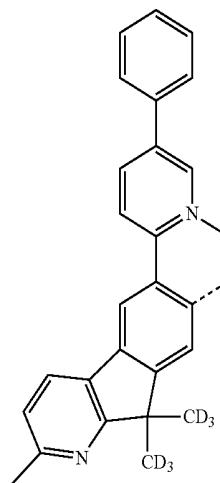
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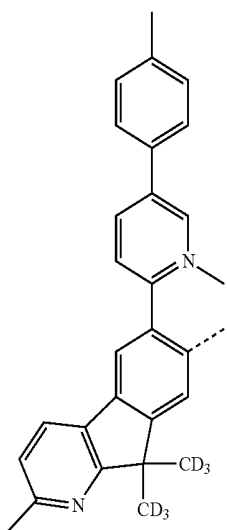
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L<sub>4393</sub>



**409**  
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L<sub>4394</sub>

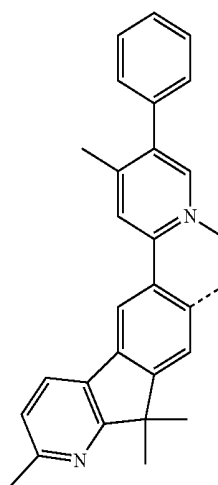
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**410**  
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L<sub>4397</sub>

L<sub>4395</sub> 25

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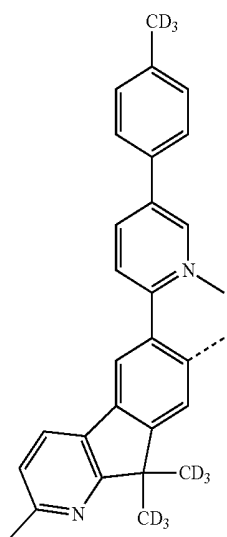
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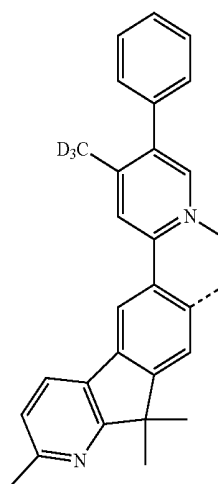
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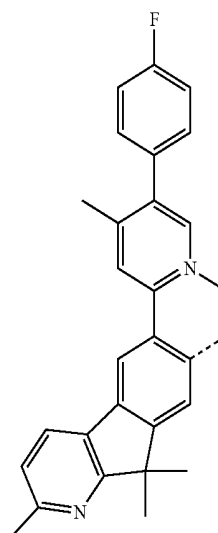
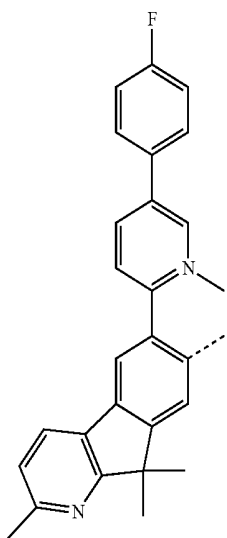
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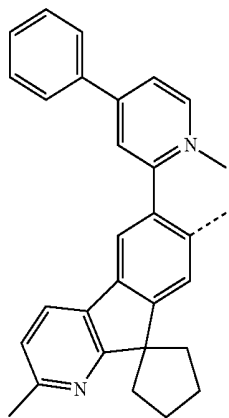
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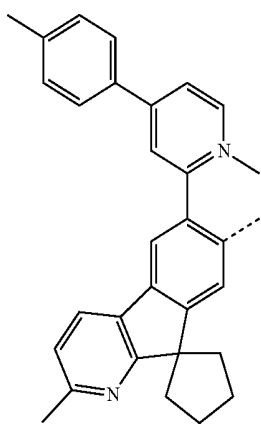


**411**  
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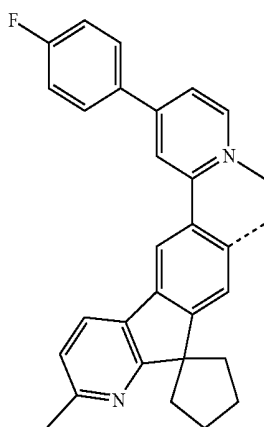
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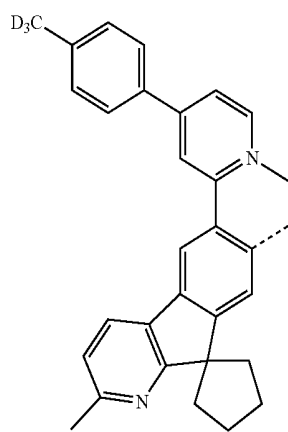
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L<sub>4402</sub>

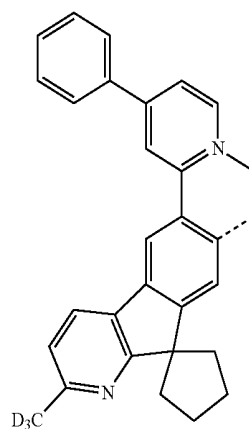
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L<sub>4403</sub>

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**412**  
-continued



L<sub>4404</sub>

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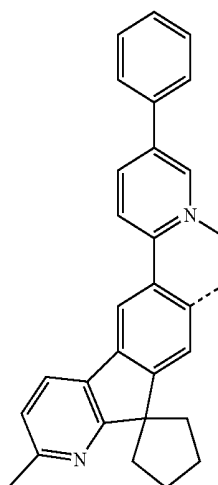
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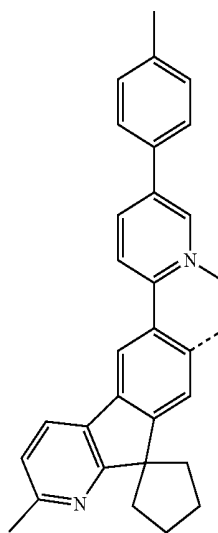
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L<sub>4405</sub>

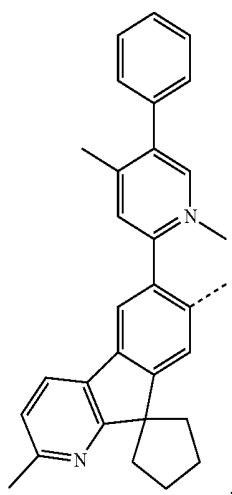
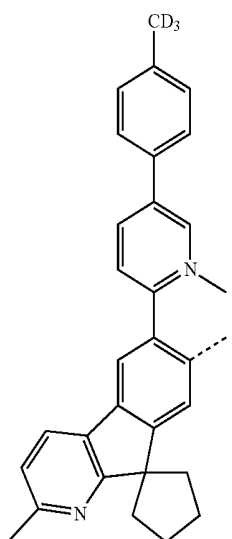
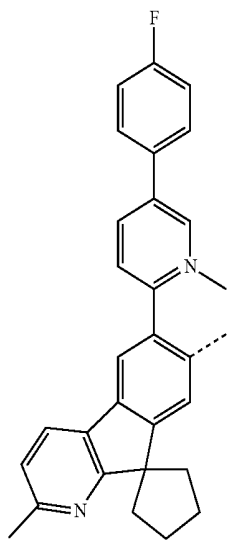
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L<sub>4406</sub>



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**413**  
-continued



**414**  
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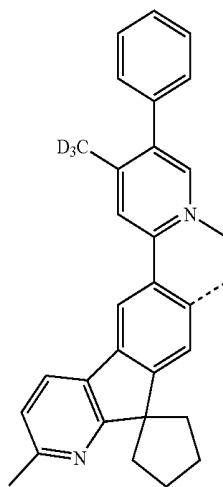
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L<sub>4410</sub>

L<sub>4408</sub>

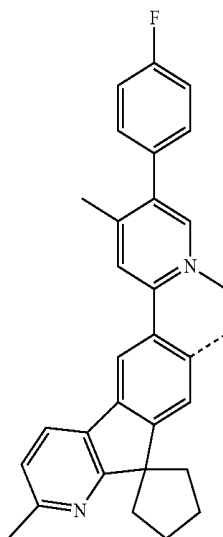
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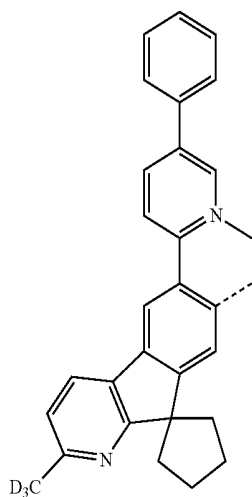
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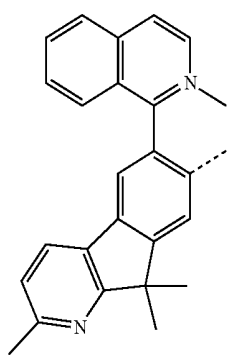
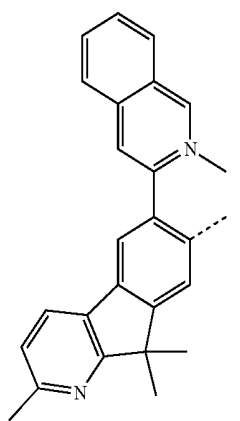
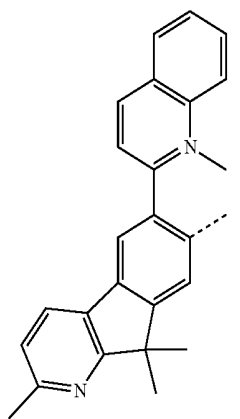
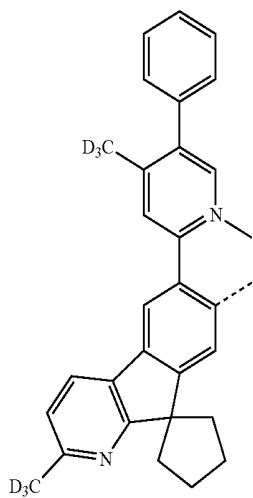
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L<sub>4412</sub>

415

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416

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L4413

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L4414

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L4415

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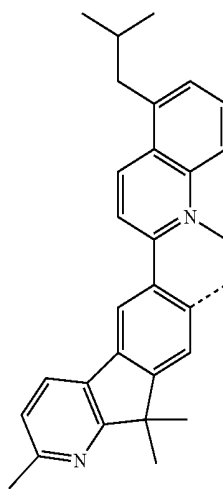
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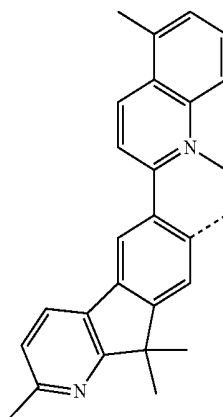
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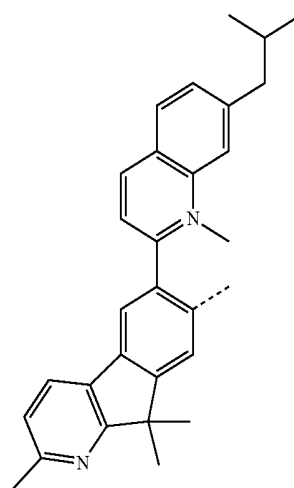
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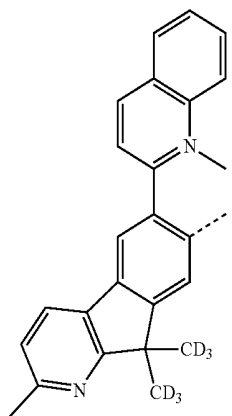
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L4419



**417**  
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L<sub>4420</sub>

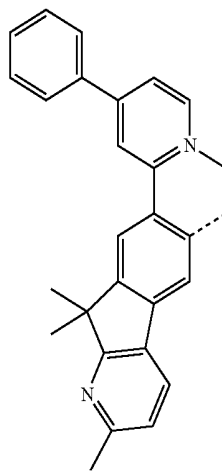
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**418**  
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L<sub>4423</sub>

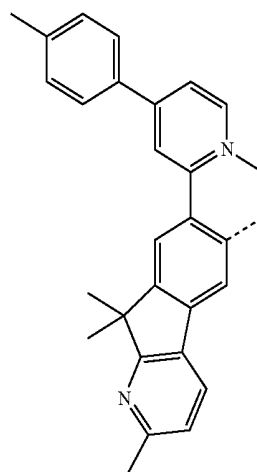
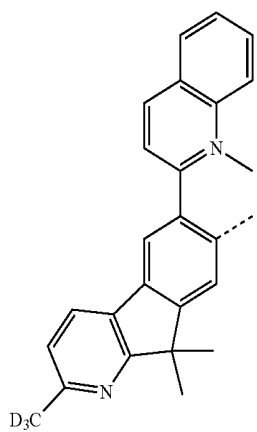
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L<sub>4424</sub>

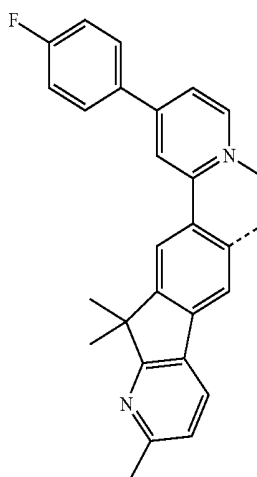
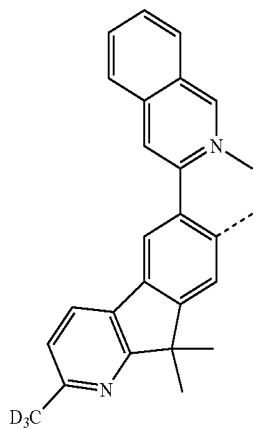
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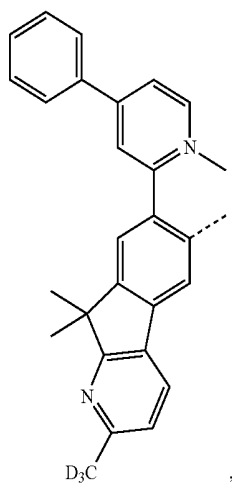
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L<sub>4425</sub>

**419**  
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L<sub>4426</sub>

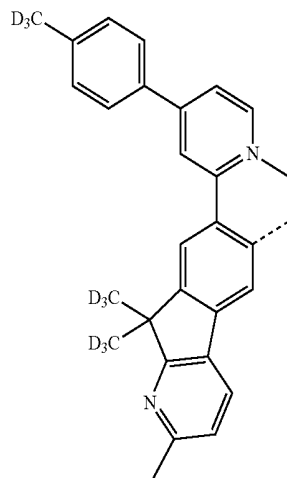
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**420**  
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L<sub>4429</sub>

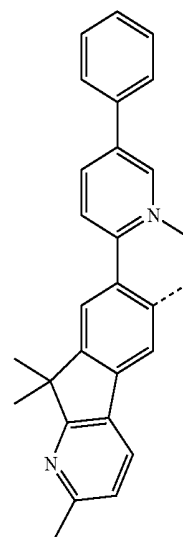
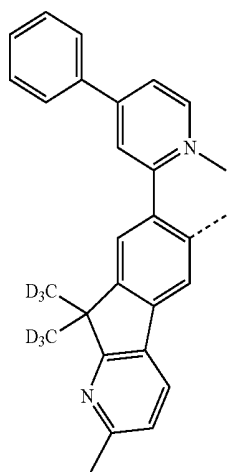
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L<sub>4427</sub>

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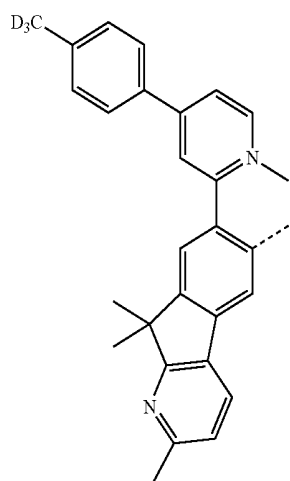
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L<sub>4430</sub>

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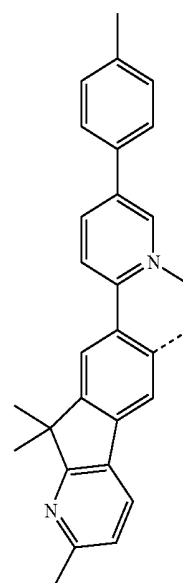
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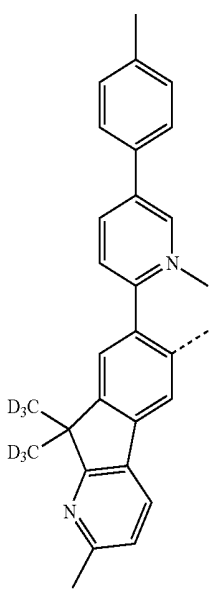
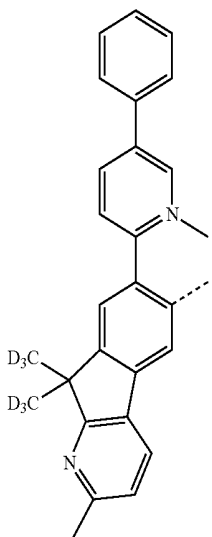
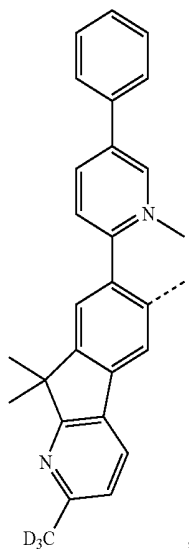
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L<sub>4431</sub>

421

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422

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L<sub>4432</sub>

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L<sub>4433</sub>

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L<sub>4434</sub>

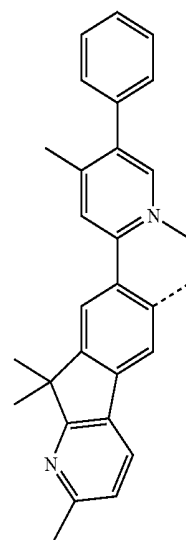
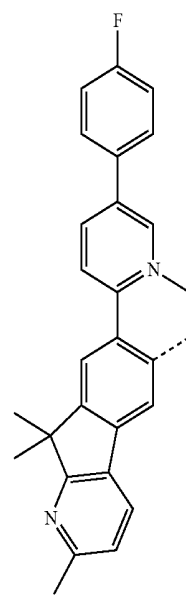
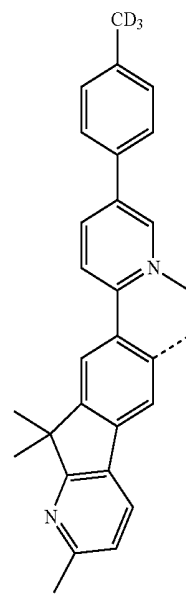
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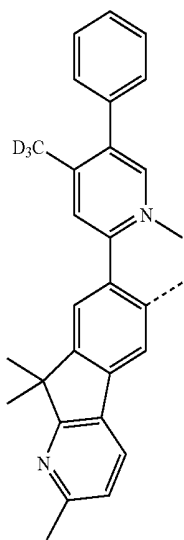
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L<sub>4436</sub>

L<sub>4437</sub>

423

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L<sub>4438</sub>

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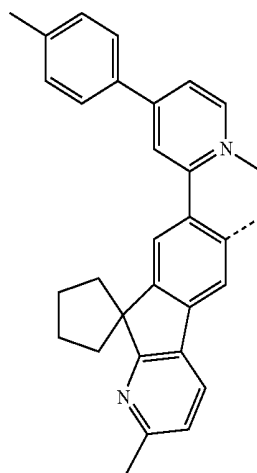
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424

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L<sub>4441</sub>

L<sub>4439</sub>

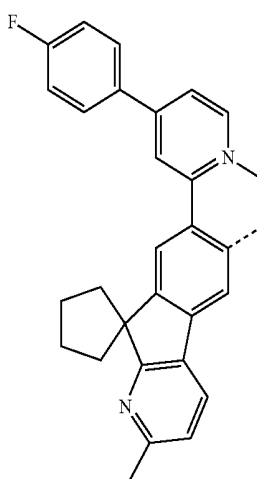
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L<sub>4442</sub>

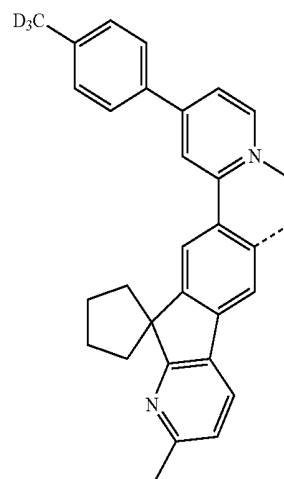
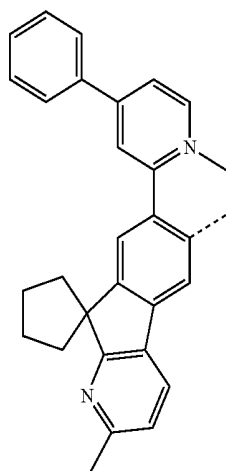
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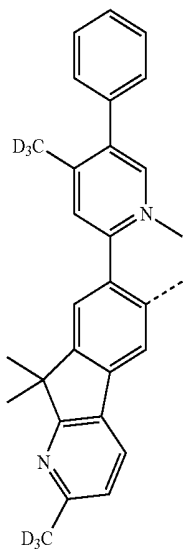
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L<sub>4443</sub>

425

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L<sub>4444</sub>

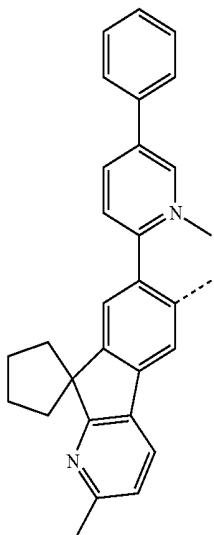
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L<sub>4445</sub>



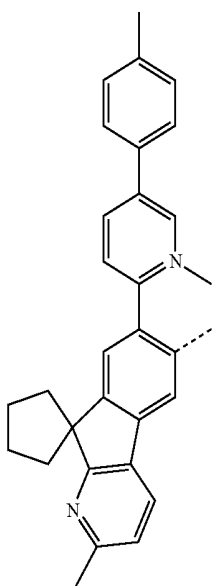
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L<sub>4446</sub>



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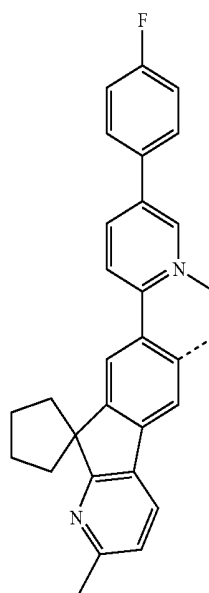
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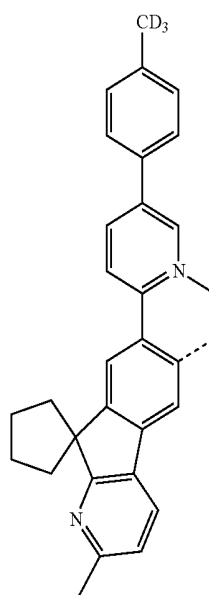
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426

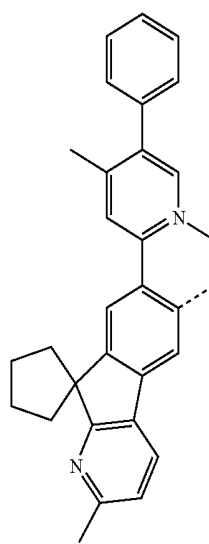
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L<sub>4447</sub>



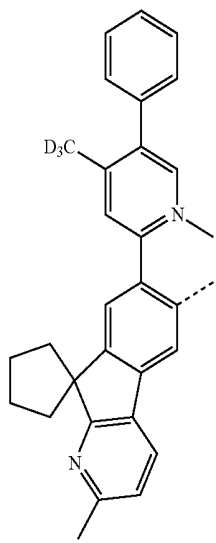
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L<sub>4449</sub>

427

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L4450

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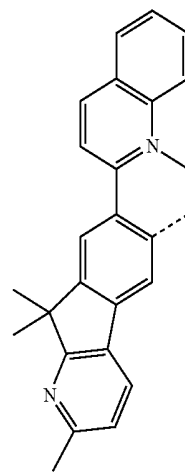
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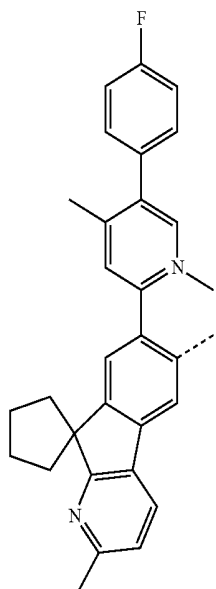
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L4453



L4451

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L4452

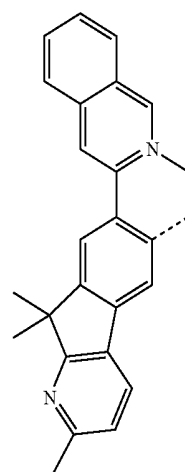
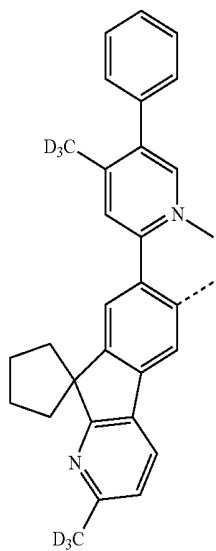
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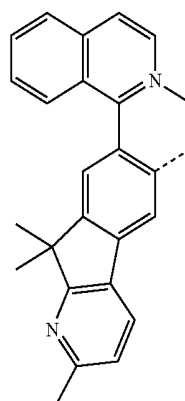
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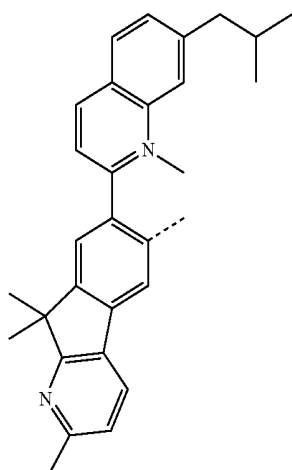
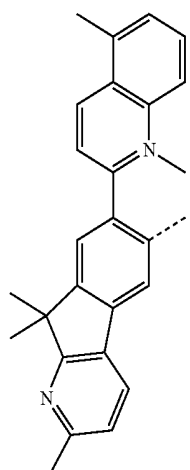
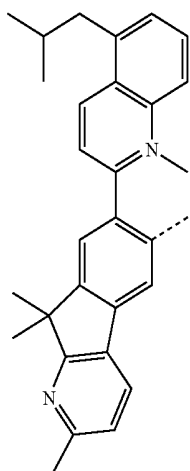
L4454



L4455

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L<sub>4456</sub>

L<sub>4459</sub>

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L<sub>4457</sub>

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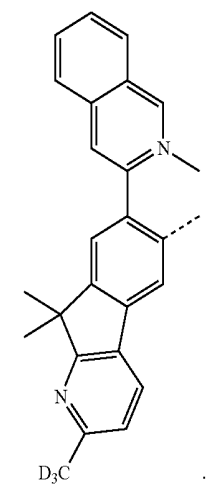
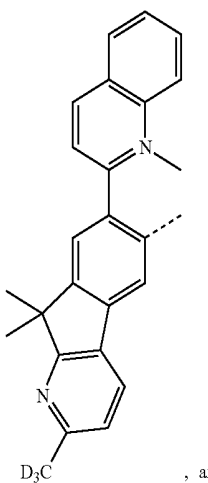
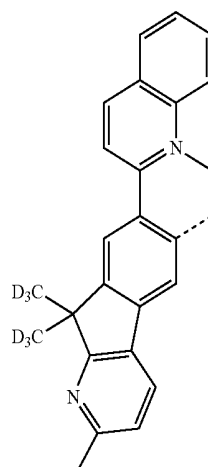
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L<sub>4458</sub>

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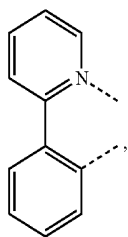


L<sub>4460</sub>

L<sub>4461</sub>

13. The compound of claim 12, wherein the compound is selected from Compound 1 through Compound 66,384, wherein each compound x has the formula  $\text{Ir}(\text{L}_{A_k})(\text{L}_{B_j})_2$ , wherein  $x=461j+k-461$ , k is an integer from 1 to 461, and j is an integer from 1 to 144; and wherein  $\text{L}_B$  is selected from the group consisting of:

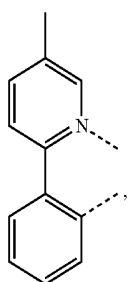
431



L<sub>B1</sub>

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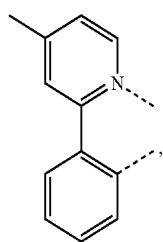
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L<sub>B2</sub>

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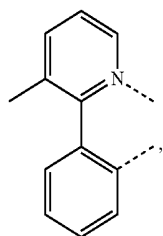
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L<sub>B3</sub>

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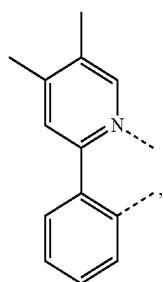
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L<sub>B4</sub>

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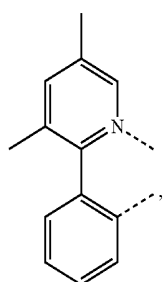
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L<sub>B5</sub>

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L<sub>B6</sub>

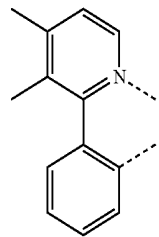
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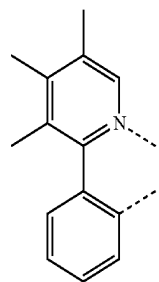
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432

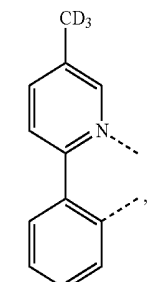
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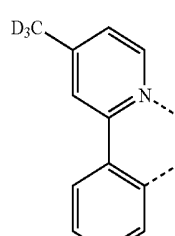
L<sub>B7</sub>



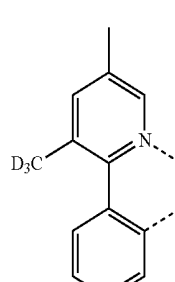
L<sub>B8</sub>



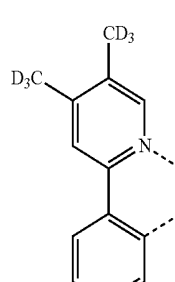
L<sub>B9</sub>



L<sub>B10</sub>



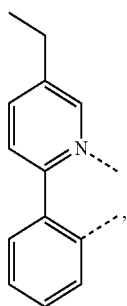
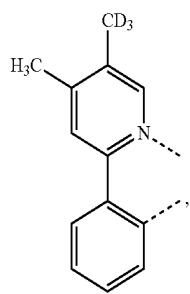
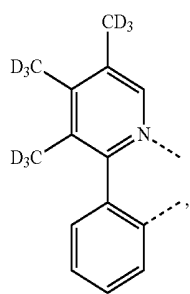
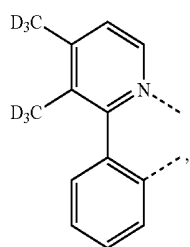
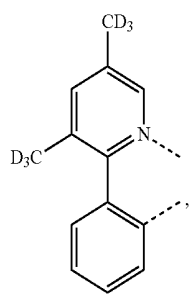
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L<sub>B12</sub>

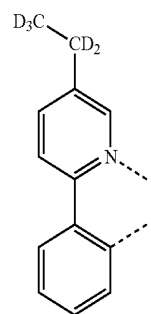
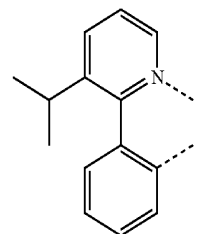
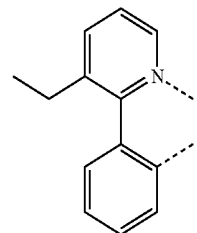
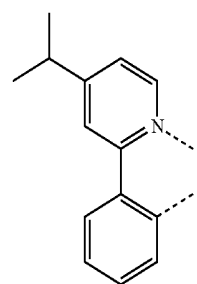
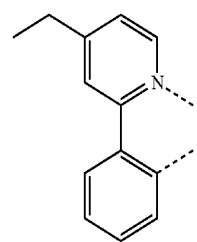
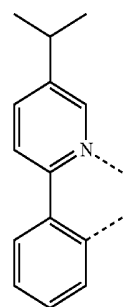
433

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434

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L<sub>B13</sub>

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L<sub>B14</sub>

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L<sub>B15</sub>

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L<sub>B16</sub>

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L<sub>B17</sub>

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L<sub>B18</sub>

L<sub>B19</sub>

L<sub>B20</sub>

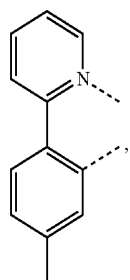
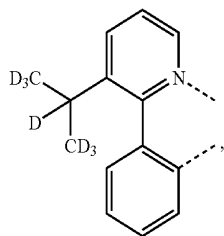
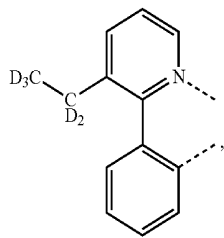
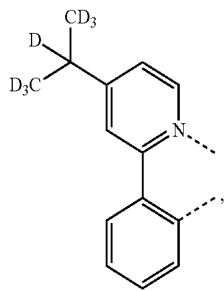
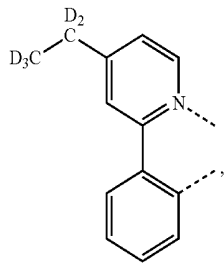
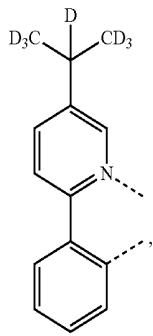
L<sub>B21</sub>

L<sub>B22</sub>

L<sub>B23</sub>

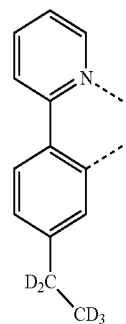
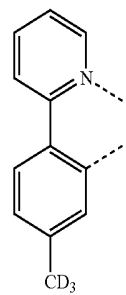
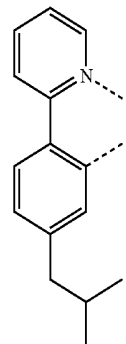
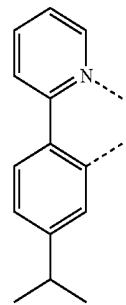
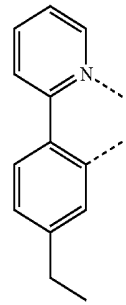
435

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L<sub>B24</sub>

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L<sub>B25</sub> 15

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L<sub>B26</sub> 25

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L<sub>B27</sub>

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L<sub>B28</sub>

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L<sub>B30</sub>

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L<sub>B31</sub>

L<sub>B32</sub>

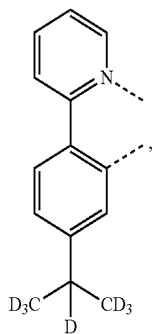
L<sub>B33</sub>

L<sub>B34</sub>

L<sub>B35</sub>

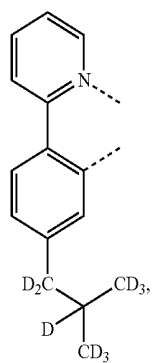
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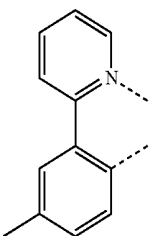
L<sub>B36</sub>

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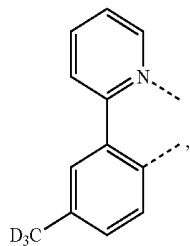
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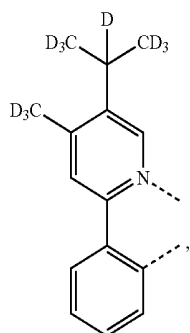
L<sub>B38</sub>

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L<sub>B39</sub>

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L<sub>B40</sub>

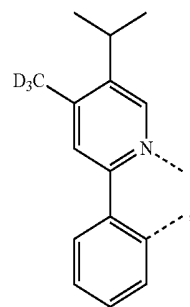
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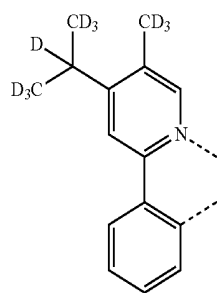
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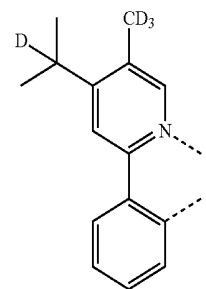
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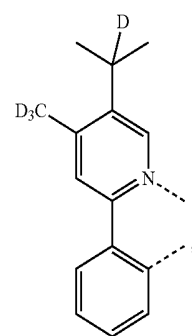
L<sub>B41</sub>



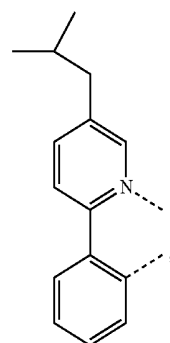
L<sub>B42</sub>



L<sub>B43</sub>



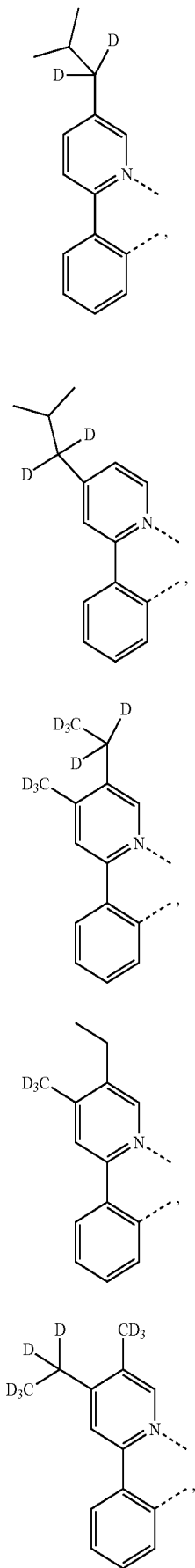
L<sub>B44</sub>



L<sub>B45</sub>

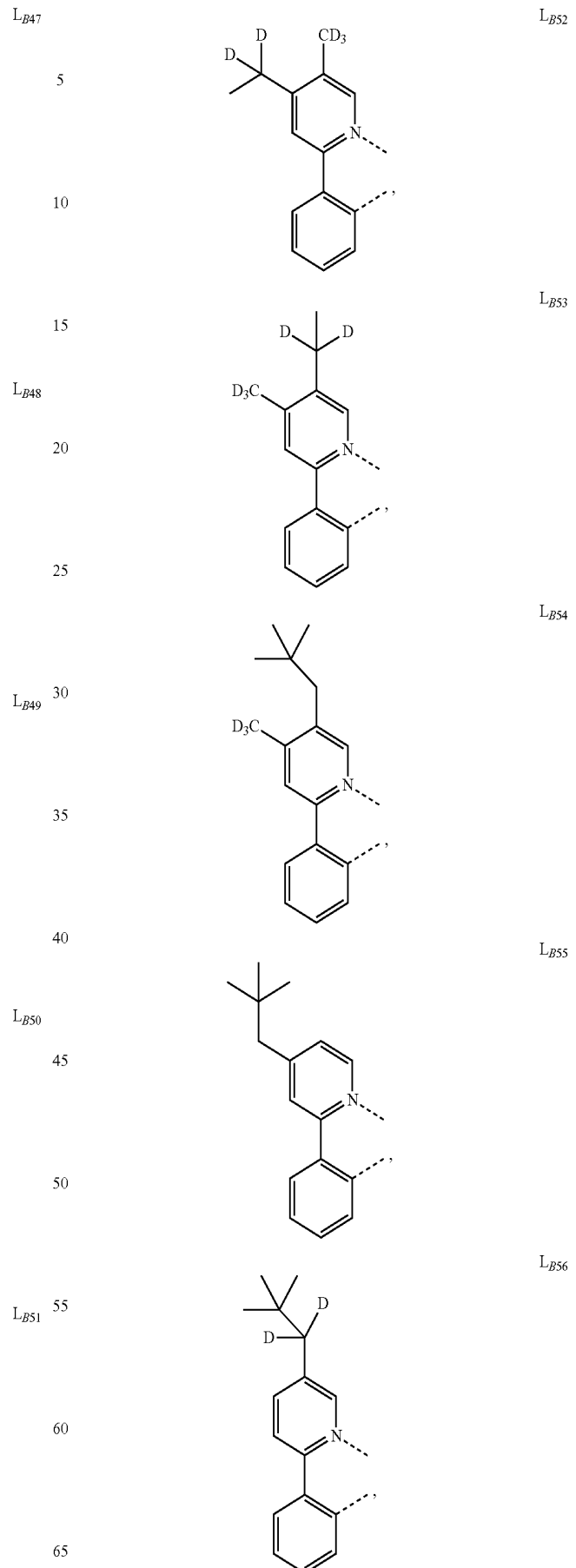
**439**

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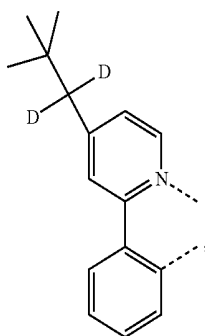
**440**

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441

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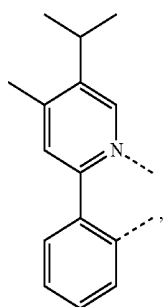
L<sub>B57</sub>

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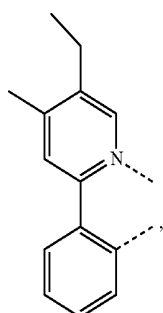
L<sub>B58</sub>



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L<sub>B59</sub>

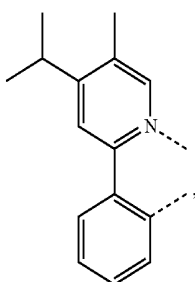


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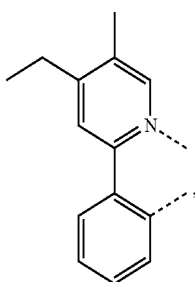
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L<sub>B61</sub>



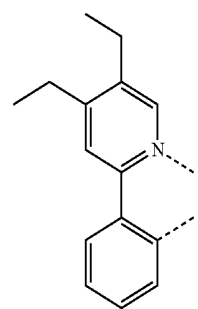
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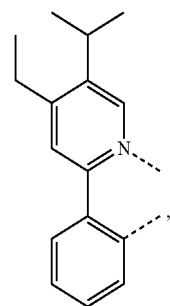
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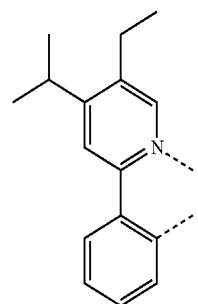


L<sub>B62</sub>

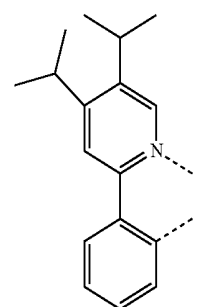
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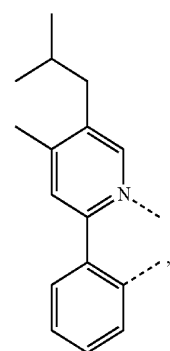
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L<sub>B65</sub>

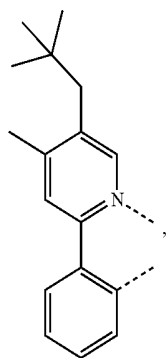


L<sub>B66</sub>



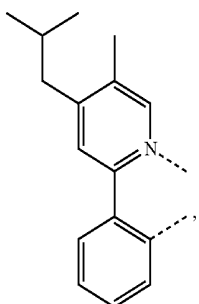
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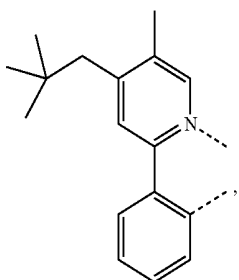
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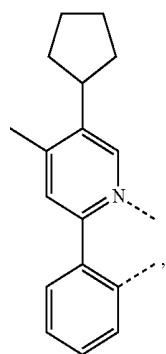
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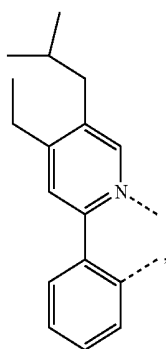
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L<sub>B70</sub>

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L<sub>B71</sub>

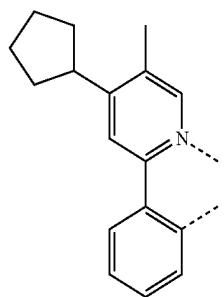
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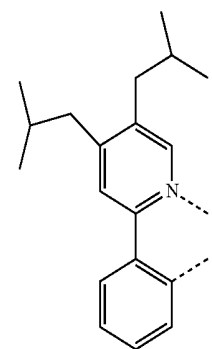
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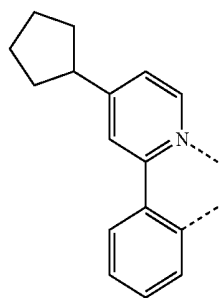


L<sub>B72</sub>

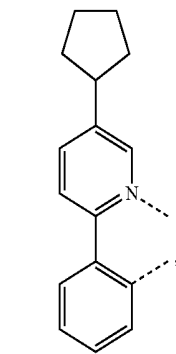
L<sub>B73</sub>



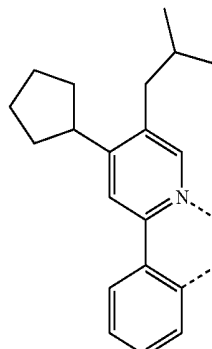
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L<sub>B75</sub>

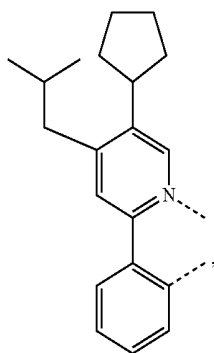


L<sub>B76</sub>



445

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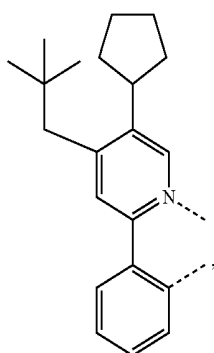


L<sub>B77</sub>

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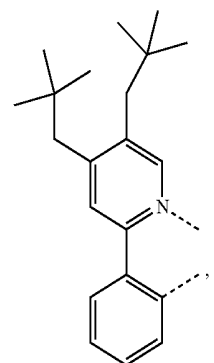


L<sub>B78</sub>

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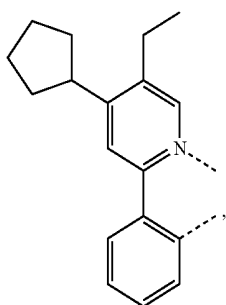
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L<sub>B80</sub>

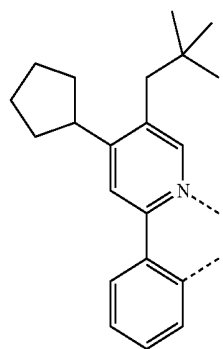
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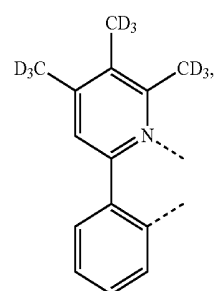
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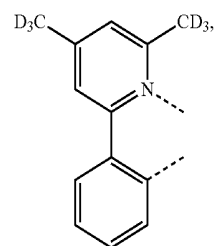
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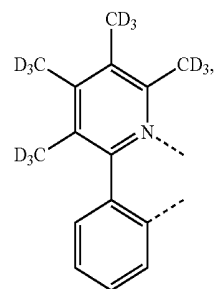
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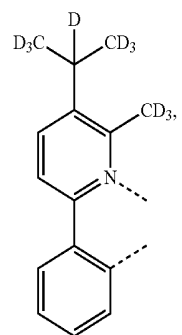
L<sub>B82</sub>



L<sub>B83</sub>



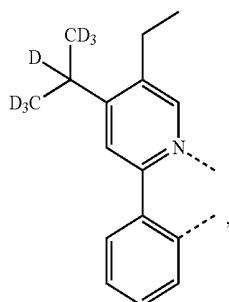
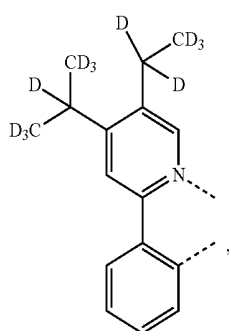
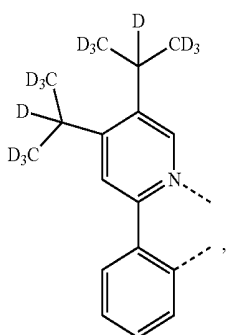
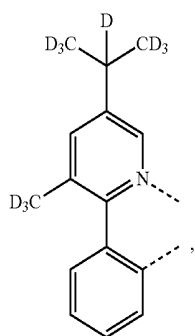
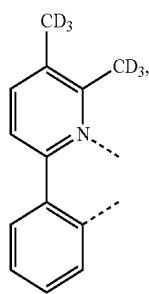
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L<sub>B85</sub>

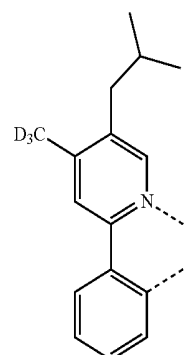
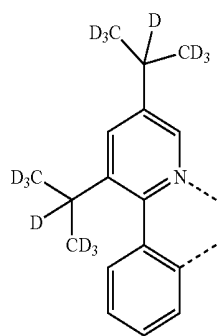
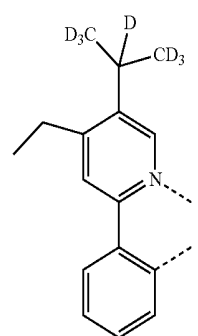
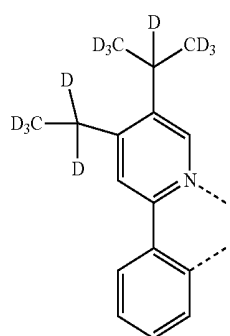
447

-continued



448

-continued



L<sub>B86</sub>

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L<sub>B87</sub>

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L<sub>B88</sub>

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L<sub>B89</sub>

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L<sub>B90</sub>

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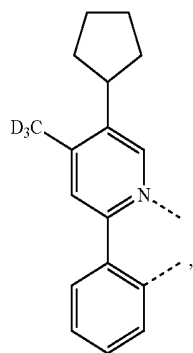
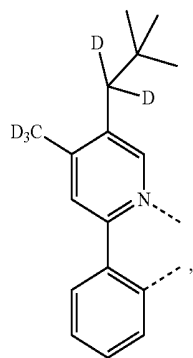
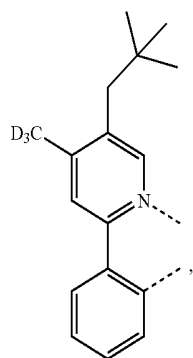
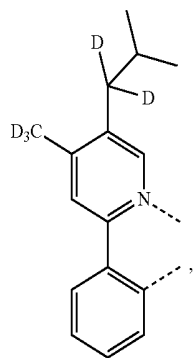
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L<sub>B92</sub>

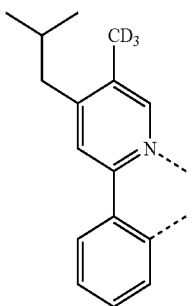
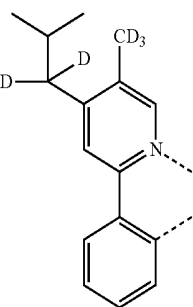
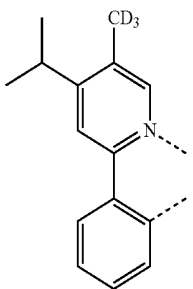
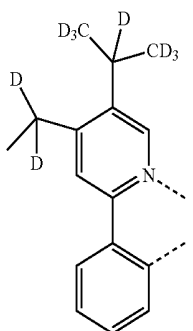
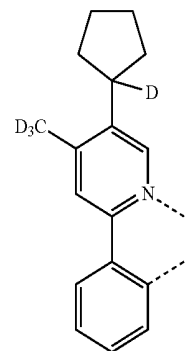
L<sub>B93</sub>

L<sub>B94</sub>

**449**  
-continued



**450**  
-continued



L<sub>B95</sub>

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L<sub>B96</sub>

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L<sub>B97</sub>

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L<sub>B98</sub>

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L<sub>B99</sub>

L<sub>B100</sub>

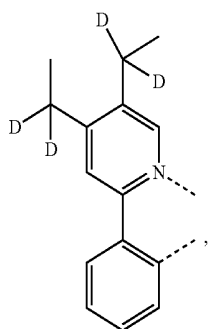
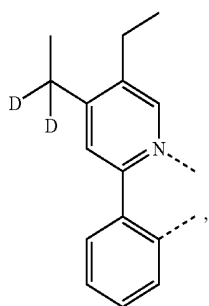
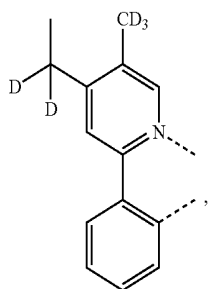
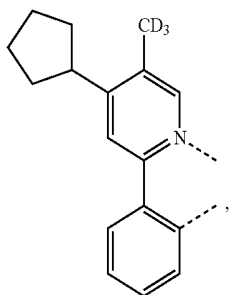
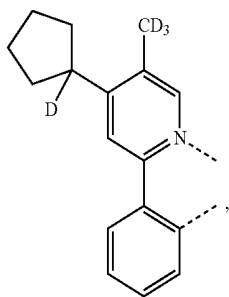
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L<sub>B102</sub>

L<sub>B103</sub>

**451**

-continued



**452**

-continued

L<sub>B104</sub>

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L<sub>B105</sub>

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L<sub>B106</sub>

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L<sub>B107</sub>

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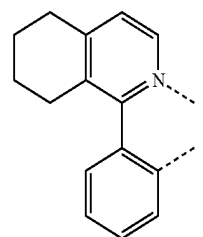
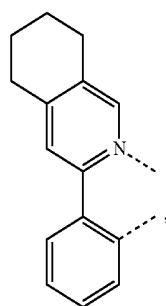
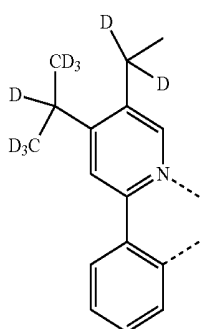
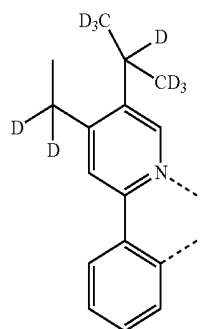
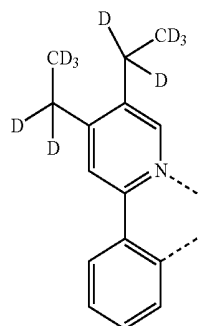
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L<sub>B108</sub>

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L<sub>B109</sub>

L<sub>B110</sub>

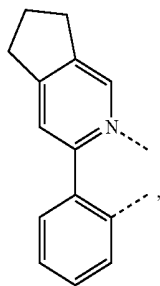
L<sub>B111</sub>

L<sub>B112</sub>

L<sub>B113</sub>

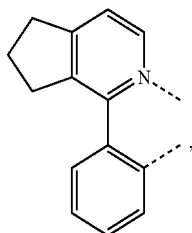
453

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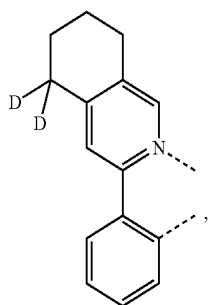
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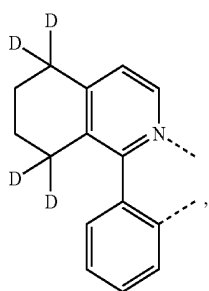
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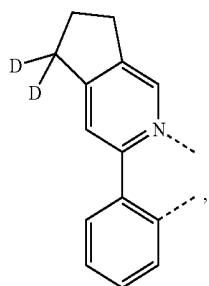
L<sub>B116</sub>

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L<sub>B117</sub>

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L<sub>B118</sub>

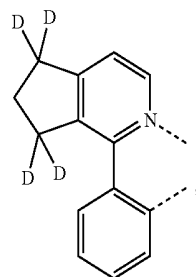
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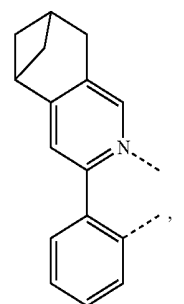
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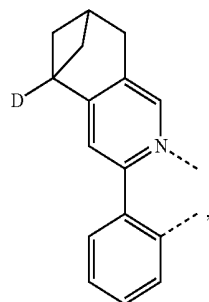
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L<sub>B120</sub>

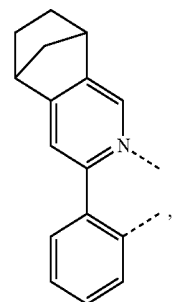
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L<sub>B121</sub>

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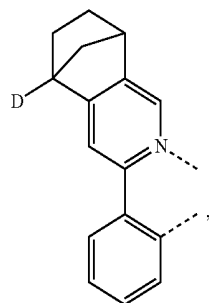


L<sub>B122</sub>

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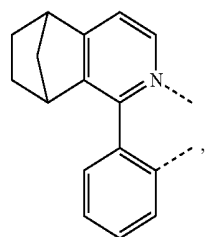
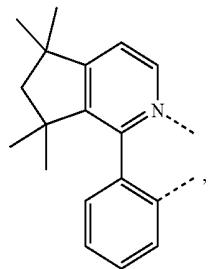
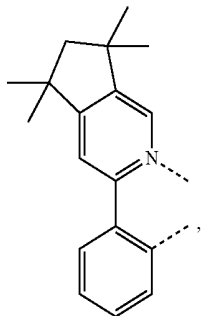
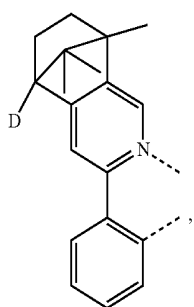
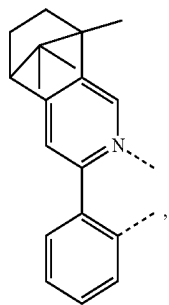
L<sub>B123</sub>

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455

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456

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L<sub>B124</sub>

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L<sub>B125</sub>

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L<sub>B126</sub>

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L<sub>B127</sub>

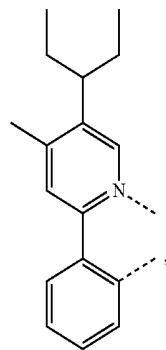
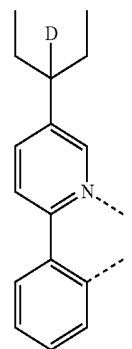
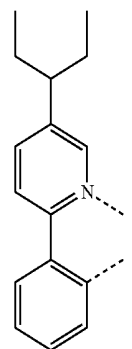
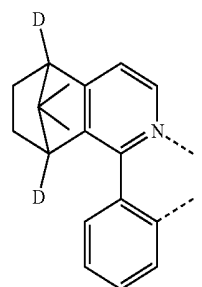
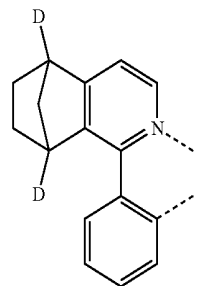
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L<sub>B128</sub>

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L<sub>B129</sub>

L<sub>B130</sub>

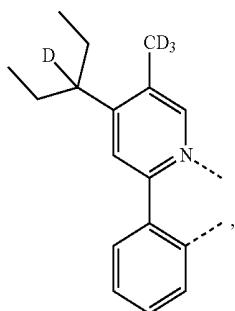
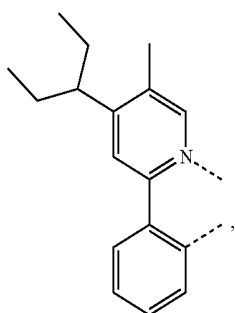
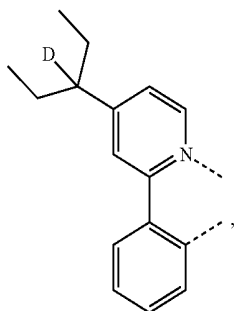
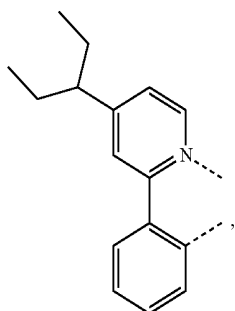
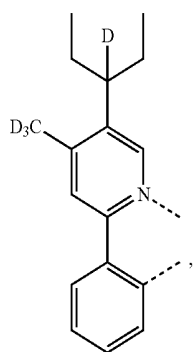
L<sub>B131</sub>

L<sub>B132</sub>

L<sub>B133</sub>

**457**

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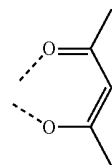


**458**

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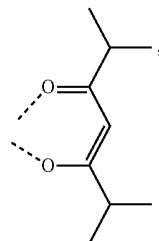
L<sub>B134</sub>

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L<sub>B139</sub>

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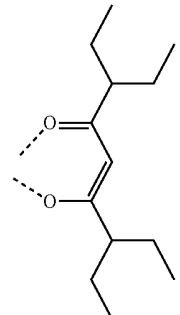


L<sub>B140</sub>

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L<sub>B135</sub>

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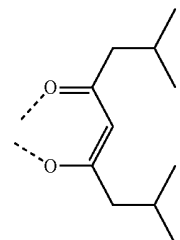


L<sub>B141</sub>

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L<sub>B136</sub>

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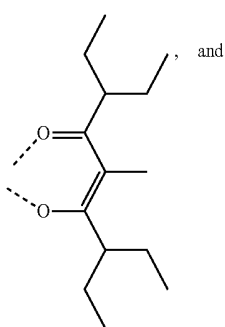
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L<sub>B137</sub>

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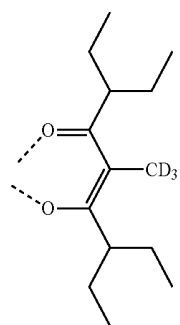


L<sub>B143</sub>

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L<sub>B138</sub>

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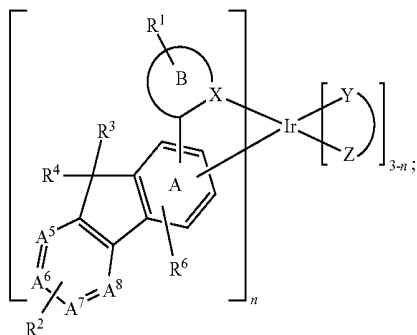
L<sub>B144</sub>

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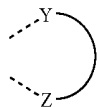
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14. A first device comprising a first organic light emitting device, the first organic light emitting device comprising:  
 an anode;  
 a cathode; and  
 an organic layer, disposed between the anode and the cathode, comprising a compound having the formula  $\text{Ir}(\text{L}_A)_n(\text{L}_B)_{3-n}$ , having the structure:



wherein  $\text{A}^5$ ,  $\text{A}^6$ ,  $\text{A}^7$ , and  $\text{A}^8$  comprise carbon or nitrogen;  
 wherein at least one of  $\text{A}^5$ ,  $\text{A}^6$ ,  $\text{A}^7$ , and  $\text{A}^8$  is nitrogen;  
 wherein ring B is bonded to ring A through a C—C bond;  
 wherein  $\text{R}^1$ ,  $\text{R}^2$  and  $\text{R}^6$  independently represent from mono-substitution to the possible maximum number of substitution, or no substitution;  
 wherein any adjacent substitutions in  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^3$ , and  $\text{R}^4$  are optionally linked together to form a ring;  
 wherein X is a neutral donor;  
 wherein



is a monoanionic bidentate ligand;  
 wherein  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^3$ ,  $\text{R}^4$ , and  $\text{R}^6$  are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and  
 wherein n is an integer from 1 to 3.

15. The first device of claim 14, wherein the organic layer is an emissive layer and the compound is an emissive dopant.

16. The first device of claim 14, wherein the organic layer further comprises a host, wherein the host comprises a triphenylene containing benzo-fused thiophene or benzo-fused furan;

wherein any substituent in the host is an unfused substituent independently selected from the group consist-

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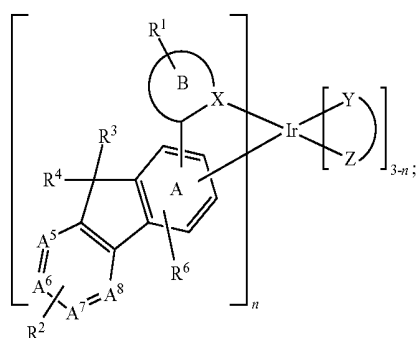
ing of  $\text{C}_n\text{H}_{2n+1}$ ,  $\text{OC}_n\text{H}_{2n+1}$ ,  $\text{OAr}_1$ ,  $\text{N}(\text{C}_n\text{H}_{2n+1})_2$ ,  $\text{N}(\text{Ar}_1)(\text{Ar}_2)$ ,  $\text{CH}=\text{CH}-\text{C}_n\text{H}_{2n+1}$ ,  $\text{C}\equiv\text{CC}_n\text{H}_{2n+1}$ ,  $\text{Ar}_1$ ,  $\text{Ar}_1-\text{Ar}_2$ , and  $\text{C}_n\text{H}_{2n}-\text{Ar}_1$ ;

wherein n is from 1 to 10; and

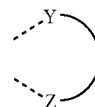
wherein  $\text{Ar}_1$  and  $\text{Ar}_2$  are independently selected from the group consisting of benzene, biphenyl, naphthalene, triphenylene, carbazole, and heteroaromatic analogs thereof.

17. The first device of claim 14, wherein the organic layer further comprises a host, wherein host comprises at least one chemical group selected from the group consisting of triphenylene, carbazole, dibenzothiophene, dibenzofuran, dibenzoselenophene, azatriphenylene, azacarbazole, aza-dibenzothiophene, aza-dibenzofuran, and aza-dibenzoselenophene.

18. A formulation comprising a compound having the formula  $\text{Ir}(\text{L}_A)_n(\text{L}_B)_{3-n}$ , having the structure:



wherein  $\text{A}^5$ ,  $\text{A}^6$ ,  $\text{A}^7$ , and  $\text{A}^8$  comprise carbon or nitrogen;  
 wherein at least one of  $\text{A}^5$ ,  $\text{A}^6$ ,  $\text{A}^7$ , and  $\text{A}^8$  is nitrogen;  
 wherein ring B is bonded to ring A through a C—C bond;  
 wherein  $\text{R}^1$ ,  $\text{R}^2$ , and  $\text{R}^6$  independently represent from mono-substitution to the possible maximum number of substitution, or no substitution;  
 wherein any adjacent substitutions in  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^3$ , and  $\text{R}^4$  are optionally linked together to form a ring;  
 wherein X is a neutral donor;  
 wherein



is a monoanionic bidentate ligand;

wherein  $\text{R}^1$ ,  $\text{R}^2$ ,  $\text{R}^3$ ,  $\text{R}^4$ , and  $\text{R}^6$  are independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and  
 wherein n is an integer from 1 to 3.

\* \* \* \* \*

专利名称(译)	有机电致发光材料和器件		
公开(公告)号	<a href="#">US10003034</a>	公开(公告)日	2018-06-19
申请号	US14/467901	申请日	2014-08-25
[标]申请(专利权)人(译)	环球展览公司		
申请(专利权)人(译)	通用显示器公司		
当前申请(专利权)人(译)	通用显示器公司		
[标]发明人	XIA CHUANJUN LIN CHUN		
发明人	XIA, CHUANJUN LIN, CHUN		
IPC分类号	H01L51/00 C07F15/00 C09K11/06 H01L51/50		
CPC分类号	H01L51/0085 C07F15/0033 C09K11/06 C09K2211/185 H01L51/5016		
代理机构(译)	DUANE MORRIS LLP		
优先权	61/884213 2013-09-30 US		
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摘要(译)

具有式I结构的化合物：被描述。在式I中，A<sub>1</sub>，A<sub>2</sub>，A<sub>3</sub>，A<sub>4</sub>，A<sub>5</sub>，A<sub>6</sub>，A<sub>7</sub>，A<sub>8</sub>可以是碳或氮；至少有一个A<sub>1</sub>，A<sub>2</sub>，A<sub>3</sub>，A<sub>4</sub>，A<sub>5</sub>，A<sub>6</sub>，A<sub>7</sub>，A<sub>8</sub>为氮；X是中性供体；是单阴离子二齿配体；n是1至3的整数；环B通过C-C键与环A键合；环A通过Ir-C键与铱键合。此外，R<sub>1</sub>，R<sub>2</sub>，R<sub>3</sub>，R<sub>4</sub>和R<sub>6</sub>独立地选自氢，氘，卤化物，烷基，环烷基，杂烷基，芳烷基，烷氧基，芳氧基，氨基，甲硅烷基，烯基，环烯基，杂烯基，炔基，芳基，杂芳基，酰基，羰基，羧酸，酯，亚硝酸盐，异腈，硫烷基，亚磺酰基，磺酰基，膦基及其组合。还描述了包含式I化合物的制剂和装置，例如OLED。

