Formula I:  

\[
\text{represented by Formula I.}
\]

**Continued on next page**
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NARROW BAND RED PHOSPHORESCENT TETRADENTATE PLATINUM (II) COMPLEXES

CROSS-REFERENCE TO RELATED APPLICATION
This application claims the benefit of US Application Serial No. 62/407,020 entitled NARROW BAND RED PHOSPHORESCENT TETRADENTATE PLATINUM (II) COMPLEXES and filed October 12, 2016, which is incorporated by reference herein in its entirety.

TECHNICAL FIELD
This invention relates to narrow band red phosphorescent tetradeionate platinum (II) complexes and light emitting devices including these emitters.

BACKGROUND
Cyclometalated metal complexes have found wide applications as emitters for OLEDs in recent decades. Much attention has been paid to the development of new improved materials for both display and solid state lighting applications. Through diligent device and materials design, OLEDs emitting efficiently across the visible spectrum have been achieved. However, one major drawback is that they exhibit relatively broad emission spectra. Particularly, the development of stable and efficient narrow band red phosphorescent emitters remains a substantial deficit for the on-going efforts. Thus, to fully realize the benefits of phosphorescent materials, greater spectral purity is needed.

SUMMARY
As described herein, with the aim of further improving the color purity and enhancing the operational stability as well as eliminating the potential intermolecular interaction, a series of narrow band red platinum (II) complexes has been designed and synthesized. This class of emitters is suitable for full color displays and lighting applications.
In particular, complexes represented by Formula I are disclosed:
wherein:

each \( A_{r1} \), \( A_{r2} \), \( A_{r3} \), \( A_{r4} \), and \( A_{r5} \) present independently represents a substituted or unsubstituted aryl or heterocyclic aryl;

each \( n \) is independently an integer of 0 to 4, as limited by valence;

\( X \) represents O, S, NR\(^{1a} \), SiR\(^{2b} \)R\(^{1c} \), or CR\(^{1d} \)R\(^{1e} \), where each of R\(^{1a} \), R\(^{2b} \), R\(^{1c} \), R\(^{1d} \), and R\(^{1e} \) independently represents substituted or unsubstituted C\(_{1-4}\) alkyl;

\( Y_{1a} \), \( Y_{2a} \), \( Y_{3b} \), and \( Y_{4a} \) each independently represents N or C;

\( Y_{3a} \) represents N, CR\(^{2a} \), or SiR\(^{2b} \), where R\(^{2a} \) and R\(^{2b} \) represent hydrogen or substituted or unsubstituted C\(_{1-4}\) alkyl, aryl, or heterocyclic aryl;

\( Y_{5a} \) and \( Y_{5b} \) each independently represents C or N; and

\( Y_{5c} \), \( Y_{5d} \), and \( Y_{5e} \) each independently represents C, N, O, or S.

Light emitting devices including a complex represented by Formula I are also disclosed.

These light emitting devices are suitable for full color displays.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts a cross section of an exemplary OLED.

FIGS. 2 and 3 show photoluminescence spectra of exemplary complexes disclosed herein.
DETAILED DESCRIPTION

This disclosure relates to complexes represented by Formula I:

\[
\text{Formula I}
\]

wherein:

- each \(A_{r1}, A_{r2}, A_{r3}, A_{r4}, \text{ and } A_{r5}\) present independently represents a substituted or unsubstituted aryl or heterocyclic aryl;
- each \(n\) is independently an integer of 0 to 4, as limited by valence;
- \(X\) represents \(O, S, NR_{1a}, SiR_{1b}R_{1c}, \text{ or } CR_{1d}R_{1e}\), where each of \(R_{1a}, R_{1b}, R_{1c}, R_{1d}, \text{ and } R_{1e}\) independently represents substituted or unsubstituted C1-C4 alkyl;
- \(Y_{1a}, Y_{2a}, Y_{3b}, \text{ and } Y_{4a}\) each independently represents \(N\) or \(C\);
- \(Y_{3a}\) represents \(N, CR_{2a}, \text{ or } SiR_{2b}\), where \(R_{2a}\) and \(R_{2b}\) represent hydrogen or substituted or unsubstituted C1-C4 alkyl, aryl, or heterocyclic aryl;
- \(Y_{5a}\) and \(Y_{5b}\) each independently represents \(C\) or \(N\); and
- \(Y_{5c}, Y_{5d}, \text{ and } Y_{5e}\) each independently represents \(C, N, O, \text{ or } S\).

In some aspects, a portion of a complex of Formula I can be represented by a formula:
which is understood to be equivalent to a formula:

where \( n \) is an integer from 0 to 4. That is, \( \text{Ar}^1 \) may be absent, or \((\text{Ar}^1)_n\) may represent up to four independent substituents, \( \text{Ar}^{1(a)} \), \( \text{Ar}^{1(b)} \), \( \text{Ar}^{1(c)} \), and \( \text{Ar}^{1(d)} \). By "independent substituents," it is meant that each \( \text{Ar}^1 \) can be independently defined. For example, if in one instance \( \text{Ar}^{1(a)} \) is phenyl, then \( \text{Ar}^{1(b)} \) is not necessarily phenyl in that instance. In addition, \( \text{Ar}^1 \) may represent one of the following chemical moieties:

where \( Z \) represents \( \text{O}, \text{S}, \text{NR}, \text{PR}, \text{CRR}', \) or \( \text{Si RR'} \), where \( R \) and \( R' \) each independently represents substituted or unsubstituted \( \text{C}_1-\text{C}_4 \) alkyl, aryl, or heterocyclic aryl.

In some aspects, a portion of a complex of Formula I may be represented by a formula:

which is understood to be equivalent to a formula:

That is, \( \text{Ar}^2 \) may be absent or may represent up to two independent substituents, \( \text{Ar}^{2(a)} \) and \( \text{Ar}^{2(b)} \). By "independent substituents," it is meant that each \( \text{Ar}^2 \) may be independently defined. For example, if in one instance \( \text{Ar}^{2(a)} \) is phenyl, then \( \text{Ar}^{2(b)} \) is not necessarily phenyl in that instance.

In some aspects, a portion of a complex of Formula I may be represented by a formula:
which is understood to be equivalent to a formula:

That is, Ar\(^3\) may be absent, or (Ar\(^3\))\(_n\) may represent up to four independent substituents, Ar\(^3(a)\), Ar\(^3(b)\), Ar\(^3(c)\), and Ar\(^3(d)\), not shown, bonded to Y\(^3b\). By "independent substituents," it is meant that each Ar\(^3\) may be independently defined. For example, if in one instance Ar\(^3(a)\) is phenyl, then Ar\(^3(b)\) is not necessarily phenyl in that instance. In some cases, Ar\(^3\) represents one of the following chemical moieties:

where Z represents O, S, NR, PR, CRR\(^'\), or Si RR\(^'\), where R and R\(^'\) each independently represents substituted or unsubstituted C\(_{1-4}\) alkyl, aryl, or heterocyclic aryl.

In some aspects, a portion of a complex of Formula I may be represented by a formula:

which is understood to be equivalent to a formula:

That is, Ar\(^4\) may be absent, or (Ar\(^4\))\(_n\) may represent up to three independent substituents, Ar\(^4(a)\), Ar\(^4(b)\), Ar\(^4(c)\), and Ar\(^4(d)\), not shown, bonded to Y\(^4a\). By "independent substituents," it is meant that each Ar\(^4\) substituent can be independently defined. For example, if in one instance Ar\(^4(a)\) is phenyl, then Ar\(^4(b)\) is not necessarily phenyl in that instance.
In some aspects, a portion of a complex of Formula I may be represented by a formula:

\[
\text{Ar}^5 \text{may be absent, or (Ar}^5)_n \text{may represent up to four independent substituents, Ar}^{5(a)}, \text{Ar}^{5(b)}, \text{Ar}^{5(c)}, \text{and Ar}^{5(d)}. \text{By "independent substituents," it is meant that each Ar}^5 \text{may be independently defined. For example, if in one instance Ar}^{5(a)} \text{is phenyl, then Ar}^{5(b)} \text{is not necessarily phenyl in that instance.}
\]

In some cases, none of Ar\(^1\), Ar\(^2\), Ar\(^3\), Ar\(^4\), and Ar\(^5\) is present. In some cases, one of Ar\(^1\), Ar\(^2\), Ar\(^3\), Ar\(^4\), and Ar\(^5\) is present. In other cases, two, three, four, or five of Ar\(^1\), Ar\(^2\), Ar\(^3\), Ar\(^4\), and Ar\(^5\) are present in any permutation. In one example, when two of Ar\(^1\), Ar\(^2\), Ar\(^3\), Ar\(^4\), and Ar\(^5\) are present, the two may be Ar\(^1\) and Ar\(^2\); Ar\(^1\) and Ar\(^3\); Ar\(^1\) and Ar\(^4\); Ar\(^1\) and Ar\(^5\); Ar\(^2\) and Ar\(^3\); Ar\(^2\) and Ar\(^4\); Ar\(^1\); Ar\(^2\) and Ar\(^5\); Ar\(^2\) and Ar\(^5\); Ar\(^3\) and Ar\(^4\); Ar\(^3\) and Ar\(^5\); or Ar\(^4\) and Ar\(^5\). In another example, when three of Ar\(^1\), Ar\(^2\), Ar\(^3\), Ar\(^4\), and Ar\(^5\) are present, Ar\(^1\), Ar\(^2\), and Ar\(^3\); Ar\(^1\), Ar\(^2\), and Ar\(^4\); Ar\(^1\), Ar\(^2\), and Ar\(^5\); Ar\(^1\), Ar\(^3\), and Ar\(^4\); Ar\(^1\), Ar\(^3\), and Ar\(^5\); Ar\(^1\), Ar\(^4\), and Ar\(^5\); Ar\(^2\), Ar\(^3\), and Ar\(^4\); Ar\(^2\), Ar\(^3\), and Ar\(^5\); Ar\(^2\), Ar\(^4\), and Ar\(^5\); or Ar\(^3\), Ar\(^4\), and Ar\(^5\) are present. In yet another example, when four of Ar\(^1\), Ar\(^2\), Ar\(^3\), Ar\(^4\), and Ar\(^5\) are present, Ar\(^1\), Ar\(^2\), Ar\(^3\), and Ar\(^4\); Ar\(^1\), Ar\(^3\), Ar\(^4\), and Ar\(^5\); or Ar\(^2\), Ar\(^3\), Ar\(^4\), and Ar\(^5\) are present.

In some cases, Ar\(^1\), Ar\(^2\), Ar\(^3\), Ar\(^4\), and Ar\(^5\) may be one of the following: pyrrolyl, furanyl, thiophenyl, imidazolyl, pyrazolyl, oxazolyl, isooxazolyl, thiazolyl, isothiazolyl, trazolyl,
furazanyl, oxadiazolyl, thiazolyl, dithiazolyl, tetrazolyl, phenyl, pyridinyl, pyranyl, thiopyranyl, diazinyls, oxazinyls, thiazinyls, dioxinyls, dithiinyls, triazinyls, tetrazinyls, pentazinyls, pyrimidyl, pyridazinyl, pyrazinyl, biphenyl, naphthyl, fluorenyl, carbazolyl, phenothiazinyl, acridinyl and dihydroacridinyl.

Examples of complexes having the structure of Formula I provided below, where Z represents O, S, NR, PR, CRR’, or Si RR’, where R and R’ each independently represents substituted or unsubstituted C1-C4 alkyl, aryl, or heterocyclic aryl.
It is to be understood that present compounds/complexes, devices, and/or methods are not limited to specific synthetic methods unless otherwise specified, or to particular reagents unless otherwise specified, as such can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of compounds of the present disclosure, example methods and materials are now described.

Disclosed are the components to be used to prepare the compositions of this disclosure as well as the compositions themselves to be used within the methods disclosed herein. These and other materials are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these materials are disclosed that while specific reference of each various individual and collective combinations and permutation of these compounds cannot be explicitly disclosed, each is specifically contemplated and described herein. For example, if a particular compound is disclosed and discussed and a number of modifications that can be made to a number of molecules including the compounds are discussed, specifically contemplated is each and every combination and permutation of the compound and the modifications that are possible unless specifically indicated to the contrary. Thus, if a class of molecules A, B, and C is disclosed as well as a class of molecules D, E, and F and an example of a combination molecule, A-D is disclosed, then even if each is not individually recited each is individually and collectively contemplated meaning combinations A-E, A-F, B-D, B-E, B-F, C-D, C-E, and C-F are considered disclosed. Likewise, any subset or combination of these is also disclosed. Thus, for example, the sub-group of A-E, B-F, and C-E would be considered disclosed. This concept applies to all aspects of this application including, but not limited to, steps in methods of making and using the compositions disclosed herein. Thus, if there are a variety of additional steps that can be performed it is understood that each of these additional steps can be performed with any specific embodiment or combination of embodiments of the methods described herein.

As referred to herein, a linking atom or group connects two atoms such as, for example, an N atom and a C atom. A linking atom or group is in one aspect disclosed as L1, L2, L3, etc. herein. The linking atom can optionally, if valency permits, have other chemical moieties attached. For example, in one aspect, an oxygen would not have any other chemical groups attached as the valency is satisfied once it is bonded to two groups (e.g., N and/or C groups). In
another aspect, when carbon is the linking atom, two additional chemical moieties can be
attached to the carbon. Suitable chemical moieties include amine, amide, thiol, aryl, heteroaryl,
cycloalkyl, and heterocyclyl moieties. The term "cyclic structure" or the like terms used herein
refer to any cyclic chemical structure which includes, but is not limited to, aryl, heteroaryl,
cycloalkyl, cycloalkenyl, heterocyclyl, carbene, and N-heterocyclic carbene.

As used herein, the term "substituted" is contemplated to include all permissible
substituents of organic compounds. In a broad aspect, the permissible substituents include
acyclic and cyclic, branched and unbranched, carbocyclic and heterocyclic, and aromatic and
nonaromatic substituents of organic compounds. Illustrative substituents include, for example,
those described below. The permissible substituents can be one or more and the same or different
for appropriate organic compounds. For purposes of this disclosure, the heteroatoms, such as
nitrogen, can have hydrogen substituents and/or any permissible substituents of organic
compounds described herein which satisfy the valences of the heteroatoms. This disclosure is not
intended to be limited in any manner by the permissible substituents of organic compounds.

Also, the terms "substitution" or "substituted with" include the implicit proviso that such
substitution is in accordance with permitted valence of the substituted atom and the substituent,
and that the substitution results in a stable compound, e.g., a compound that does not
spontaneously undergo transformation such as by rearrangement, cyclization, elimination, etc. It
is also contemplated that, in certain aspects, unless expressly indicated to the contrary, individual
substituents can be further optionally substituted (i.e., further substituted or unsubstituted).

In defining various terms, "A1", "A2", "A3", "A4" and "A5" are used herein as generic
symbols to represent various specific substituents. These symbols can be any substituent, not
limited to those disclosed herein, and when they are defined to be certain substituents in one
instance, they can, in another instance, be defined as some other substituents.

The term "alkyl" as used herein is a branched or unbranched saturated hydrocarbon group
of 1 to 24 carbon atoms, such as methyl, ethyl, ^-propyl, isopropyl, ^-butyl, isobutyl, s-butyl, t-
butyl, ^-pentyl, isopentyl, s-pentyl, neopentyl, hexyl, heptyl, octyl, nonyl, decyl, dodecyl,
tetradecyl, hexadecyl, eicosyl, tetracosyl, and the like. The alkyl group can be cyclic or acyclic.
The alkyl group can be branched or unbranched. The alkyl group can also be substituted or
unsubstituted. For example, the alkyl group can be substituted with one or more groups
including, but not limited to, alkyl, cycloalkyl, alkoxy, amino, ether, halide, hydroxy, nitro, silyl,
sulfo-oxo, or thiol, as described herein. A "lower alkyl" group is an alkyl group containing from one to six (e.g., from one to four) carbon atoms.

Throughout the specification "alkyl" is generally used to refer to both unsubstituted alkyl groups and substituted alkyl groups; however, substituted alkyl groups are also specifically referred to herein by identifying the specific substituent(s) on the alkyl group. For example, the term "halogenated alkyl" or "haloalkyl" specifically refers to an alkyl group that is substituted with one or more halide, e.g., fluorine, chlorine, bromine, or iodine. The term "alkoxyalkyl" specifically refers to an alkyl group that is substituted with one or more alkoxy groups, as described below. The term "alkylamino" specifically refers to an alkyl group that is substituted with one or more amino groups, as described below, and the like. When "alkyl" is used in one instance and a specific term such as "alkylalcohol" is used in another, it is not meant to imply that the term "alkyl" does not also refer to specific terms such as "alkylalcohol" and the like.

This practice is also used for other groups described herein. That is, while a term such as "cycloalkyl" refers to both unsubstituted and substituted cycloalkyl moieties, the substituted moieties can, in addition, be specifically identified herein; for example, a particular substituted cycloalkyl can be referred to as, e.g., an "alkylcycloalkyl." Similarly, a substituted alkoxy can be specifically referred to as, e.g., a "halogenated alkoxy," a particular substituted alkenyl can be, e.g., an "alkenylalcohol," and the like. Again, the practice of using a general term, such as "cycloalkyl," and a specific term, such as "alkylcycloalkyl," is not meant to imply that the general term does not also include the specific term.

The term "aryl" as used herein is a group that contains any carbon-based aromatic group including, but not limited to, benzene, naphthalene, phenyl, biphenyl, phenoxybenzene, and the like. The term "aryl" also includes "heteroaryl," which is defined as a group that contains an aromatic group that has at least one heteroatom incorporated within the ring of the aromatic group. Examples of heteroatoms include, but are not limited to, nitrogen, oxygen, sulfur, and phosphorus. Likewise, the term "non-heteroaryl," which is also included in the term "aryl," defines a group that contains an aromatic group that does not contain a heteroatom. The aryl group can be substituted or unsubstituted. The aryl group can be substituted with one or more groups including, but not limited to, alkyl, cycloalkyl, alkoxy, alkenyl, cycloalkenyl, alkylnyl, cycloalkynyl, aryl, heteroaryl, aldehyde, amino, carboxylic acid, ester, ether, halide, hydroxy, ketone, azide, nitro, silyl, sulfo-oxo, or thiol as described herein. The term "biaryl" is a specific
type of aryl group and is included in the definition of "aryl." Biaryl refers to two aryl groups that are bound together via a fused ring structure, as in naphthalene, or are attached via one or more carbon-carbon bonds, as in biphenyl.

The term "heterocyclyl," as used herein refers to single and multi-cyclic non-aromatic ring systems and "heteroaryl as used herein refers to single and multi-cyclic aromatic ring systems: in which at least one of the ring members is other than carbon. The terms includes azetidine, dioxane, furan, imidazole, isothiazole, isoxazole, morpholine, oxazole, oxazole, including, 1,2,3-oxadiazole, 1,2,5-oxadiazole and 1,3,4-oxadiazole, piperazine, piperidine, pyrazine, pyrazole, pyridazine, pyridine, pyrimidine, pyrrole, pyrrolidine, tetrahydrofuran, tetrahydropyran, tetrazine, including, 1,2,4,5-tetrazine, tetrazole, including 1,2,3,4-tetrazole and 1,2,4,5-tetrazole, thiadiazole, including, 1,2,3-thiadiazole, 1,2,5-thiadiazole, and 1,3,4-thiadiazole, thiazole, thiophene, triazine, including 1,3,5-triazine and 1,2,4-triazine, triazole, including, 1,2,3-triazole, 1,3,4-triazole, and the like.

"R¹," "R²," "R³," "Rⁿ," where n is an integer, as used herein can, independently, possess one or more of the groups listed above. For example, if R¹ is a straight chain alkyl group, one of the hydrogen atoms of the alkyl group can optionally be substituted with a hydroxyl group, an alkoxy group, an alkyl group, a halide, and the like. Depending upon the groups that are selected, a first group can be incorporated within second group or, alternatively, the first group can be pendant (i.e., attached) to the second group. For example, with the phrase "an alkyl group comprising an amino group," the amino group can be incorporated within the backbone of the alkyl group. Alternatively, the amino group can be attached to the backbone of the alkyl group. The nature of the group(s) that is (are) selected will determine if the first group is embedded or attached to the second group.

Compounds described herein may contain "optionally substituted" moieties. In general, the term "substituted," whether preceded by the term "optionally" or not, means that one or more hydrogens of the designated moiety are replaced with a suitable substituent. Unless otherwise indicated, an "optionally substituted" group may have a suitable substituent at each substitutable position of the group, and when more than one position in any given structure may be substituted with more than one substituent selected from a specified group, the substituent may be either the same or different at every position. Combinations of substituents envisioned by this disclosure are preferably those that result in the formation of stable or chemically feasible compounds. In is
also contemplated that, in certain aspects, unless expressly indicated to the contrary, individual substituents can be further optionally substituted (i.e., further substituted or unsubstituted).

In some aspects, a structure of a compound can be represented by a formula:

\[
\begin{array}{c}
\text{structure 1} \\
\end{array}
\]

which is understood to be equivalent to a formula:

\[
\begin{array}{c}
\text{structure 2} \\
\end{array}
\]

wherein \( n \) is typically an integer of 0 to 5. That is, \( R^n \) is understood to be absent or to represent up to five independent substituents, \( R_{n(A)}, R_{n(B)}, R_{n(C)}, R_{n(D)}, R_{n(E)} \). By "independent substituents," it is meant that each \( R \) substituent can be independently defined. For example, if in one instance \( R_{n(A)} \) is halogen, then \( R_{n(B)} \) is not necessarily halogen in that instance.

Several references to \( R \setminus R^1, R^2, R^3, R^4, R^5, R^6 \), etc. are made in chemical structures and moieties disclosed and described herein. Any description of \( R^1, R^2, R^3, R^4, R^5, R^6 \), etc. in the specification is applicable to any structure or moiety reciting \( R^1, R^2, R^3, R^4, R^5, R^6 \), etc. respectively.

The complexes disclosed herein are suited for use in a wide variety of devices, including, for example, optical and electro-optical devices, including, for example, photo-absorbing devices such as solar- and photo-sensitive devices, organic light emitting diodes (OLEDs), photo-emitting devices, or devices capable of both photo-absorption and emission and as markers for bio-applications.

Also disclosed herein are compositions including one or more complexes disclosed herein. The present disclosure provides light emitting device that include one or more complexes or compositions described herein. The light emitting device can be an OLED (e.g., a phosphorescent OLED device). The present disclosure also provides a photovoltaic device comprising one or more complexes or compositions described herein. Further, the present disclosure also provides a luminescent display device comprising one or more complexes or compositions described herein.

Compounds described herein can be used in a light emitting device such as an OLED. FIG. 1 depicts a cross-sectional view of an OLED 100. OLED 100 includes substrate 102, anode
104, hole-transporting material(s) (HTL) 106, light processing material 108, electron-
transporting material(s) (ETL) 110, and a metal cathode layer 112. Anode 104 is typically a
transparent material, such as indium tin oxide. Light processing material 108 may be an emissive
material (EML) including an emitter and a host.

In various aspects, any of the one or more layers depicted in FIG. 1 may include indium
tin oxide (ITO), poly(3,4-ethylenedioxythiophene) (PEDOT), polystyrene sulfonate (PSS), N,N’-
di-1-naphthyl-N,N-diphenyl- 1,1’-biphenyl-4,4’diamine (NPD), 1,1-bis((di-4-
tolylamino)phenyl)cyclohexane (TAPC), 2,6-Bis(N-carbazolyl)pyridine (mCpy), 2,8-
bis(diphenylphosphoryl)dibenzothiophene (P015), LiF, Al, or a combination thereof.

Light processing material 108 may include one or more complexes of the present
disclosure optionally together with a host material. The host material can be any suitable host
material known in the art. The emission color of an OLED is determined by the emission energy
(optical energy gap) of the light processing material 108, which can be tuned by tuning the
electronic structure of the emitting complexes, the host material, or both. Both the hole-
transporting material in the HTL layer 106 and the electron-transporting material(s) in the ETL
layer 110 may include any suitable hole-transporter known in the art.

Complexes described herein may exhibit phosphorescence. Phosphorescent OLEDs (i.e.,
OLEDs with phosphorescent emitters) typically have higher device efficiencies than other
OLEDs, such as fluorescent OLEDs. Light emitting devices based on electrophosphorescent
emitters are described in more detail in WO2000/070655 to Baldo et al., which is incorporated
herein by this reference for its teaching of OLEDs, and in particular phosphorescent OLEDs.

EXAMPLES

The following examples are put forth so as to provide those of ordinary skill in the art
with a complete disclosure and description of how the complexes, compositions, articles,
devices and/or methods claimed herein are made and evaluated, and are intended to be purely
exemplary and are not intended to be limiting in scope. Efforts have been made to ensure
accuracy with respect to numbers (e.g., amounts, temperature, etc.), but some errors and
deviations should be accounted for. Unless indicated otherwise, parts are parts by weight,
temperature is in °C or is at ambient temperature, and pressure is at or near atmospheric.

Various methods for the preparation method of the complexes described herein are
recited in the examples. These methods are provided to illustrate various methods of preparation, but are not intended to limit any of the methods recited herein. Accordingly, one of skill in the art in possession of this disclosure could readily modify a recited method or utilize a different method to prepare one or more of the complexes described herein. The following aspects are only exemplary and are not intended to be limiting in scope. Temperatures, catalysts, concentrations, reactant compositions, and other process conditions can vary, and one of skill in the art, in possession of this disclosure, could readily select appropriate reactants and conditions for a desired complex.

¾ spectra were recorded at 400 MHz on Varian Liquid-State NMR instruments in CDCh solutions and chemical shifts were referenced to residual protiated solvent. ¾ NMR spectra were recorded with tetramethylsilane (δ = 0.00 ppm) as internal reference. The following abbreviations (or combinations thereof) were used to explain ¾ NMR multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, p = quintet, m = multiplet, br = broad.

Example 1: Synthesis of PtN8ppy

Synthesis of 2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9-(3-(pyridin-2-yl)phenyl)-9H-carbazole (N8ppy)

\begin{center}
\begin{tikzpicture}
\node at (0,0) {\includegraphics[width=0.5\textwidth]{example1}};
\end{tikzpicture}
\end{center}

2-(1-niethyl-1H-benzo[d]imidazol-2-yl)-9H-carbazole (200 mg, 0.67 mmol), 2-(3-bromophenyl)pyridine (173.2 mg, 0.74 mmol), Pd$_2$(dba)$_3$ (31 mg, 0.033 mmol), Johnphos (20.1 mg, 0.067 mmol), and Na(t-BuO) (100 mg, 1 mmol) were placed in a round-bottom three-neck flask under a nitrogen atmosphere, 10 mL of toluene and 10 mL dioxane was added, the mixture was stirred and refluxed for 2 days. After completion of the reaction, the resulting solution was washed with dichloromethane and water. The organic layer was collected, dried with MgSO$_4$ and separated by column, thus obtaining 2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9H-carbazole (N8ppy) (230 mg, 76% yield). $^1$HNMR (DMSO·d$_6$, 500 MHz): δ 8.68 (s, 1H), 8.46 (d, J = 3.4 Hz, 1H), 8.41-8.35 (m, 2H), 8.28 (d, J = 7.8 Hz, 1H), 8.10 (d, J =
8.0 Hz, 1H), 7.90 (t, J = 7.9 Hz, 2H), 7.85-7.73 (m, 3H), 7.65 (brs, 2H), 7.56-7.46 (m, 2H), 7.42-7.35 (m, 2H), 7.27 (t, J = 7.5 Hz, 1H), 7.22 (brs, 1H), 3.93 (s, 3H).

**Synthesis of PtN8ppy**

![Synthesis of PtN8ppy](image)

2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9-(3-(pyridin-2-yl)phenyl)-9H-carbazole (100 mg, 0.22 mmol), potassium tetrachloroplatinate(II) K₂PtCl₄ (101.3 mg, 0.25 mmol), n-butylammonium bromide (32.2 mg, 0.1 mmol) and 2-ethoxyethanol (10 mL) were placed in a round-bottom flask under a nitrogen atmosphere. The mixture was stirred and refluxed for 2 days. After completion of the reaction, the resulting solution was washed with dichloromethane and water. The organic layer was collected, dried with MgSO₄, and purified by column chromatography (ethyl acetate: DCM = 10:1 to 5:1) with A1203, thus obtaining PtN8ppy (90 mg, 63% yield) as a red solid. ¹H NMR (DMSO-d₆, 500 MHz): δ 9.44 (d, J = 5.0 Hz, 1H), 8.33 - 8.24 (m, 3H), 8.19 (t, J = 6.3 Hz, 1H), 8.12 (d, J = 8.1 Hz, 1H), 8.01 (d, J = 7.8 Hz, 1H), 7.96 (d, J = 7.8 Hz, 1H), 7.91 (d, J = 7.3 Hz, 1H), 7.87 (d, J = 7.3 Hz, 1H), 7.78 (d, J = 7.4 Hz, 1H), 7.68 (t, J = 6.4 Hz, 1H), 7.53 (t, J = 7.7 Hz, 1H), 7.48 - 7.37 (m, 3H), 7.31 (t, J = 7.3 Hz, 1H), 4.37 (s, 3H). FIG. 2 shows photoluminescent intensity as a function of wavelength for PtN8ppy.

**Example 2: Synthesis of PtN8ppy-P**

**Synthesis of 6-bromo-2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9-(3-(pyridin-2-yl)phenyl)-9H-carbazole (BrN8ppy)**

![Synthesis of BrN8ppy](image)
N-Bromosuccinimide (36 mg, 0.02 mol) was added to a solution of 2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9-(3-(pyridin-2-yl)phenyl)-9H-carbazole (N8ppy) (90 mg, 0.2 mmol) and silica-gel (100 mg) in methylene chloride (5 mL). The reaction mixture was stirred at room temperature. Before extraction with water and Methylene chloride, the reaction mixture was filtered with Methylene chloride. The mixture of reaction was purified by column chromatography and recrystallization with ethanol (90 mg, 85% yield). 1H NMR (DMSO-d6, 500 MHz): 5 8.7-8.66 (m, 2H), 8.55 (d, J = 8.3 Hz, 1H), 8.39 (s, 1H), 8.31 (d, J = 7.8 Hz, 1H), 8.11 (d, J = 8.3 Hz, 1H), 7.91 (t, J = 7.9 Hz, 1H), 7.85-7.73 (m, 3H), 7.78 (d, J = 7.9 Hz, 1H), 7.69-7.63 (m, 3H), 7.44 (t, J = 8.8 Hz, 1H), 7.39 (t, J = 5.9 Hz, 1H), 7.32 (t, J = 7.5 Hz, 1H), 7.27 (t, J = 7.5 Hz, 1H), 3.95 (s, 3H).

Synthesis of 2-(1-methyl-1H-benzo[d]imidazol-2-yl)-6-phenyl-9-(3-(pyridin-2-yl)phenyl)-9H-carbazole (N8ppy-P)

The benzoboric acid (117 mg, 1 mmol), [Pd2(dba)3] (16 mg, 0.016 mmol), 6-bromo-2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9-(3-(pyridin-2-yl)phenyl)-9H-carbazole (170 mg, 0.032 mmol) and PCy3F4 (11.8 mg, 0.032 mmol) were added to a 25-mL Schlenk flask equipped with a stir bar in air. The flask was evacuated and refilled with argon five times. Dioxane (6 mL) and aqueous K3PO4 (136 mg, 2 mL, 0.64 mmol) were added by syringe. The Schlenk flask was sealed and heated in an oil bath at 100°C for 18 h with vigorous stirring. The mixture was then filtered through a pad of silica gel (washing with EtOAc), the filtrate concentrated under reduced pressure, and the aqueous residue extracted three times with EtOAc. The combined extracts were dried over anhydrous MgSO4, filtered, and concentrated. The residue was then purified by column chromatography on silica gel (140 mg, 83% yield).
Synthesis of PtN8ppy-P

\[ \text{Synthesis of PtN8ppy-P} \]

\[
\begin{align*}
\text{PtN8ppy-P} & \quad \text{K}_2\text{PtCl}_4 \\
\text{HOCH}_2\text{CH}_2\text{OCH}_2\text{CH}_3 & \quad \text{PtN8ppy-P}
\end{align*}
\]

2-(1-methyl-1H-benzo[d]imidazol-2-yl)-6-phenyl-9-(3-(pyridin-2-yl)phenyl)-9H-carbazole (100 mg, 0.19 mmol), potassium tetrachloroplatinate(II) \( \text{K}_2\text{PtCl}_4 \) (86.7 mg, 0.21 mmol), n-butylammonium bromide (32.2 mg, 0.1 mmol) and 2-ethoxyethanol (10 mL) were placed in a round-bottom flask under a nitrogen atmosphere. The mixture was stirred and refluxed for 2 days. After completion of the reaction, the resulting solution was washed with dichloromethane and water. The organic layer was collected, dried with \( \text{MgS}_0_4 \), and purified by column chromatography (ethyl acetate: DCM = 10:1 to 5:1) with \( \text{Al}_2\text{O}_3 \), thus obtaining PtN8ppy-P (85 mg, 62 % yield) as a red solid. \( ^1\text{H} \text{NMR} \) (DMSO-d6, 500 MHz): \( \delta \) 9.43 (d, \( J = 4.9 \text{ Hz} \), 1H), \( \delta \) 8.6 (d, \( J = 1.5 \text{ Hz} \), 1H), 8.36 (d, \( J = 9.3 \text{ Hz} \), 1H), 8.30 (d, \( J = 8.3 \text{ Hz} \), 1H), 8.21-8.1 (m, 3H), 7.98 (d, \( J = 8.2 \text{ Hz} \), 1H), 7.91 (d, \( J = 7.9 \text{ Hz} \), 1H), 7.89-7.82 (m, 4H), 7.78 (d, \( J = 7.8 \text{ Hz} \), 1H), 7.68 (t, \( J = 6.1 \text{ Hz} \), 1H), 7.53 (t, \( J = 7.8 \text{ Hz} \), 2H), 7.48-7.37 (m, 4H), 4.37 (s, 3H).

FIG. 3 shows photoluminescent intensity of PtN8ppy-P at room temperature and 77K.

Example 3: Synthesis of PtN8N-ben

\[ \text{Synthesis of 5-((1-methyl-1H-benzo[d]imidazol-2-yl)-7-(9-(pyridin-2-yl)-9H-carbazol-2-yl)-7H-benzo[c]carbazole (N8N-ben)} \]

\[
\begin{align*}
\text{N} & \quad \text{N} \\
\text{NH} & \quad \text{Br}
\end{align*}
\]

5% \( \text{Pd}_3\text{(dba)}_3 \)
10% \( \text{Johnphos} \)
1.5 \( \text{BuONa} \)
Toluene 95-105°C, 2d
5-(1-methyl-1H-benzo[d]imidazol-2-yl)-7H-benzo[c]carbazole (300 mg, 0.86 mmol), 2-bromo-9-(pyridin-2-yl)-9H-carbazole (418 mg, 1.30 mmol), Pd2(dba)3 (39 mg, 0.043 mmol), Johnphos (26 mg, 0.086 mmol), and Na(t-BuO) (124 mg, 1.29 mmol) were placed in a round-bottom three-neck flask under a nitrogen atmosphere, 10 mL of toluene was added, the mixture was stirred and refluxed for 2 days. After completion of the reaction, the resulting solution was washed with dichloromethane and water. The organic layer was collected, dried with MgSO₄, and separated by column, thus obtaining 5-(1-methyl-1H-benzo[d]imidazol-2-yl)-7-(9-(pyridin-2-yl)-9H-carbazol-2-yl)-7H-benzo[c]carbazole (N8N-ben) (355 mg, 70% yield). 1H NMR (DMSO-d6, 500 Hz) δ 9.06 (d, J = 8.3 Hz, 1H), 8.85 (d, J = 7.9 Hz, 1H), 8.65 (d, J = 3.7 Hz, 1H), 8.56 (d, J = 8.2 Hz, 1H), 8.37 (d, J = 7.8 Hz, 1H), 8.10 (s, 1H), 8.07 (t, J = 7.9 Hz, 1H), 7.90 - 7.81 (m, 5H), 7.71 (d, J = 7.8 Hz, 1H), 7.65 (dd, J = 8.1, 1.7 Hz, 1H), 7.62-7.57 (m, 2H), 7.57-7.47 (m, 4H), 7.46 - 7.38 (m, 2H), 7.29 (dt, J = 24.2, 7.6 Hz, 2H), 3.57 (s, 3H).

Synthesis of PtN8N-ben

5-(1-methyl-1H-benzo[d]imidazol-2-yl)-7-(9-(pyridin-2-yl)-9H-carbazol-2-yl)-7H-benzo[c]carbazole (100 mg, 0.17 mmol), potassium tetrachloroplatinate(II) K₂PtCl₄ (84 mg, 0.20 mmol), n-butylammonium bromide (5 mg, 0.017 mmol) and 2-ethoxyethanol (10 mL) were placed in a round-bottom flask under a nitrogen atmosphere. The mixture was stirred and refluxed for 3 days. After completion of the reaction, the resulting solution was washed with dichloromethane and water. The organic layer was collected, dried with MgSO₄, and purified by column with Al₂O₃, thus obtaining PtN8N-ben as a red solid.
Example 4: Synthesis of PtN8N'

Synthesis of 9,10-dihydro-9,9-dimethyl-3-(2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9H-carbazol-9-yl)-10-(pyridin-2-yl)acridine (N8N)

2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9H-carbazole (200 mg, 0.67 mmol), 3-bromo-9,10-dihydro-9,9-dimethyl-10-(pyridin-2-yl)acridine (269.5 mg, 0.74 mmol), Pd2(dba)3 (31 mg, 0.033 mmol), Johnphos (20 mg, 0.067 mmol), and Na(t-BuO) (100 mg, 1 mmol) were placed in a round-bottom three-neck flask under a nitrogen atmosphere, 20 mL of toluene was added, the mixture was stirred and refluxed for 2 days. After completion of the reaction, the resulting solution was washed with dichloromethane and water. The organic layer was collected, dried with MgSO4, and separated by column, thus obtaining 9,10-dihydro-9,9-dimethyl-3-(2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9H-carbazol-9-yl)-10-(pyridin-2-yl)acridine (N8N') (280 mg, 72% yield).

Synthesis of PtN8N'

9,10-dihydro-9,9-dimethyl-3-(2-(1-methyl-1H-benzo[d]imidazol-2-yl)-9H-carbazol-9-yl)-10-(pyridin-2-yl)acridine (200 mg, 0.34 mmol), potassium tetrachloroplatinate(II) K2PtCl4 (157 mg, 0.38 mmol), water (3 mL) and 2-ethoxyethanol (12 mL) were placed in a round-bottom flask under a nitrogen atmosphere. The mixture was stirred and refluxed for 3 days. After completion
of the reaction, the resulting solution was washed with dichloromethane and water. The organic layer was collected, dried with MgSO$_4$, and purified by column with Al$_2$O$_3$, thus obtaining PtN$_8$N'.

$^1$H NMR (DMSO-$d_6$, 500 Hz) δ 8.99 (d, J = 4.2 Hz, 1H), 8.22 (d, J = 7.6 Hz, 1H), 8.15 (d, J = 8.5 Hz, 1H), 8.05 (t, J = 7.8, 1H), 7.91 (dd, J = 32.9, 8.1 Hz, 2H), 7.83 (t, J = 7.9 Hz, 2H), 7.58 (d, J = 6.9 Hz, 1H), 7.49 (t, J = 8.0 Hz, 1H), 7.39 (d, J = 8.7 Hz, 1H), 7.36 (t, J = 8.0 Hz, 1H), 7.32 - 7.14 (m, 8H), 4.34 (s, 3H), 1.34 (s, 3H).

A number of embodiments have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. Accordingly, other embodiments are within the scope of the following claims.
WHAT IS CLAIMED IS:

1. A complex represented by Formula I:

   \[ \text{Formula I} \]

   wherein:
   - each \( A_{r1}, A_{r2}, A_{r3}, A_{r4}, \) and \( A_{r5} \) present independently represents a substituted or unsubstituted aryl or heterocyclic aryl;
   - each \( n \) is independently an integer of 0 to 4, as limited by valence;
   - \( X \) represents O, S, NR\(^{a}\), SiR\(^{b}\)R\(^{c}\), or CR\(^{d}\)R\(^{e}\), where each of \( R^{a}, R^{b}, R^{c}, R^{d}, \) and \( R^{e} \) independently represents substituted or unsubstituted C1-C4 alkyl;
   - \( Y^{1a}, Y^{2a}, Y^{3b}, \) and \( Y^{4a} \) each independently represents N or C;
   - \( Y^{3a} \) represents N, CR\(^{2a}\), or SiR\(^{3b}\), where \( R^{2a} \) and \( R^{3b} \) represent hydrogen or substituted or unsubstituted C1-C4 alkyl, aryl, or heterocyclic aryl;
   - \( Y^{5a} \) and \( Y^{5b} \) each independently represents C or N; and
   - \( Y^{5c}, Y^{5d}, \) and \( Y^{5e} \) each independently represents C, N, O, or S.

2. The complex of claim 1, wherein at least one of \( A_{r1}, A_{r2}, A_{r3}, A_{r4}, \) and \( A_{r5} \) is present.

3. The complex of claim 2, wherein one of \( A_{r1}, A_{r2}, A_{r3}, A_{r4}, \) and \( A_{r5} \) is present.

4. The complex of claim 2, wherein two of \( A_{r1}, A_{r2}, A_{r3}, A_{r4}, \) and \( A_{r5} \) are present.
5. The complex of claim 4, wherein Ar1 and Ar2; Ar1 and Ar3; Ar1 and Ar4; Ar1 and Ar5; Ar2 and Ar3; Ar2 and Ar4; Ar2 and Ar5; Ar3 and Ar4; Ar3 and Ar5; or Ar4 and Ar5 are present.

6. The complex of claim 2, wherein three of Ar1, Ar2, Ar3, Ar4, and Ar5 are present.

7. The complex of claim 6, wherein Ar1, Ar2, and Ar3; Ar1, Ar2, and Ar4; Ar1, Ar2, and Ar5; Ar1, Ar3, and Ar4; Ar1, Ar3, and Ar5; Ar1, Ar4, and Ar5; Ar2, Ar3, and Ar4; Ar2, Ar3, and Ar5; Ar2, Ar4, and Ar5; or Ar3, Ar4, and Ar5 are present.

8. The complex of claim 2, wherein four of Ar1, Ar2, Ar3, Ar4, and Ar5 are present.

9. The complex of claim 8, wherein Ar1, Ar2, Ar3, and Ar4; Ar1, Ar2, Ar3, and Ar5; Ar1, Ar2, Ar4, and Ar5; Ar1, Ar3, Ar4, and Ar5; or Ar2, Ar3, Ar4, and Ar5 are present.

10. The complex of claim 1, wherein each Ar1, Ar2, Ar3, Ar4, and Ar5 present independently represents pyrrolyl, furanyl, thiophenyl, imidazolyl, pyrazolyl, oxazolyl, isooxazolyl, thiazolyl, isothiazolyl, trazolyl, furazanyl, oxadiazolyl, thidiazolyl, dithiazolyl, tetrazolyl, phenyl, pyridinyl, pyranyl, thiopyranyl, diazinyls, oxazinyls, thiazylnyls, dioxinyls, dithiinyls, triazinyls, tetrazinyls, pentazinyls, pyrimidyl, pyridazinyl, pyrazinyl, biphenyl, naphthyl, fluorenyl, carbazolyl, phenothiazinyl, acridinyl, and dihydroacridinyl.

11. The complex of claim 1, wherein the complex is selected from one of the following structures, where Z represents O, S, NR, PR, CRR', or Si RR', where R and R' each independently represents substituted or unsubstituted C1-C4 alkyl, aryl, or heterocyclic aryl:
12. The complex of claim 1, wherein the complex has the following structure:

13. The complex of claim 1, wherein the complex has the following structure:

14. The complex of claim 1, wherein the complex has the following structure:
15. The complex of claim 1, wherein the complex has the following structure:

16. A light emitting device comprising the complex of claim 1.

17. A light emitting device comprising a complex of claim 16.
A. CLASSIFICATION OF SUBJECT MATTER
C07F 15/00(2006.01)i, C09K 11/06(2006.01)i, H01L 51/00(2006.01)i

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

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
C07F 15/00; H01L 51/00; H01L 51/52; H01L 51/50; C09K 11/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal), STN(Registry, Caplus), Google & keywords: platinum complex, benzimidazole, carbazole, emitter, narrow band, red, phosphorescent

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>11, 12, 14</td>
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<td>US 2015-0105556 (LI, J. et al.) 16 April 2015 See claims 1-12, 22; and claim as 1, 11.</td>
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<td>US 2015-0008419 (LI, J.) 08 January 2015 See paragraphs [0074]-[0083]; and claims 14, 15.</td>
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<td>A</td>
<td>WO 2012-162488 (ARIZONA BOARD OF REGENTS ACTING FOR AND ON BEHALF OF ARIZONA STATE UNIVERSITY) 29 November 2012 See the whole document.</td>
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</tr>
<tr>
<td>A</td>
<td>WO 2012-116231 A2 (UNIVERSAL DISPLAY CORPORATION) 30 August 2012 See the whole document.</td>
<td>1-17</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search
12 February 2018 (12.02.2018)

Date of mailing of the international search report
13 February 2018 (13.02.2018)

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<td>CN 104693243 A</td>
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<td>27/04/2015</td>
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<td>KR 10-2015-0043225 A</td>
<td>22/04/2015</td>
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<td>US 2017-012224 Al</td>
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<td>US 9385329 B2</td>
<td>05/07/2016</td>
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<td>07/01/2015</td>
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<td>US 9318725 B2</td>
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<td>WO 2013-130483 Al</td>
<td>06/09/2013</td>
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<td>WO 2012-162488 Al</td>
<td>29/11/2012</td>
<td>TW 201307365 A</td>
<td>16/02/2013</td>
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<td>TW 201710277 A</td>
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<td>TW 1551606 B</td>
<td>01/10/2016</td>
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<td>US 2012-0302753 Al</td>
<td>29/11/2012</td>
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<td>JP 2014-507444 A</td>
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