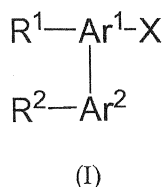


WE CLAIM:

1. A phosphine ligand, said ligand having a structure corresponding to formula (I),



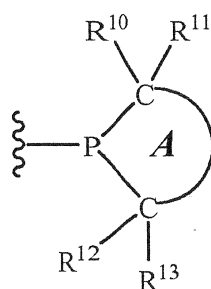
or a salt thereof,

wherein

Ar^1 and Ar^2 are each independently aryl or heteroaryl, and wherein Ar^1 and Ar^2 are each independently optionally substituted with one or more R^1 and R^2 , respectively;

R^1 and R^2 are independently selected at each occurrence from the group consisting of hydrogen; amino; hydroxyl; cyano; halo; alkyl; alkenyl; alkynyl; haloalkyl; haloalkoxy; oxoalkyl; alkoxy; aryloxy; heteroaryloxy; arylamino; heteroarylamino; alkylamino; dialkylamino; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; cycloalkyloxy optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; 5- or 6-membered heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; hydroxyalkoxy; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; $\text{L}^1-\text{C}(\text{O})-\text{OR}^{1'}$, $\text{L}^1-\text{P}(\text{O})-(\text{OR}^{1'})_2$, or $\text{L}^1-\text{S}(\text{O})_2-\text{OR}^{1'}$, wherein L^1 is a bond or alkylene, and $\text{R}^{1'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $\text{L}^2-\text{O}-\text{C}(\text{O})-\text{R}^{2'}$, wherein L^2 is a bond or alkylene, and $\text{R}^{2'}$ is alkyl or hydroxyalkyl; $\text{L}^3-\text{C}(\text{O})-\text{NR}^{3'}\text{R}^{4'}$, wherein L^3 is a bond or alkylene, and $\text{R}^{3'}$ and $\text{R}^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $\text{L}^4-\text{NR}^{5'}-\text{C}(\text{O})-\text{R}^{6'}$, wherein L^4 is a bond or alkylene, $\text{R}^{5'}$ is hydrogen or alkyl, and $\text{R}^{6'}$ is alkyl or hydroxyalkyl; sulfamoyl; *N*-(alkyl)sulfamoyl; *N,N*-(dialkyl)sulfamoyl; sulfonamide; sulfate; alkylthio; thioalkyl; and a ring containing an alkylene or $-\text{O}-(\text{CH}_2)_m-\text{O}-$ formed by the joining together of any two R^1 or any two R^2 or an R^1 and an R^2 , wherein m is 1, 2, 3 or 4;

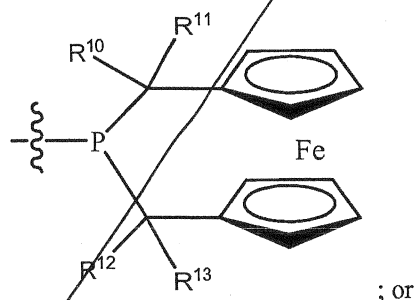
X is a phosphine of formula (Ia):



(Ia)

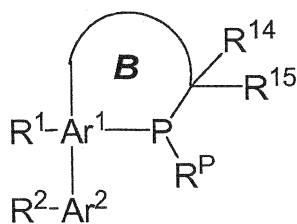
wherein ring **A** is a monocyclic heterocyclic ring, bicyclic heterocyclic ring, or tricyclic heterocyclic ring, and wherein ring **A** includes 0 to 9 ring atoms in addition to the phosphorus and 2 carbon ring atoms of formula (Ia), wherein said ring atoms are each independently selected from the group consisting of carbon, oxygen, nitrogen, phosphorus and sulfur; or

X is a phosphine of formula (Ib):



(Ib)

X is a phosphine fused to Ar¹ to give a compound of formula (Ic):



(Ic)

wherein, ring **B** is a phosphorus heterocyclic ring with 0 to 5 ring atoms in addition to the phosphorus and carbon ring atoms of formula (I-c), wherein said ring atoms are each independently selected from the group consisting of carbon, oxygen, nitrogen, phosphorus and sulfur, and

wherein the ring atoms of ring *A* and ring *B* are each independently optionally substituted with one or more substituents selected from the group consisting of alkenyl; alkoxy; alkoxyalkyl; alkyl; alkylamino; alkylthio; alkynyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; arylalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; dialkylamino; halo; haloalkyl; fluoroalkyl; C_{5,6} heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxy; hydroxyalkyl; oxo; an exocyclic double bond optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; a 3- to 7-membered spiro ring containing zero, one, or two heteroatoms; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; L¹-C(O)-OR^{1'}, L¹-P(O)-(OR^{1'})₂, or L¹-S(O)₂-OR^{1'}, wherein L¹ is a bond or alkylene, and R^{1'} is selected from the group consisting of hydrogen, alkyl or hydroxyalkyl; L²-O-C(O)-R^{2'}, wherein L² is a bond or alkylene, and R^{2'} is alkyl or hydroxyalkyl; L³-C(O)-NR^{3'}R^{4'}, wherein L³ is a bond or alkylene, and R^{3'} and R^{4'} are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; L⁴-NR^{5'}-C(O)-R^{6'}, wherein L⁴ is a bond or alkylene, R^{5'} is hydrogen or alkyl, and R^{6'} is alkyl or hydroxyalkyl; and L⁷-NR^{8'}-S(O)₂-R^{9'}, wherein L⁷ is a bond or alkylene, R^{8'} is hydrogen or alkyl, and R^{9'} is alkyl or hydroxyalkyl;

R^P is selected from the group consisting of alkyl, alkenyl, alkynyl, cycloalkyl, aryl, and heteroaryl, wherein R^P is optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; or R^P is a bridging group between the phosphorus and another *B* ring atom, wherein R^P is selected from the group consisting of alkylene, alkenylene, alkynylene, and -(CR⁴¹R⁴²-O)_q-, wherein R⁴¹ and R⁴² are each independently hydrogen or alkyl, and wherein q is 1 or 2, and wherein R^P is optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy;

as to R¹⁰, R¹¹, R¹², and R¹³,

- i. R¹⁰ or R¹¹ together with R¹² or R¹³ form a ring; or
- ii. R¹⁰ and R¹¹ together with the carbon atom to which they are attached form a spirocyclic ring and/or R¹² and R¹³ together with the carbon atom to which they are attached form a spirocyclic ring; or
- iii. one or more of R¹⁰, R¹¹, R¹² and R¹³ form a ring together with a ring substituent of ring *A*; wherein, if any of substituents R¹⁰, R¹¹, R¹², and R¹³ do not form a ring,

said substituents are each independently selected from the group consisting of hydrogen; alkyl; alkenyl; haloalkyl; alkynyl; oxoalkyl; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocyclyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; C₅₋₆ heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; thioalkyl; L¹³-C(O)-OR^{14'}, L¹³-P(O)-(OR^{14'})₂, or L¹³-S(O)₂-OR^{14'}, wherein L¹³ is a bond or alkylene, and R^{14'} is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; L¹⁵-O-C(O)-R^{16'}, wherein L¹⁵ is alkylene and R^{16'} is alkyl or hydroxyalkyl; L¹⁷-C(O)-NR^{18'}R^{19'}, wherein L¹⁷ is a bond or alkylene, and R^{18'} and R^{19'} are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; and L²⁰-NR^{21'}-C(O)-R^{22'}, wherein L²⁰ is alkylene, R^{21'} is hydrogen or alkyl, and R^{22'} is alkyl or hydroxyalkyl; and

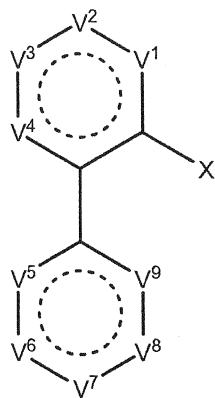
as to R¹⁴ and R¹⁵,

R¹⁴ and R¹⁵ together with the carbon atom to which they are attached form a spirocyclic ring; or

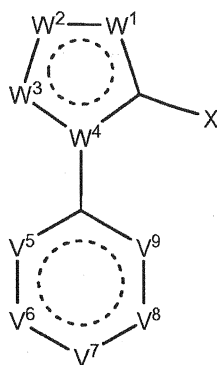
one or more of R¹⁴ and R¹⁵ form a ring together with a ring atom or ring substituent of ring *B*,

wherein, if any of substituents R¹⁴ and R¹⁵ do not form a ring, said substituents are each independently selected from the group consisting of hydrogen; alkyl; alkenyl; haloalkyl; alkynyl; oxoalkyl; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; heterocyclyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; C₅₋₆ heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; thioalkyl; L¹³-C(O)-OR^{14'}, L¹³-P(O)-(OR^{14'})₂, or L¹³-S(O)₂-OR^{14'} wherein L¹³ is a bond or alkylene, and R^{14'} is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; L¹⁵-O-C(O)-R^{16'} wherein L¹⁵ is alkylene, and R^{16'} is alkyl or hydroxyalkyl; L¹⁷-C(O)-NR^{18'}R^{19'}, wherein L¹⁷ is a bond or alkylene and R^{18'} and R^{19'} are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; and L²⁰-NR^{21'}-C(O)-R^{22'}, wherein L²⁰ is alkylene, R^{21'} is hydrogen or alkyl, and R^{22'} is alkyl or hydroxyalkyl.

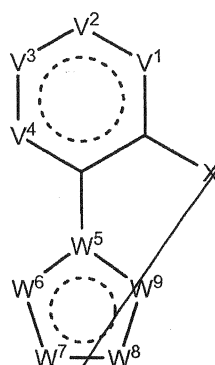
2. The phosphine ligand according to claim 1, said ligand having a structure corresponding to a structure of a formula selected from the group consisting of formulae (I-1) - (I-42), or a salt thereof:



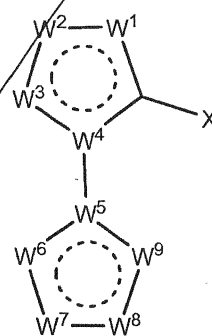
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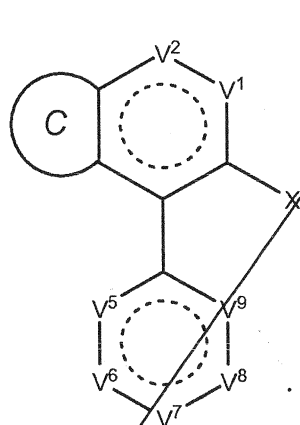
(I-2)



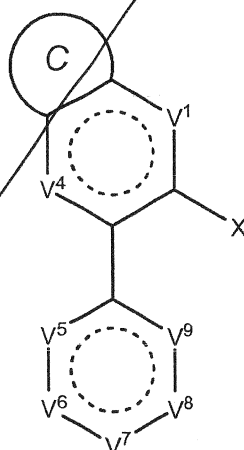
(I-3)



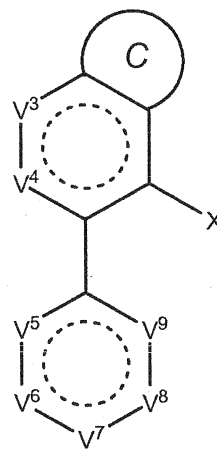
(I-4)



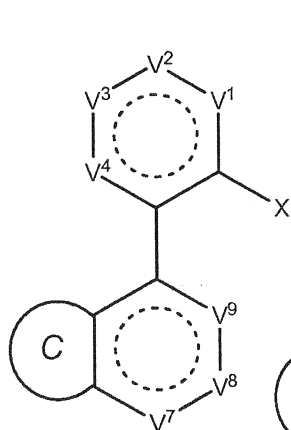
(I-5)



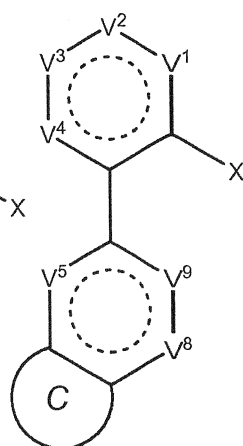
(I-6)



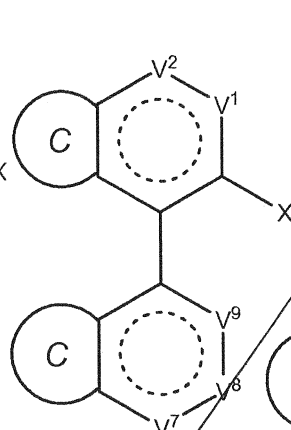
(I-7)



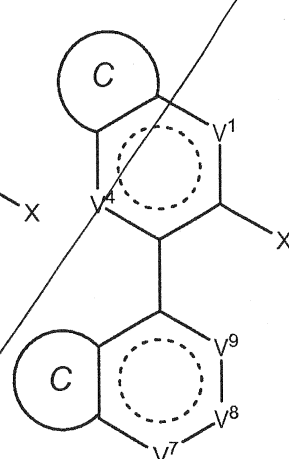
(I-8)



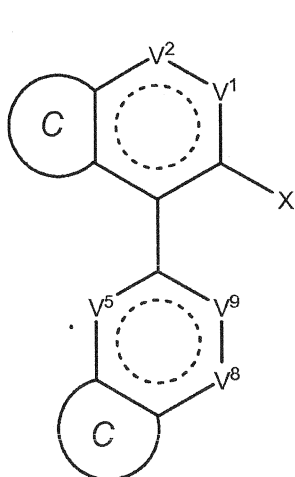
(I-9)



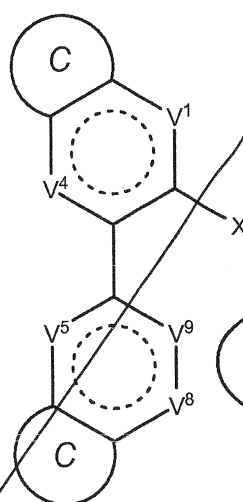
(I-10)



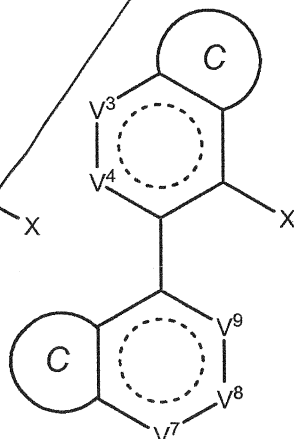
(I-11)



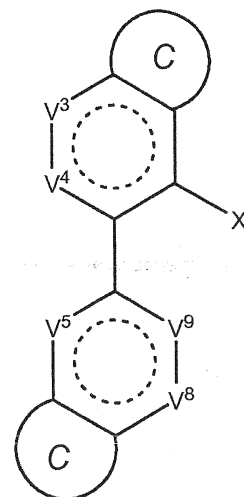
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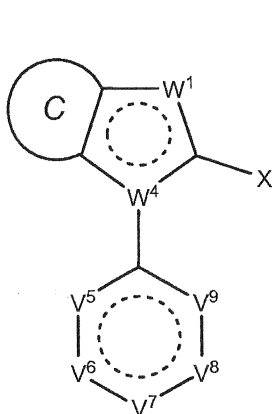
(I-13)



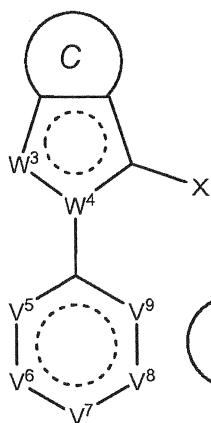
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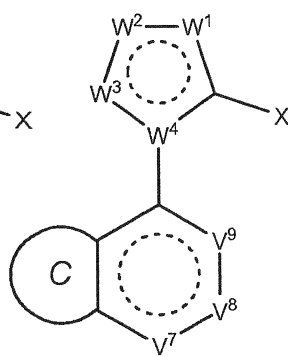
(I-15)



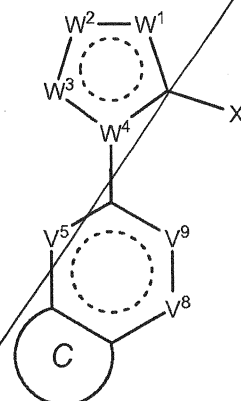
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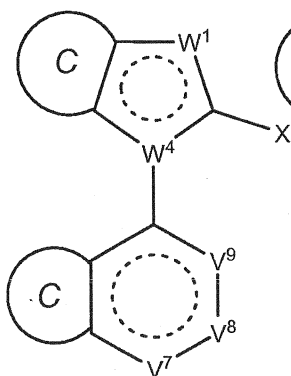
(I-17)



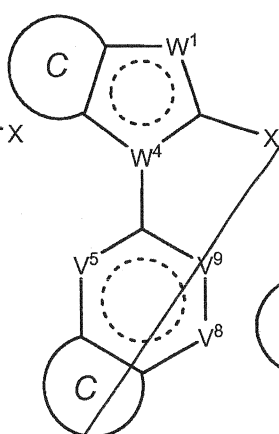
(I-18)



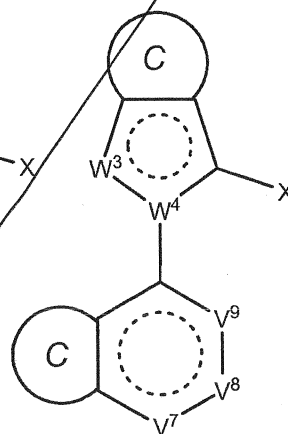
(I-19)



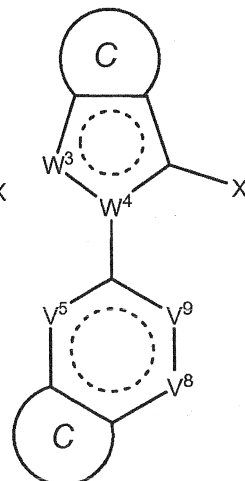
(I-20)



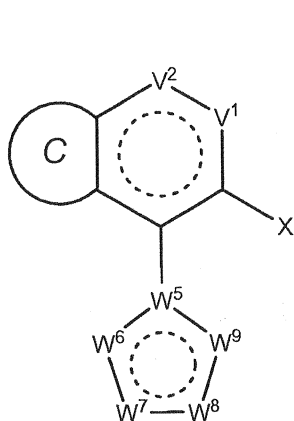
(I-21)



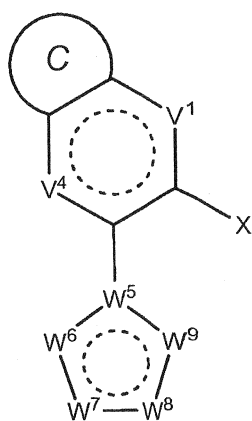
(I-22)



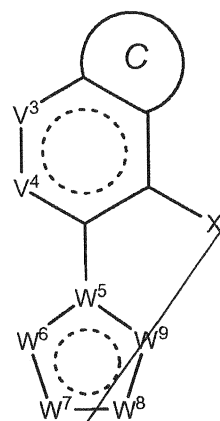
(I-23)



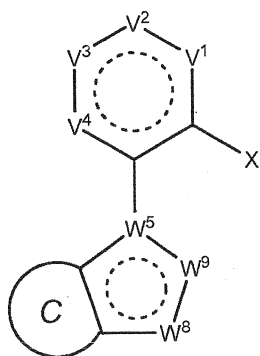
(I-24)



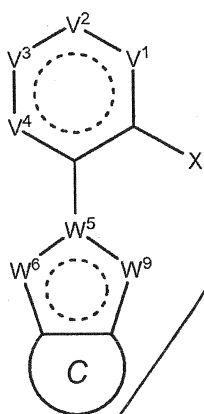
(I-25)



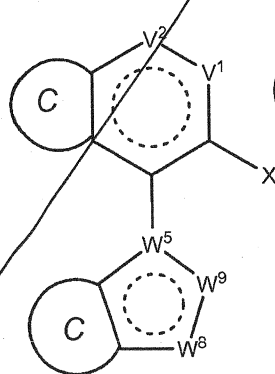
(I-26)



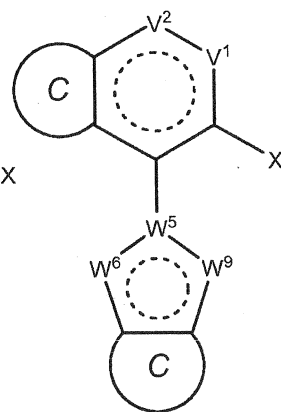
(I-27)



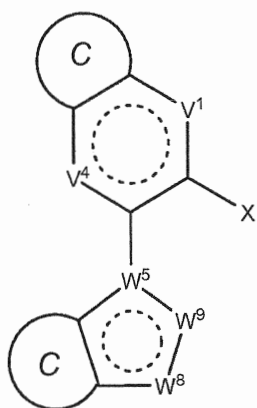
(I-28)



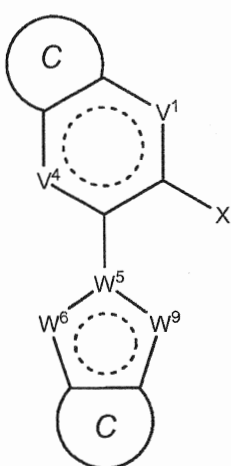
(I-29)



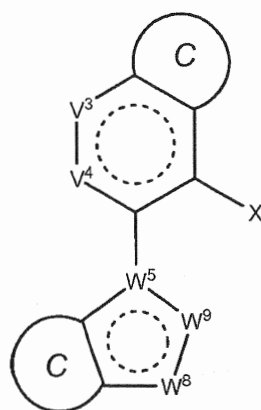
(I-30)



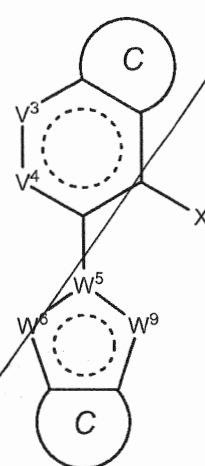
(I-31)



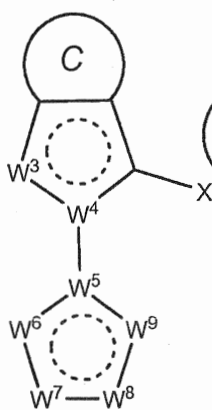
(I-32)



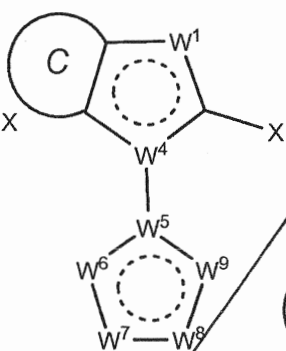
(I-33)



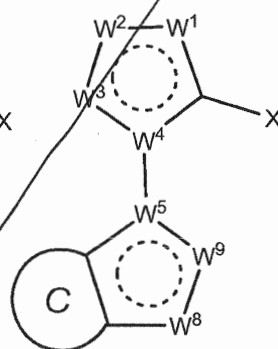
(I-34)



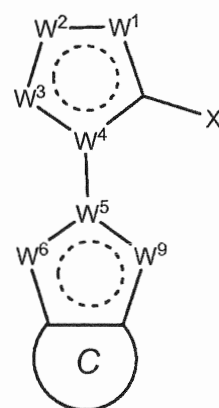
(I-35)



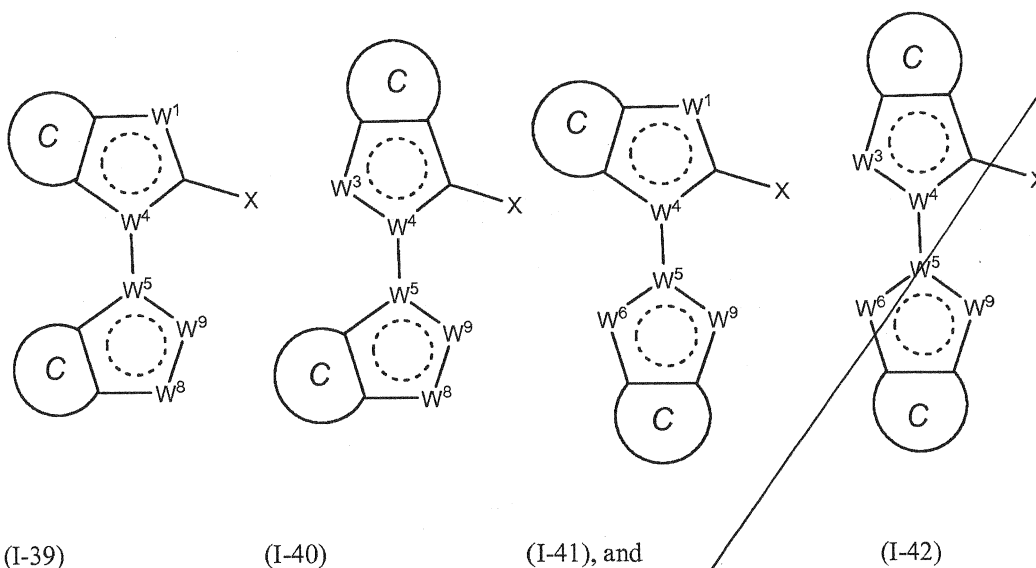
(I-36)



(I-37)



(I-38)



wherein

X is a phosphine of formula (Ia) or (Ib);

V^1 , V^2 , V^3 , and V^4 are each independently CR^1 or N;

V^5 , V^6 , V^7 , V^8 and V^9 are each independently CR^2 or N;

W^1 , W^2 , and W^3 are each independently selected from the group consisting of CR^1 , NR^1 , N and O;

W^4 is C or N;

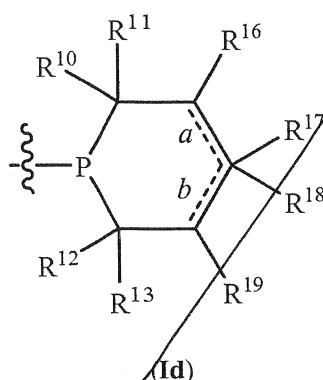
W^5 is C or N;

W^6 , W^7 , W^8 and W^9 are each independently selected from the group consisting of CR^2 , NR^2 , N and O; and

ring C, at each occurrence, is a fused-aryl or fused-heteroaryl and is optionally substituted with R^1 and R^2 .

3 The compound according to claim 1 or claim 2, wherein ring A is a 4-, 5-, 6-, 7-, or 8-membered ring, and wherein each of the ring atoms in addition to the phosphorus and 2 carbon ring atoms of formula (Ia) are carbon.

4. The compound according to claim 1, wherein ring *A* of formula (Ia) is bicyclic.
5. The compound according to claim 1, wherein ring *A* of formula (Ia) is tricyclic.
6. The compound according to claim 1 or claim 2, wherein X is a phosphine of formula (Id), or a salt thereof:



wherein

one or more of R^{16} , R^{17} , R^{18} , and R^{19} optionally form a ring with R^{10} , R^{11} , R^{12} , or R^{13} ;

or

R^{17} together with R^{18} optionally form a carbonyl; an exocyclic double bond optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; or a 3- to 7-membered spiro ring containing zero, one, or two heteroatoms, optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; or

R^{16} and R^{19} are each independently selected from the group consisting of hydrogen, halo, alkyl, haloalkyl, fluoroalkyl, alkenyl, and alkoxy; or

R^{17} and R^{18} are each independently selected from the group consisting of hydrogen; halo; fluoro; alkyl; alkenyl; alkynyl; haloalkyl; fluoroalkyl; alkyloxy; *N*-alkylamino; *N,N*-dialkylamino; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; C_{5-6} heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy, phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or

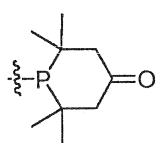
haloalkoxy; arylalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; $L^1-C(O)-OR^{1'}$, $L^1-P(O)-(OR^{1'})_2$, or $L^1-S(O)_2-OR^{1'}$, wherein L^1 is a bond or alkylene, and $R^{1'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^2-O-C(O)-R^{2'}$, wherein L^2 is a bond or alkylene, and $R^{2'}$ is alkyl or hydroxyalkyl; $L^3-C(O)-NR^{3'}R^{4'}$, wherein L^3 is a bond or alkylene, $R^{3'}$ and $R^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $L^4-NR^{5'}-C(O)-R^{6'}$, wherein L^4 is a bond or alkylene, and $R^{5'}$ is hydrogen or alkyl, $R^{6'}$ is alkyl or hydroxyalkyl; and alkylthio; and

at least one of bonds *a* and *b* in formula (Id) is a single bond and one of bonds *a* or *b* is optionally a double bond.

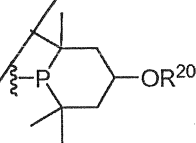
7. The compound according to claim 6, wherein R^{16} and R^{19} are hydrogen.

8. The compound according to claim 6, wherein R^{17} and R^{18} together with the carbon atom to which they are attached form a 3-, 4-, 5-, 6-, or 7-membered spirocyclic ring containing 0, 1, or 2 ring heteroatoms.

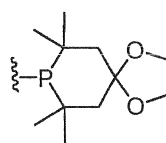
9. The compound according to claim 6, wherein X is a phosphine having a structure corresponding to a formula selected from the group consisting of:



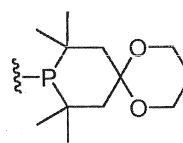
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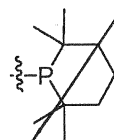
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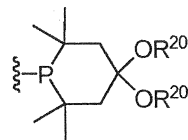
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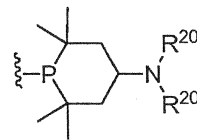
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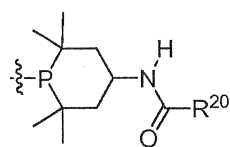
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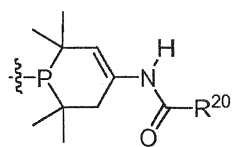
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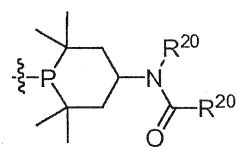
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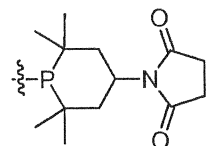
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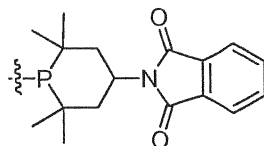
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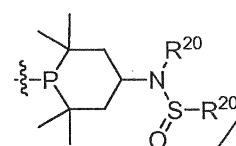
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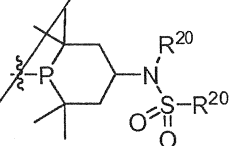
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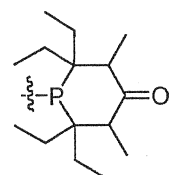
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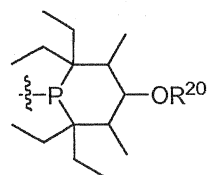
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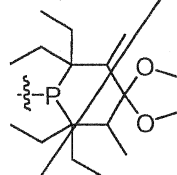
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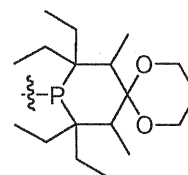
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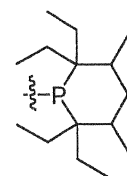
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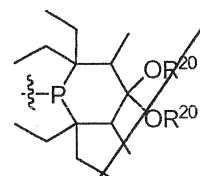
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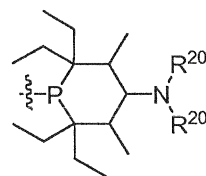
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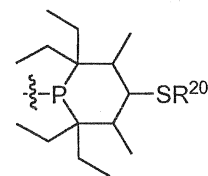
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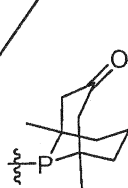
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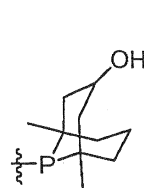
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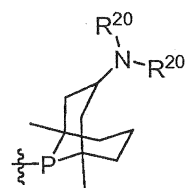
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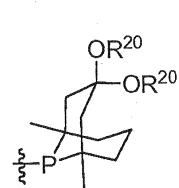
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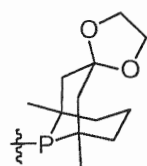
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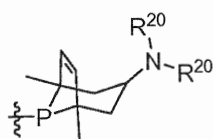
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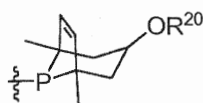
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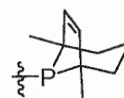
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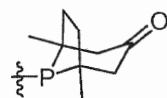
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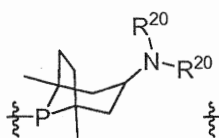
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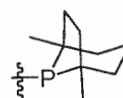
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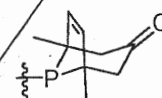
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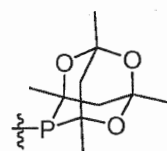
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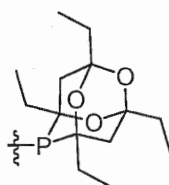
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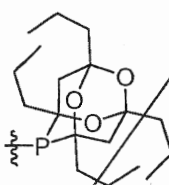
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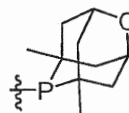
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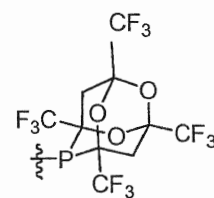
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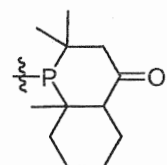
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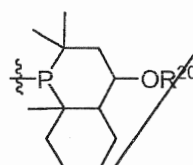
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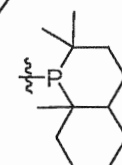
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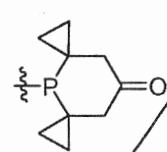
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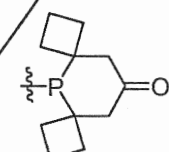
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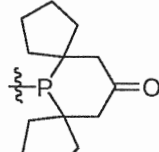
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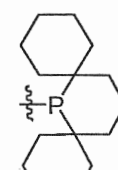
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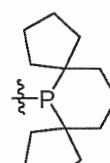
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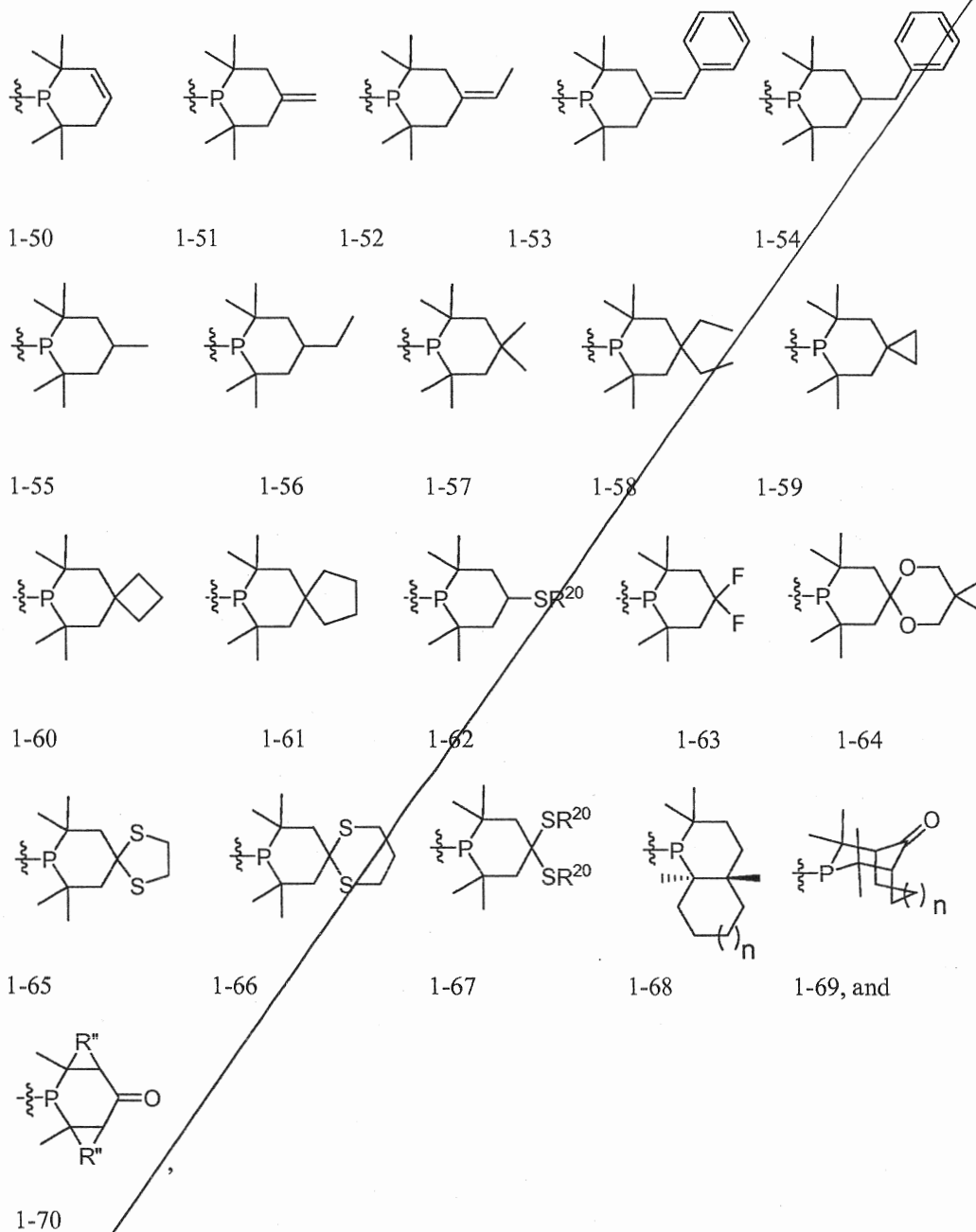
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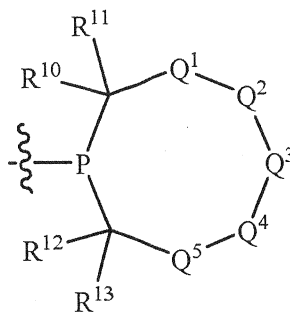


or a salt thereof, wherein R'' is selected from the group consisting of oxygen, NR^{20} , and $C(R^{20})_2$,

R^{20} is hydrogen, alkyl, aryl, heteroaryl, arylalkyl or heteroarylalkyl, wherein the aryl, heteroaryl, aryl of arylalkyl and heteroaryl of heteroarylalkyl are optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; and

n is 0, 1, or 2.

10. The compound according to claim 1 or claim 2, wherein X is a phosphine of formula (Ie), or a salt thereof,



(Ie)

wherein

Q^1 is selected from the group consisting of a bond, $-O-$, $-S-$, $-N(R^{21})-$, $=C(R^{22})-$, and $-C(R^{23})(R^{24})-$;

Q^2 is selected from the group consisting of a bond, $-O-$, $-S-$, $-N(R^{25})-$, $=C(R^{26})-$, and $-C(R^{27})(R^{28})-$;

Q^3 is selected from the group consisting of a bond, $-O-$, $-S-$, $-N(R^{29})-$, $=C(R^{30})-$, and $-C(R^{32})(R^{30})-$;

Q^4 is selected from the group consisting of a bond, $-O-$, $-S-$, $-N(R^{33})-$, $=C(R^{34})-$, and $-C(R^{35})(R^{36})-$;

Q^5 is selected from the group consisting of a bond, $-O-$, $-S-$, $-N(R^{37})-$, $=C(R^{38})-$, and $-C(R^{39})(R^{40})-$; and at least one of Q^1 , Q^2 , Q^3 , Q^4 , and Q^5 is not a bond; or

two of Q^1 , Q^2 , Q^3 , Q^4 , or Q^5 together form a carbonyl; an exocyclic double bond optionally substituted with alkyl, alkenyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; or a 3-8-membered spiro ring containing zero, one, or two hetero ring atoms, optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy;

R^{21} – R^{40} are, at each occurrence, independently selected from the group consisting of hydrogen, halo, fluoro, alkyl, haloalkyl, fluoroalkyl, alkenyl, alkynyl, alkyloxy, *N*-alkylamino, *N,N*-dialkylamino, *N,N,N*-trialkylammoniumalkyl; substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted C_{5-6} heteroaryl, substituted or unsubstituted phenyl;

hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl;

$L^1-C(O)-OR^{1'}$, $L^1-P(O)-(OR^{1'})_2$, or $L^1-S(O)_2-OR^{1'}$ where $R^{1'}$ is hydrogen, alkyl or hydroxyalkyl and L^1 is a bond or alkylene;

$L^2-O-C(O)-R^{2'}$ where $R^{2'}$ is alkyl or hydroxyalkyl and L^2 is a bond or alkylene;

$L^3-C(O)-NR^{3'}R^{4'}$ where $R^{3'}$ and $R^{4'}$ are independently selected from H, alkyl, and hydroxyalkyl and wherein L^3 is a bond or alkylene;

$L^4-NR^{5'}-C(O)-R^{6'}$ wherein $R^{5'}$ is selected from H and alkyl, $R^{6'}$ is selected from alkyl and hydroxyalkyl, and L^4 is a bond or alkylene; and

alkylthio; or additionally

one or more of $R^{21}-R^{40}$ form a ring with another of R^{10} , R^{11} , R^{12} , R^{13} , and $R^{21}-R^{40}$.

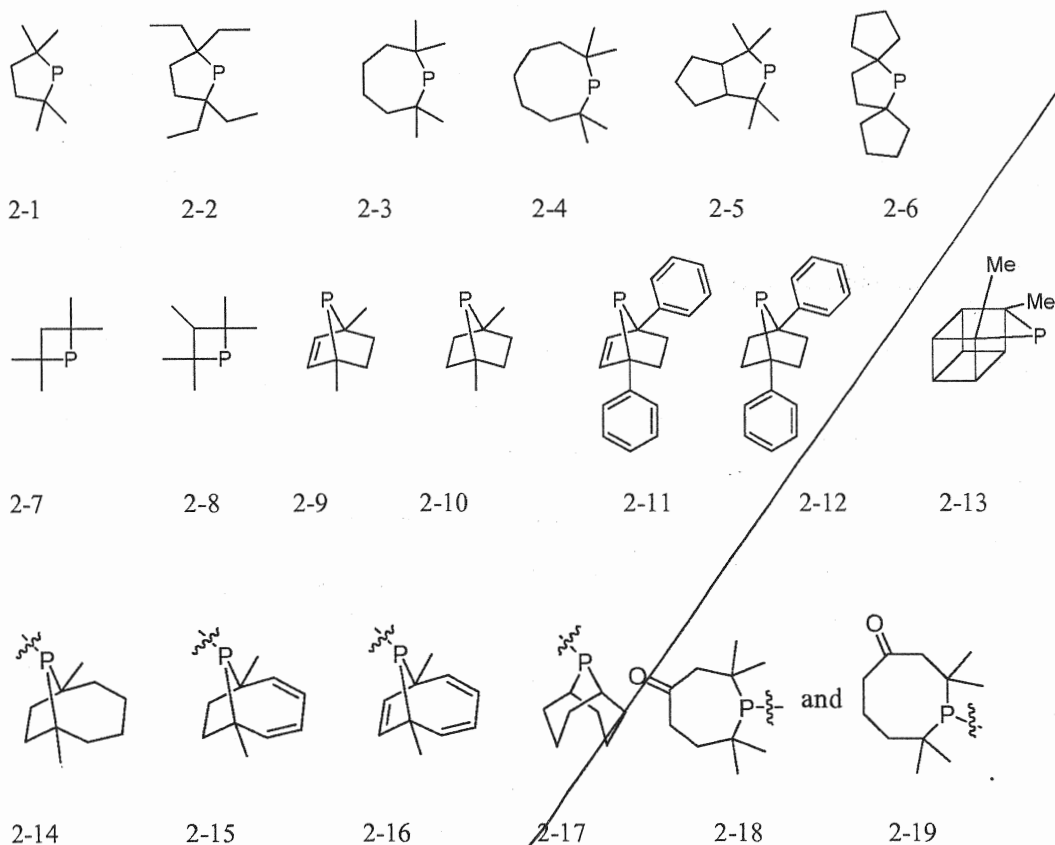
11. The compound according to claim 10, wherein X comprises a 4-membered ring.

12. The compound according to claim 10, wherein X comprises a 5-membered ring.

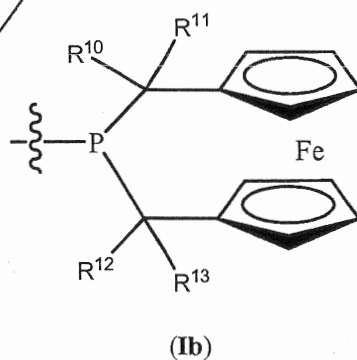
13. The compound according to claim 10, wherein X comprises a 7-membered ring or an 8-membered ring.

14. The compound according to claim 10, wherein R^{10} , R^{11} , R^{12} , and R^{13} are selected from the group consisting of alkyl, phenyl, and heteroaryl, or wherein R^{10} or R^{11} together with R^{12} or R^{13} form a ring.

15. The compound according to claim 10, wherein X is a phosphine having a structure corresponding to a formula selected from the group consisting of



16. The compound according to claim 1 or claim 2, wherein X is a phosphine of formula (Ib),



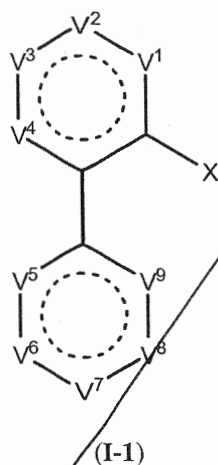
or a salt thereof,

wherein

R^{10} , R^{11} , R^{12} , and R^{13} are, at each occurrence, independently selected from the group consisting of alkyl, aryl, heteroaryl, and a ring formed by joining together R^{10} or R^{11} with R^{12} or R^{13} .

17. The phosphine ligand of claim 2, said ligand having a structure corresponding to any of formulae (I-1) - (I-42), wherein X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae (Ia) and (Ib).

18. The phosphine ligand of claim 17, said ligand having a structure corresponding to formula (I-1),



or a salt thereof,

wherein

V^1 and V^4 are CR^1 , wherein R^1 is independently, at each occurrence, hydrogen or alkoxy;

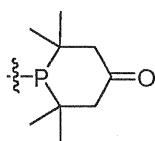
V^2 and V^3 are CR^1 , wherein R^1 is independently, at each occurrence, hydrogen or alkoxy;

V^5 and V^9 are CR^2 , wherein R^2 is independently, at each occurrence, selected from the group consisting of hydrogen, alkoxy, alkyl, and dialkylamino;

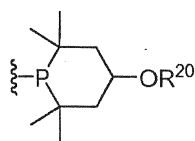
V^6 and V^8 are CR^2 , wherein R^2 is independently, at each occurrence, hydrogen or alkoxy;

V^7 is CR^2 , wherein R^2 is hydrogen or alkyl; and

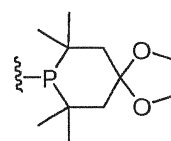
X is selected from the group consisting of phosphines of formulae 1-1, 1-2, 1-3, 1-4, 1-5, and 1-64.



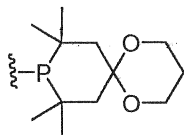
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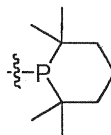
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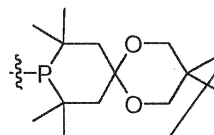
1-3



1-4



1-5



1-64

19. The phosphine ligand of claim 18, wherein the ligand is selected from the group consisting of:

2,2,6,6-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphinane;

2,2,6,6-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphinan-4-one;

2,2,6,6-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphinan-4-ol;

7,7,9,9-tetramethyl-8-(2',4',6'-triisopropylbiphenyl-2-yl)-1,4-dioxo-8-phosphaspiro[4.5]decane;

8,8,10,10-tetramethyl-9-(2',4',6'-triisopropylbiphenyl-2-yl)-1,5-dioxo-9-phosphaspiro[5.5]undecane;

3,3,8,8,10,10-hexamethyl-9-(2',4',6'-triisopropylbiphenyl-2-yl)-1,5-dioxo-9-phosphaspiro[5.5]undecane;

1-(2'-(dimethylamino)-6'-methoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2',6'-bis(dimethylamino)biphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2',6'-dimethoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2',6'-diisopropoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2'-(dimethylamino)biphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(biphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(1,1'-binaphthyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

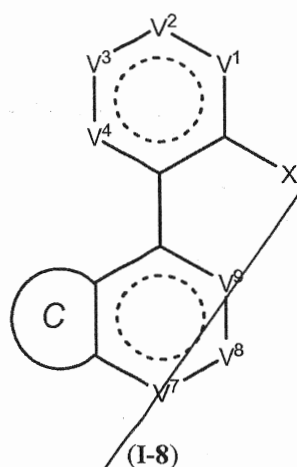
1-(2'-methoxy-1,1'-binaphthyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(3,6-dimethoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;
1-(3,6-dimethoxy-2',4',6'-trimethylbiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;
2,2,6,6-tetramethyl-1-(2',4',6'-triisopropyl-3,6-dimethoxybiphenyl-2-yl)phosphinan-4-one;
2,2,6,6-tetramethyl-1-(2',4',6'-triisopropyl-4,5-dimethoxybiphenyl-2-yl)phosphinan-4-one;
1-(3',5'-dimethoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;
1-(4'-*tert*-butylbiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;
6-methoxy-*N,N*-dimethyl-2'-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)biphenyl-2-amine;
*N*²,*N*²,*N*⁶,*N*⁶-tetramethyl-2'-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)biphenyl-2,6-diamine;
8-(2',6'-dimethoxybiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
8-(2',6'-diisopropoxybiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
N,N-dimethyl-2'-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)biphenyl-2-amine;
8-(biphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
8-(3,6-dimethoxybiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
8-(3,6-dimethoxy-2',4',6'-trimethylbiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
7,7,9,9-tetramethyl-8-(2',4',6'-triisopropyl-3,6-dimethoxybiphenyl-2-yl)-1,4-dioxo-8-phosphaspiro[4.5]decane;
7,7,9,9-tetramethyl-8-(2',4',6'-triisopropyl-4,5-dimethoxybiphenyl-2-yl)-1,4-dioxo-8-phosphaspiro[4.5]decane;
8-(3',5'-dimethoxybiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;

8-(4'-*tert*-butylbiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane; and

2,2,6,6-tetramethyl-1-(2',4',6'-triisopropyl-3,6-dimethoxybiphenyl-2-yl)phosphinane.

20. The phosphine ligand of claim 17, said ligand having a structure corresponding to formula (I-8),



or a salt thereof,

wherein

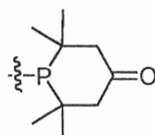
V^1 and V^2 are each CR^1 , wherein R^1 is, at each occurrence, hydrogen;

V^7 and V^8 are each CR^2 , wherein R^2 is, at each occurrence, hydrogen;

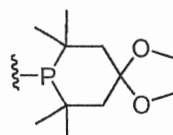
V^9 is CR^2 , wherein R^2 is hydrogen;

ring C at each occurrence is an unsubstituted fused-phenyl; and

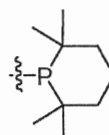
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3 and 1-5.



1-1



1-3



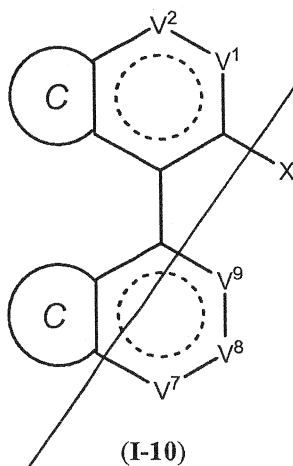
1-5

21. The phosphine ligand of claim 20, wherein said ligand is selected from the group consisting of:

2,2,6,6-tetramethyl-1-(2-(naphthalen-1-yl)phenyl)phosphinan-4-one; and

7,7,9,9-tetramethyl-8-(4-methyl-2-(naphthalen-1-yl)phenyl)-1,4-dioxo-8-phosphaspiro[4.5]decane.

22. The phosphine ligand of claim 17, said ligand having a structure corresponding to formula (I-10),



or a salt thereof,

wherein

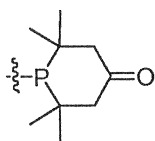
V^1 and V^2 are each CR^1 , wherein R^1 is, at each occurrence, hydrogen;

V^7 and V^8 are each CR^2 , wherein R^2 is, at each occurrence, hydrogen;

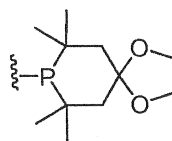
V^9 is CR^2 , wherein R^2 is hydrogen or alkoxy;

ring C at each occurrence is an unsubstituted fused-phenyl; and

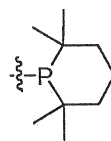
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3, and 1-5.



1-1



1-3



1-5

23. The phosphine ligand of claim 22, wherein said ligand is selected from the group consisting of:

1-(1,1'-binaphthyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

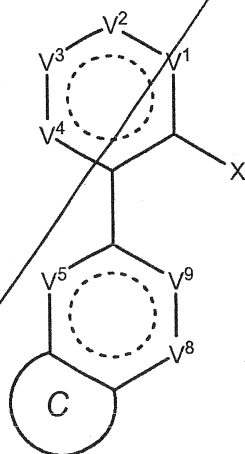
1-(2'-methoxy-1,1'-binaphthyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

8-(1,1'-binaphthyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;

and

8-(2'-methoxy-1,1'-binaphthyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane.

24. The phosphine ligand of claim 17, said ligand having a structure corresponding to formula (I-9),



(I-9)

or a salt thereof,

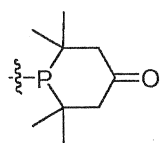
wherein

V^1 , V^2 , V^3 , and V^4 are each CR^1 , wherein R^1 , at each occurrence, is hydrogen;

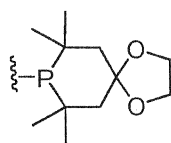
V^5 , V^6 and V^7 are each CR^2 , wherein R^2 , at each occurrence, is hydrogen;

ring C is an unsubstituted fused-phenyl; and

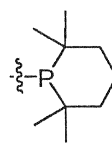
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3, and 1-5.



1-1



1-3



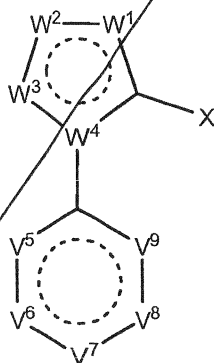
1-5

25. The phosphine ligand of claim 24, wherein said ligand is selected from the group consisting of:

2,2,6,6-tetramethyl-1-(2-(naphthalen-2-yl)phenyl)phosphinan-4-one; and

7,7,9,9-tetramethyl-8-(2-(naphthalen-2-yl)phenyl)-1,4-dioxo-8-phosphaspiro[4.5]decane.

26. The phosphine ligand of claim 17, said ligand having a structure corresponding to formula (I-2),



(I-2)

or a salt thereof,

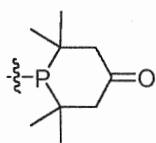
wherein

W^1 and W^2 are each CR^1 , wherein R^1 , at each occurrence, is hydrogen;

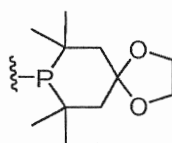
W^3 and W^4 are each N;

V^5 , V^6 , V^7 , V^8 , and V^9 are each CR^2 , wherein R^2 , at each occurrence, is hydrogen; and

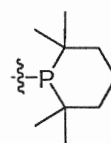
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3 and 1-5.



1-1



1-3



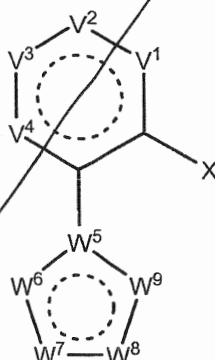
1-5

27. The phosphine ligand of claim 26, wherein said ligand is selected from the group consisting of:

2,2,6,6-tetramethyl-1-(1-phenyl-1*H*-pyrazol-5-yl)phosphinan-4-one; and

1-phenyl-5-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)-1*H*-pyrazole.

28. The phosphine ligand of claim 17, said ligand having a structure corresponding to formula (I-3),



(I-3)

or a salt thereof,

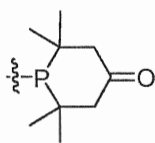
wherein

V^1 , V^2 , V^3 and V^4 are each CR^1 , wherein R^1 , at each occurrence, is hydrogen;

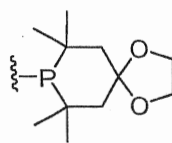
W^6 , W^7 , W^8 and W^9 are each CR^2 , wherein R^2 , at each occurrence, is hydrogen;

W^5 is N; and

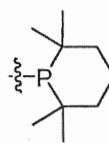
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3 and 1-5.



1-1



1-3



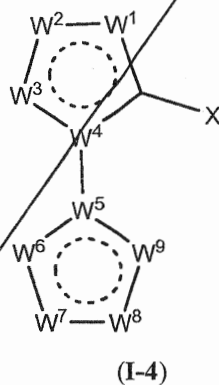
1-5

29. The phosphine ligand of claim 28, wherein said ligand is selected from the group consisting of:

1-(2-(1*H*-pyrrol-1-yl)phenyl)-2,2,6,6-tetramethylphosphinan-4-one, and

1-(2-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)phenyl)-1*H*-pyrrole.

30. The phosphine ligand of claim 17, said ligand having a structure corresponding to formula (I-4),



or a salt thereof,

wherein

W^1 and W^2 are each CR^1 , wherein R^1 , at each occurrence, is hydrogen;

W^3 and W^4 are each N;

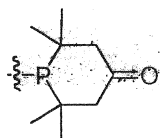
W^5 is C;

W^6 and W^9 are each CR^2 , wherein R^2 , at each occurrence, is substituted or unsubstituted phenyl;

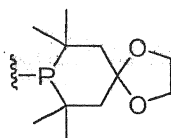
W^7 is N;

W^8 is NR^2 , wherein R^2 , at each occurrence, is phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; and

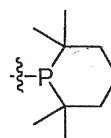
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3 and 1-5.



1-1



1-3



1-5

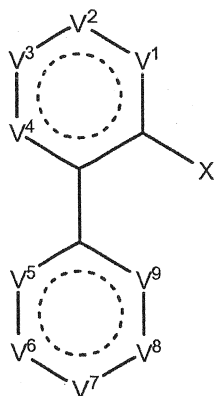
31. The phosphine ligand of claim 30, wherein said ligand is selected from the group consisting of:

2,2,6,6-Tetramethyl-1-(1',3',5'-triphenyl-1'H-1,4'-bipyrazol-5-yl)phosphinan-4-one;

1',3',5'-Triphenyl-5-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)-1'H-1,4'-bipyrazole; and

1',3',5'-Triphenyl-5-(2,2,6,6-tetramethylphosphinan-1-yl)-1'H-1,4'-bipyrazole.

32. The phosphine ligand of claim 17, said ligand having a structure corresponding to formula (I-1),



(I-1)

or a salt thereof,

wherein

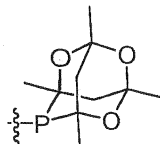
V^1 , V^2 , V^3 and V^4 are each CR^1 , wherein R^1 is, at each occurrence, hydrogen;

V^5 and V^9 are CR^2 , wherein R^2 is independently, at each occurrence, hydrogen or alkyl;

V^6 and V^8 are CR^2 , wherein R^2 , at each occurrence, is hydrogen;

V^7 is CR^2 , wherein R^2 is hydrogen or alkyl; and

X is a phosphine of formula 1-37.



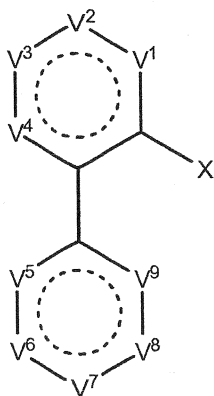
1-37

33. The phosphine ligand of claim 32, wherein the ligand is selected from the group consisting of:

1,3,5,7-tetramethyl-8-(2',4',6'-triisopropylbiphenyl-2-yl)-2,4,6-trioxa-8-phosphatricyclo[3.3.1.1^{3,7}]decane; and

8-(biphenyl-2-yl)-1,3,5,7-tetramethyl-2,4,6-trioxa-8-phosphatricyclo[3.3.1.1^{3,7}]decane.

34. The phosphine ligand of claim 17, said ligand having a structure corresponding to formula (I-1),



(I-1)

or a salt thereof,

wherein

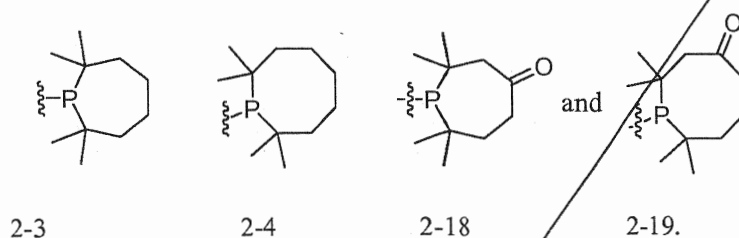
V^1 , V^2 , V^3 and V^4 are each CR^1 , wherein R^1 is, at each occurrence, hydrogen;

V^5 and V^9 are CR^2 , wherein R^2 is independently, at each occurrence, hydrogen or alkyl;

V^6 and V^8 are CR^2 , wherein R^2 , at each occurrence, is hydrogen;

V^7 is CR^2 , wherein R^2 is hydrogen or alkyl; and

X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 2-3, 2-4, 2-18, and 2-19



35. The phosphine ligand of claim 34, wherein the ligand is selected from the group consisting of:

1-(biphenyl-2-yl)-2,2,7,7-tetramethylphosphhepan-4-one;

1-(biphenyl-2-yl)-2,2,7,7-tetramethylphosphhepane;

2,2,7,7-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphhepan-4-one;

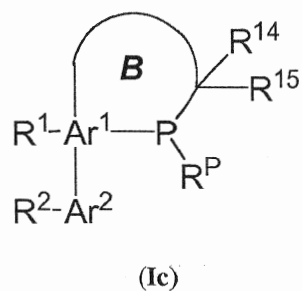
2,2,7,7-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphhepane;

2,2,8,8-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphocan-4-one;

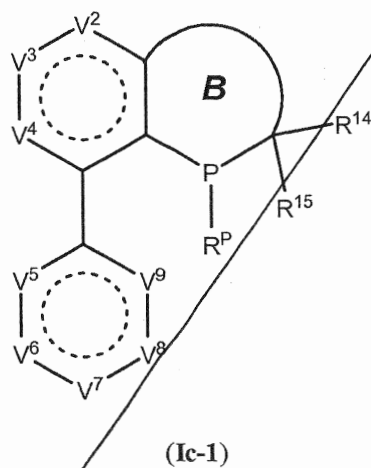
and

2,2,8,8-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphocane.

36. The phosphine ligand of claim 1, said ligand having a structure corresponding to formula (Ic), or a salt thereof,



37. The phosphine ligand of claim 34, said ligand having a structure corresponding to formula (Ic-1),



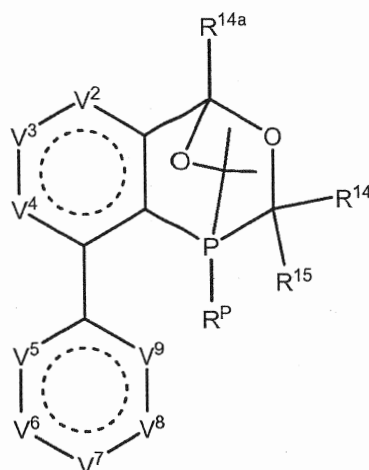
or a salt thereof,

wherein,

V^2 , V^3 , and V^4 are each independently CR^1 or N; and

V^5 , V^6 , V^7 , V^8 and V^9 are each independently CR^2 or N.

38. The phosphine ligand of claim 37, said ligand having a structure corresponding to formula (Ic-1a), or a salt thereof,



(Ic-1a)

wherein,

R^{14a} is selected from the group consisting of alkenyl; alkoxy; alkoxyalkyl; alkyl; *N*-alkylamino; alkylthio; alkynyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; substituted or unsubstituted arylalkyl; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; dialkylamino; halo; haloalkyl; fluoroalkyl; C_{3-6} heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxy; hydroxyalkyl; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; $L^1-C(O)-OR^1$, $L^1-P(O)-(OR^1)_2$, or $L^1-S(O)_2-OR^1$, wherein L^1 is a bond or alkylene, and R^1 is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^2-O-C(O)-R^2$, wherein L^2 is a bond or alkylene, and R^2 is alkyl or hydroxyalkyl; $L^3-C(O)-NR^3R^4$, wherein L^3 is a bond or alkylene, and R^3 and R^4 are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $L^4-NR^5-C(O)-R^6$, wherein L^4 is a bond or alkylene, R^5 is hydrogen and alkyl, and R^6 is alkyl or hydroxyalkyl; and $L^7-NR^8-S(O)_2-R^9$, wherein L^7 is a bond or alkylene, R^8 is hydrogen or alkyl, and R^9 is alkyl or hydroxyalkyl.

39. A catalyst composition comprising a transition metal catalyst precursor and a phosphine ligand according to claim 1.

40. The catalyst composition according to claim 39, wherein the transition metal catalyst precursor is selected from the group consisting of palladium, rhodium, ruthenium, platinum, gold, cobalt, iridium, copper and nickel.
41. The catalyst composition according to claim 40, wherein the transition metal catalyst precursor contains palladium.
42. A catalyst composition comprising a palladium catalyst precursor and a phosphine ligand according to claim 9.
43. A catalyst composition comprising a palladium catalyst precursor and a phosphine ligand according to claim 15.
44. A catalyst composition comprising a palladium catalyst precursor and a phosphine ligand according to claim 39.
45. A heterogeneous catalyst composition comprising a ligand according to any one of claims 1-38 covalently bonded to a solid catalyst support.
46. A method for synthesizing a secondary organic sulfonamide, comprising reacting an aryl nonaflate with a primary sulfonamide in the presence of a palladium catalyst precursor and a ligand selected from those of formula (I).
47. A method of performing a bond-forming reaction comprising catalyzing said reaction with a ligand of formula (I), wherein the bond-forming reaction is selected from the group consisting of carbon-nitrogen, carbon-oxygen, carbon-carbon, carbon-sulfur, carbon-phosphorus, carbon-boron, carbon-fluorine and carbon-hydrogen.
48. A method of forming a bond in a chemical reaction comprising catalyzing said reaction with a ligand of formula (I), wherein the bond is selected from the group consisting of a carbon-nitrogen bond, a carbon-oxygen bond, a carbon-carbon bond, a carbon-

sulfur bond, a carbon-phosphorus bond, a carbon-boron bond, a carbon-fluorine bond and a carbon-hydrogen bond.

49. A method of preparing phosphacycles of formula (I) comprising:

methylation of a biaryl halide to form a biaryl lithium species;

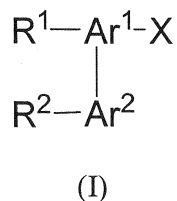
reacting a chlorophosphate with said biaryl lithium species to form biaryl phosphonate;

reduction of second product to form primary phosphine; and

reacting primary phosphine with a divinylketone.

WE CLAIM:

1. A compound having a structure corresponding to formula (I),



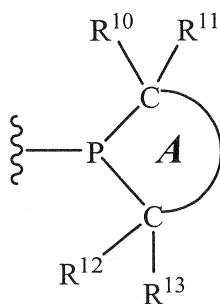
or a salt thereof,

wherein

Ar^1 and Ar^2 are each independently aryl or heteroaryl, and wherein Ar^1 and Ar^2 are each independently optionally substituted with one or more R^1 and R^2 , respectively;

R^1 and R^2 are independently selected at each occurrence from the group consisting of hydrogen; amino; hydroxyl; cyano; halo; alkyl; alkenyl; alkynyl; haloalkyl; haloalkoxy; oxoalkyl; alkoxy; aryloxy; heteroaryloxy; arylamino; heteroarylamino; alkylamino; dialkylamino; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; cycloalkyloxy optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; 5- or 6-membered heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; hydroxyalkoxy; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; $\text{L}^1-\text{C}(\text{O})-\text{OR}^{1'}$, $\text{L}^1-\text{P}(\text{O})-(\text{OR}^{1'})_2$, or $\text{L}^1-\text{S}(\text{O})_2-\text{OR}^{1'}$, wherein L^1 is a bond or alkylene, and $\text{R}^{1'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $\text{L}^2-\text{O}-\text{C}(\text{O})-\text{R}^{2'}$, wherein L^2 is a bond or alkylene, and $\text{R}^{2'}$ is alkyl or hydroxyalkyl; $\text{L}^3-\text{C}(\text{O})-\text{NR}^{3'}\text{R}^{4'}$, wherein L^3 is a bond or alkylene, and $\text{R}^{3'}$ and $\text{R}^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $\text{L}^4-\text{NR}^{5'}-\text{C}(\text{O})-\text{R}^{6'}$, wherein L^4 is a bond or alkylene, $\text{R}^{5'}$ is hydrogen or alkyl, and $\text{R}^{6'}$ is alkyl or hydroxyalkyl; sulfamoyl; *N*-(alkyl)sulfamoyl; *N,N*-(dialkyl)sulfamoyl; sulfonamide; sulfate; alkylthio; thioalkyl; and a ring containing an alkylene or $-\text{O}-(\text{CH}_2)_m-\text{O}-$ formed by the joining together of any two R^1 or any two R^2 or an R^1 and an R^2 , wherein m is 1, 2, 3 or 4;

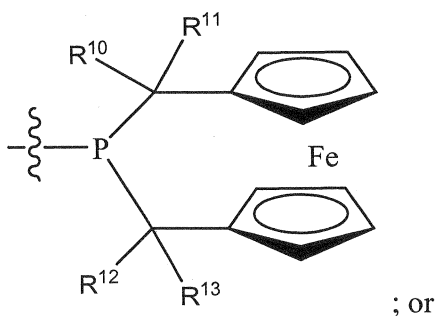
X is a 6-membered cyclic phosphine of formula (Ia):



(Ia)

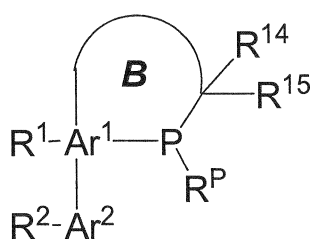
wherein ring **A** includes three carbon ring atoms in addition to the phosphorus and 2 carbon ring atoms of formula (Ia); or

X is a phosphine of formula (Ib):



(Ib)

X is a 6-membered cyclic phosphine fused to Ar¹ to give a compound of formula (Ic):



(Ic)

wherein, ring **B** is a phosphorus heterocyclic ring with four ring atoms in addition to the phosphorus and carbon ring atoms of formula (I-c), wherein said ring atoms are each independently selected from the group consisting of carbon, oxygen, nitrogen, phosphorus and sulfur, and

wherein the ring atoms of ring **A** and ring **B** are each independently optionally substituted with one or more substituents selected from the group consisting of alkenyl; alkoxy; alkoxyalkyl; alkyl; alkylamino; alkylthio; alkynyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; arylalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; dialkylamino; halo; haloalkyl; fluoroalkyl; heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxy; hydroxyalkyl; oxo; an exocyclic double bond optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; a 3- to 7-membered spiro ring containing zero, one, or two heteroatoms; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; $L^1-C(O)-OR^{1'}$, $L^1-P(O)-(OR^{1'})_2$, or $L^1-S(O)_2-OR^{1'}$, wherein L^1 is a bond or alkylene, and $R^{1'}$ is selected from the group consisting of hydrogen, alkyl or hydroxyalkyl; $L^2-O-C(O)-R^{2'}$, wherein L^2 is a bond or alkylene, and $R^{2'}$ is alkyl or hydroxyalkyl; $L^3-C(O)-NR^{3'}R^{4'}$, wherein L^3 is a bond or alkylene, and $R^{3'}$ and $R^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $L^4-NR^{5'}-C(O)-R^{6'}$, wherein L^4 is a bond or alkylene, $R^{5'}$ is hydrogen or alkyl, and $R^{6'}$ is alkyl or hydroxyalkyl; and $L^7-NR^{8'}-S(O)_2-R^{9'}$, wherein L^7 is a bond or alkylene, $R^{8'}$ is hydrogen or alkyl, and $R^{9'}$ is alkyl or hydroxyalkyl;

R^P is selected from the group consisting of alkyl, alkenyl, alkynyl, cycloalkyl, aryl, and heteroaryl, wherein R^P is optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; or R^P is a bridging group between the phosphorus and another **B** ring atom, wherein R^P is selected from the group consisting of alkylene, alkenylene, alkynylene, and $-(CR^{41}R^{42}-O)_q-$, wherein R^{41} and R^{42} are each independently hydrogen or alkyl, and wherein q is 1 or 2, and wherein R^P is optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy;

as to R^{10} , R^{11} , R^{12} , and R^{13} ,

- i. R^{10} or R^{11} together with R^{12} or R^{13} form a ring; or

ii. R^{10} and R^{11} together with the carbon atom to which they are attached form a spirocyclic ring and/or R^{12} and R^{13} together with the carbon atom to which they are attached form a spirocyclic ring; or

iii. one or more of R^{10} , R^{11} , R^{12} and R^{13} form a ring together with a ring substituent of ring A; or

iv. R^{10} , R^{11} , R^{12} , and R^{13} do not form a ring, wherein R^{10} , R^{11} , R^{12} , and R^{13} are each independently selected from the group consisting of hydrogen; alkyl; alkenyl; haloalkyl; alkynyl; oxoalkyl; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocyclyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; thioalkyl; $L^{13}-C(O)-OR^{14'}$, $L^{13}-P(O)-(OR^{14'})_2$, or $L^{13}-S(O)_2-OR^{14'}$, wherein L^{13} is a bond or alkylene, and $R^{14'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^{15}-O-C(O)-R^{16'}$, wherein L^{15} is alkylene and $R^{16'}$ is alkyl or hydroxyalkyl; $L^{17}-C(O)-NR^{18'}R^{19'}$, wherein L^{17} is a bond or alkylene, and $R^{18'}$ and $R^{19'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; and $L^{20}-NR^{21'}-C(O)-R^{22'}$, wherein L^{20} is alkylene, $R^{21'}$ is hydrogen or alkyl, and $R^{22'}$ is alkyl or hydroxyalkyl; and

as to R^{14} and R^{15} ,

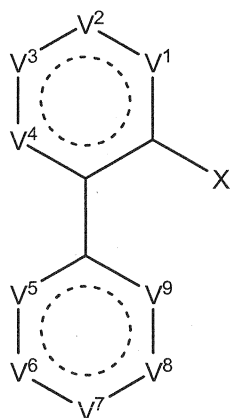
R^{14} and R^{15} together with the carbon atom to which they are attached form a spirocyclic ring; or

one or more of R^{14} and R^{15} form a ring together with a ring atom or ring substituent of ring B,

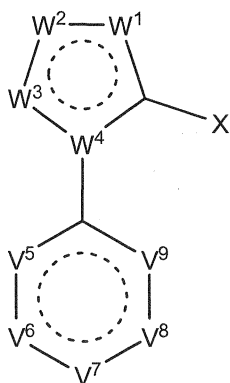
wherein, if any of substituents R^{14} and R^{15} do not form a ring, said substituents are each independently selected from the group consisting of hydrogen; alkyl; alkenyl; haloalkyl; alkynyl; oxoalkyl; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; heterocyclyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heteroaryl optionally substituted with alkyl,

alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; thioalkyl; $L^{13}-C(O)-OR^{14'}$, $L^{13}-P(O)-(OR^{14'})_2$, or $L^{13}-S(O)_2-OR^{14'}$ wherein L^{13} is a bond or alkylene, and $R^{14'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^{15}-O-C(O)-R^{16'}$ wherein L^{15} is alkylene, and $R^{16'}$ is alkyl or hydroxyalkyl; $L^{17}-C(O)-NR^{18'}R^{19'}$, wherein L^{17} is a bond or alkylene and $R^{18'}$ and $R^{19'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; and $L^{20}-NR^{21'}-C(O)-R^{22'}$, wherein L^{20} is alkylene, $R^{21'}$ is hydrogen or alkyl, and $R^{22'}$ is alkyl or hydroxyalkyl.

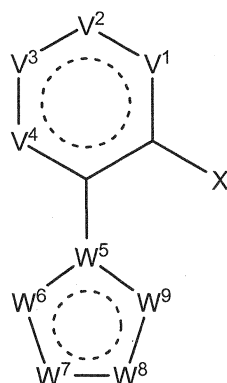
2. The compound according to claim 1, said compound having a structure corresponding to a structure of a formula selected from the group consisting of formulae (I-1) - (I-42), or a salt thereof:



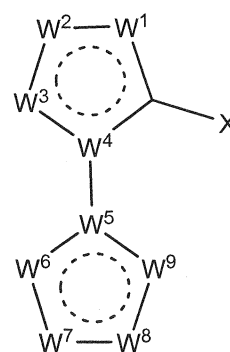
(I-1)



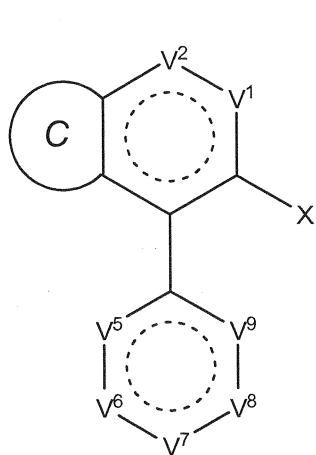
(I-2)



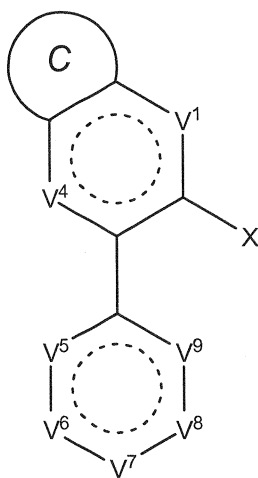
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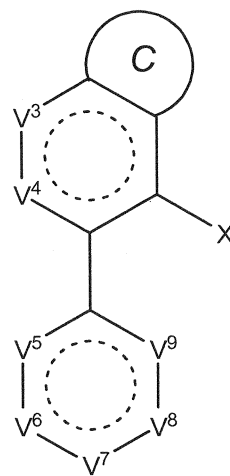
(I-4)



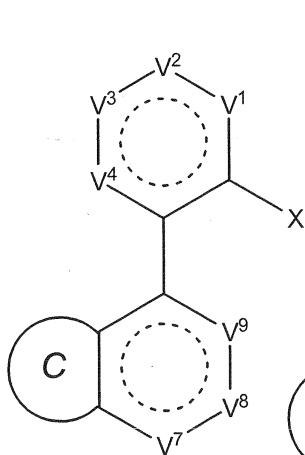
(I-5)



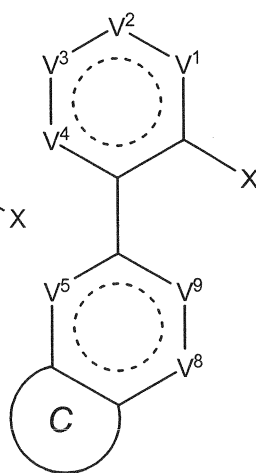
(I-6)



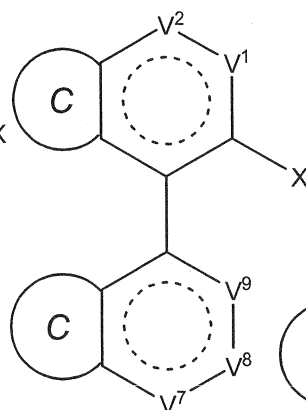
(I-7)



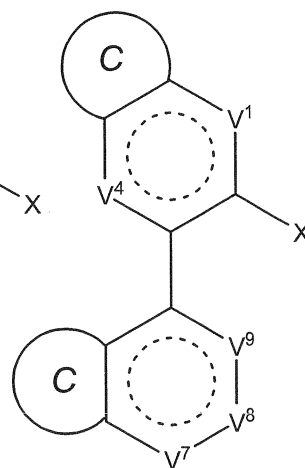
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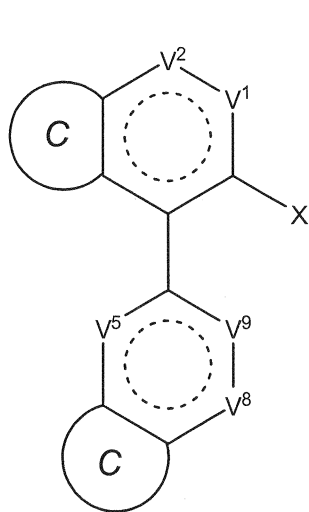
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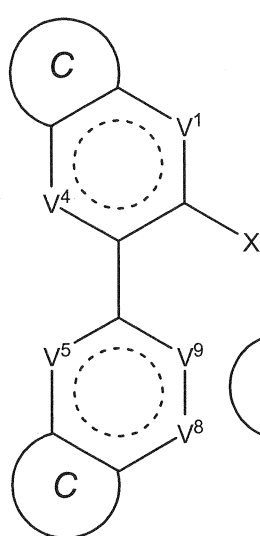
(I-10)



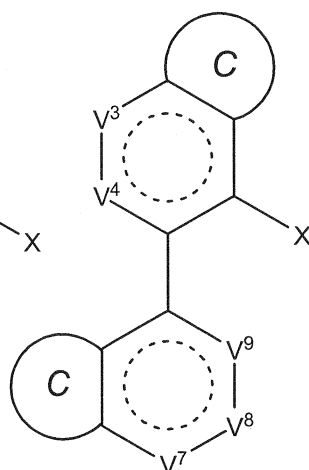
(I-11)



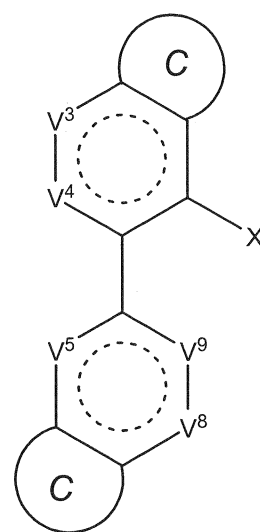
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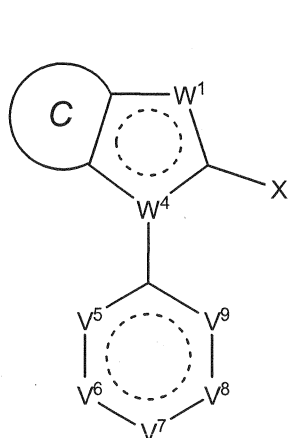
(I-13)



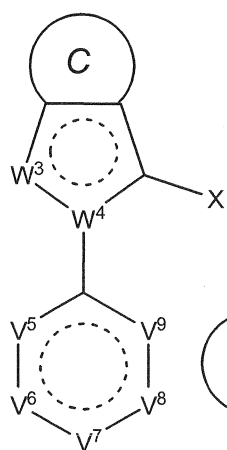
(I-14)



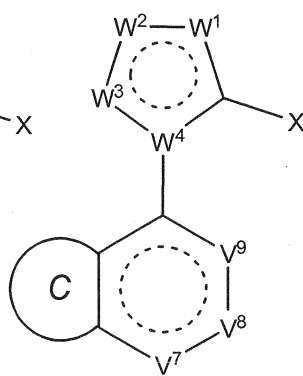
(I-15)



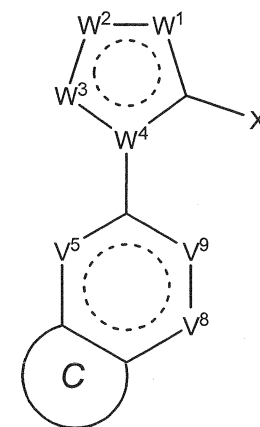
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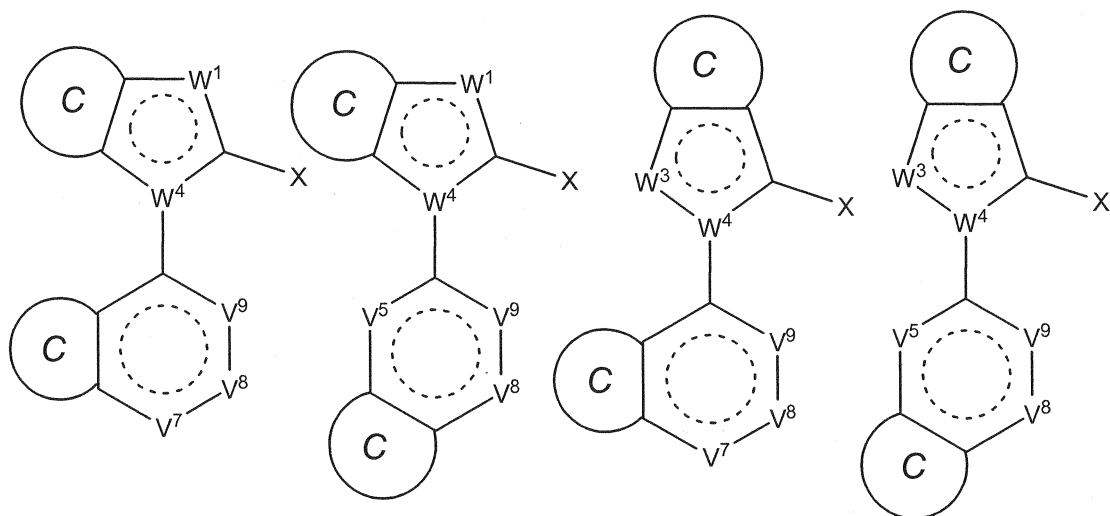
(I-17)



(I-18)



(I-19)

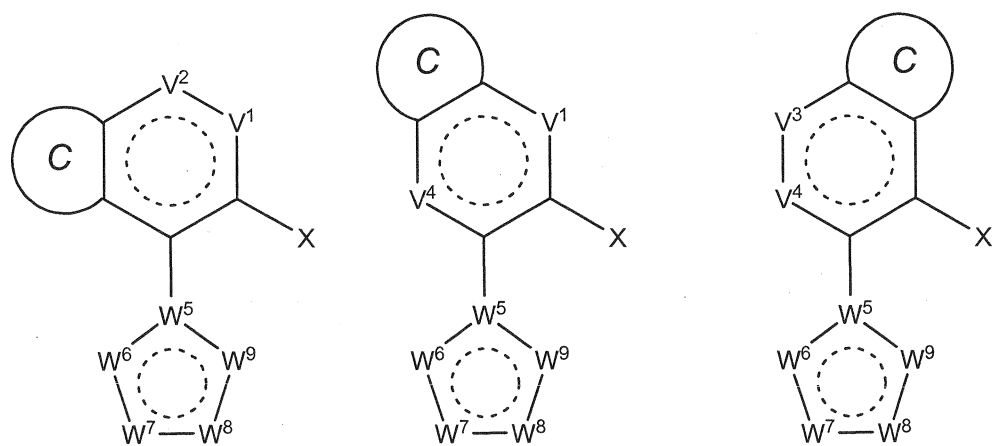


(I-20)

(I-21)

(I-22)

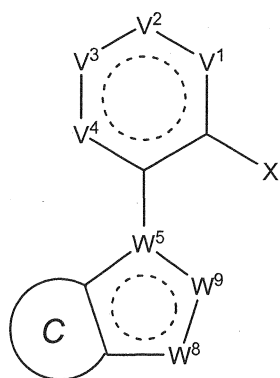
(I-23)



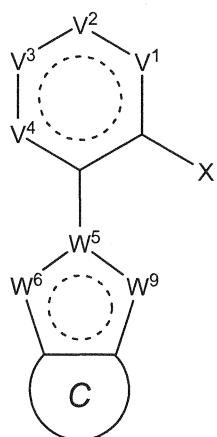
(I-24)

(I-25)

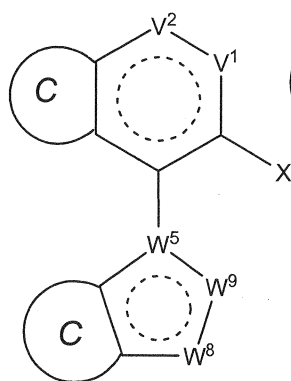
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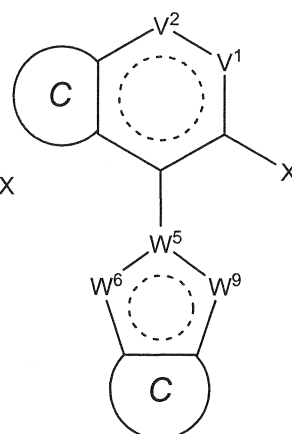
(I-27)



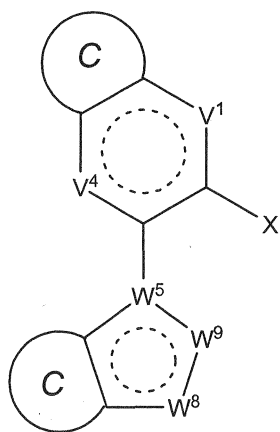
(I-28)



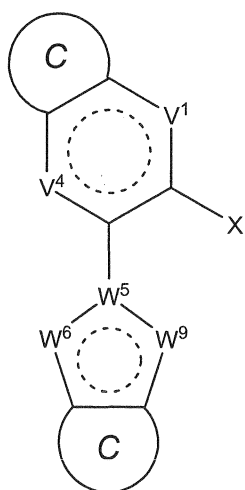
(I-29)



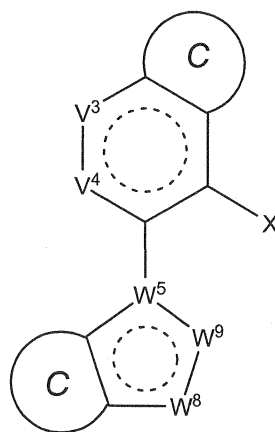
(I-30)



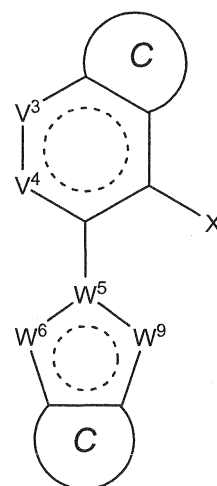
(I-31)



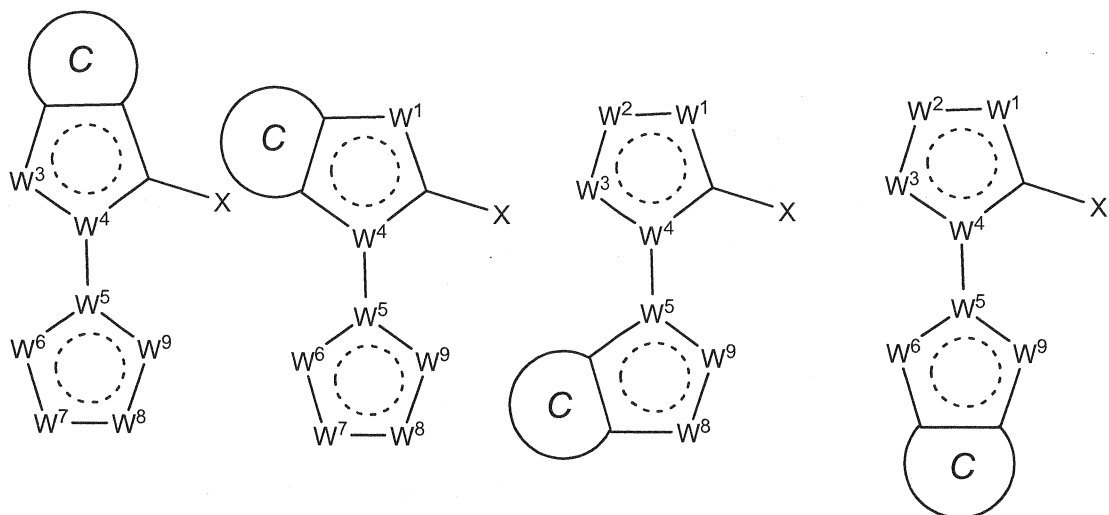
(I-32)



(I-33)



(I-34)

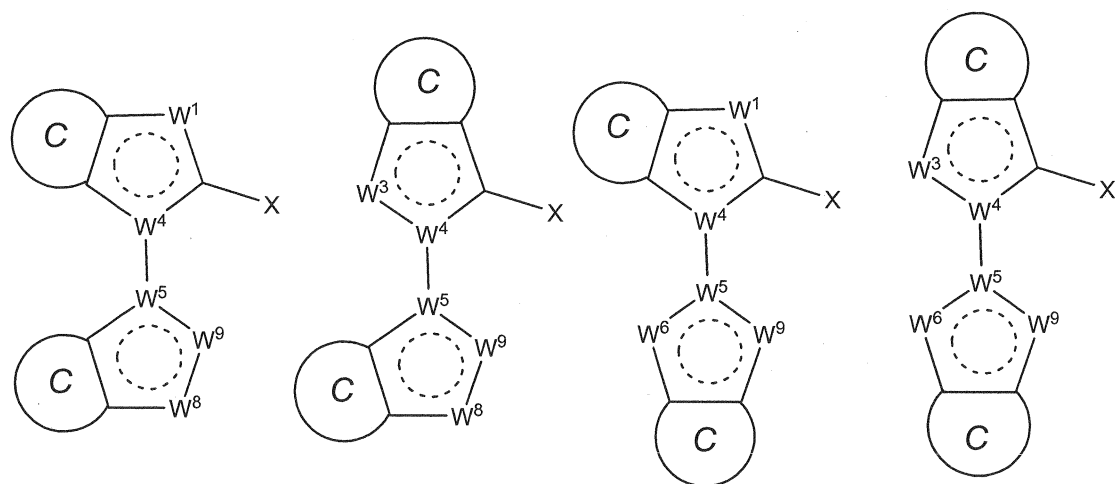


(I-35)

(I-36)

(I-37)

(I-38)



(I-39)

(I-40)

(I-41), and

(I-42)

wherein

X is a 6-membered cyclic phosphine of formula (Ia) or a phosphine of formula (Ib);

V^1 , V^2 , V^3 , and V^4 are each independently CR^1 or N;

V^5 , V^6 , V^7 , V^8 and V^9 are each independently CR^2 or N;

W^1 , W^2 , and W^3 are each independently selected from the group consisting of CR^1 , NR^1 , N and O;

W⁴ is C or N;

W⁵ is C or N;

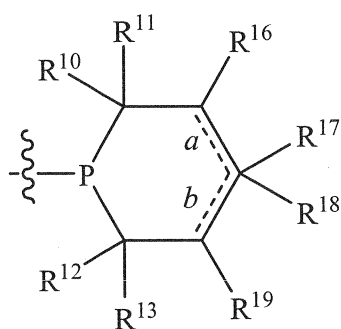
W⁶, W⁷, W⁸ and W⁹ are each independently selected from the group consisting of CR², NR², N and O; and

ring C, at each occurrence, is a fused-aryl or fused-heteroaryl and is optionally substituted with R¹ and R².

3. The compound according to claim 1 or claim 2, wherein X is the 6-membered cyclic phosphine of formula (Ia).

4. The compound according to claim 1, wherein X is the 6-membered cyclic phosphine of formula (Ia) and wherein X is attached to an atom of Ar¹ adjacent to the atom bonded to Ar².

5. The compound according to claim 1 or claim 2, wherein X is a phosphine of formula (Id), or a salt thereof:



(Id)

wherein

one or more of R¹⁶, R¹⁷, R¹⁸, and R¹⁹ optionally form a ring with R¹⁰, R¹¹, R¹², or R¹³; or

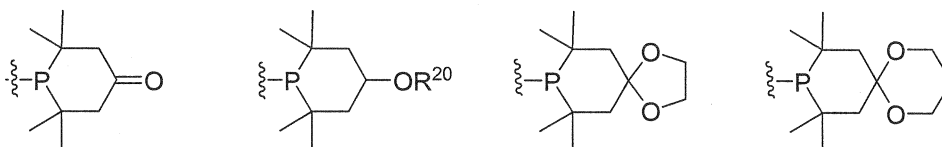
R¹⁷ together with R¹⁸ optionally form a carbonyl; an exocyclic double bond optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; or a 3- to 7-membered spiro ring containing zero, one, or two heteroatoms, optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; or

R^{16} and R^{19} are each independently selected from the group consisting of hydrogen, halo, alkyl, haloalkyl, fluoroalkyl, alkenyl, and alkoxy; or

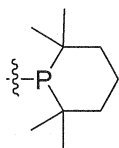
R^{17} and R^{18} are each independently selected from the group consisting of hydrogen; halo; fluoro; alkyl; alkenyl; alkynyl; haloalkyl; fluoroalkyl; alkyloxy; *N*-alkylamino; *N,N*-dialkylamino; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy, phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; arylalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; $L^1-C(O)-OR^{1'}$, $L^1-P(O)-(OR^{1'})_2$, or $L^1-S(O)_2-OR^{1'}$, wherein L^1 is a bond or alkylene, and $R^{1'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^2-O-C(O)-R^{2'}$, wherein L^2 is a bond or alkylene, and $R^{2'}$ is alkyl or hydroxyalkyl; $L^3-C(O)-NR^{3'}R^{4'}$, wherein L^3 is a bond or alkylene, $R^{3'}$ and $R^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $L^4-NR^{5'}-C(O)-R^{6'}$, wherein L^4 is a bond or alkylene, and $R^{5'}$ is hydrogen or alkyl, $R^{6'}$ is alkyl or hydroxyalkyl; and alkylthio; and

at least one of bonds *a* and *b* in formula (Id) is a single bond and one of bonds *a* or *b* is optionally a double bond.

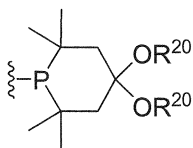
6. The compound according to claim 5, wherein R^{16} and R^{19} are hydrogen.
7. The compound according to claim 5, wherein R^{17} and R^{18} together with the carbon atom to which they are attached form a 3-, 4-, 5-, 6-, or 7-membered spirocyclic ring containing 0, 1, or 2 ring heteroatoms.
8. The compound according to claim 5, wherein X is a phosphine having a structure corresponding to a formula selected from the group consisting of:



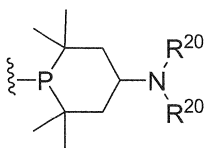
1-1



1-2

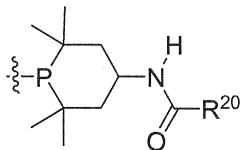


1-3

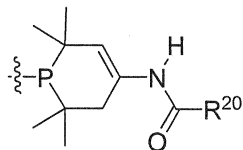


1-4

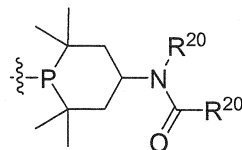
1-5



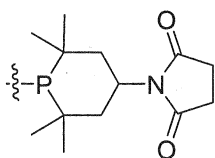
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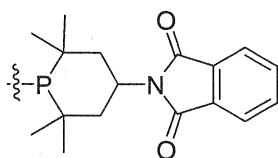
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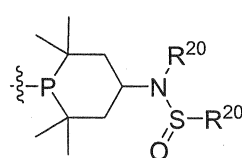
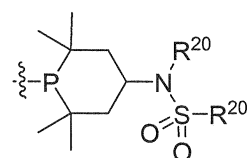
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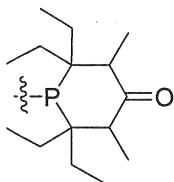
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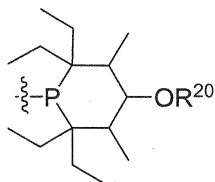
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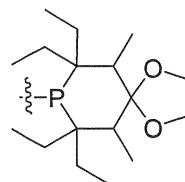
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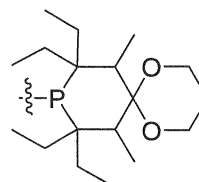
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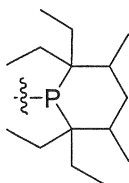
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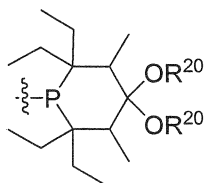
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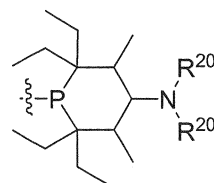
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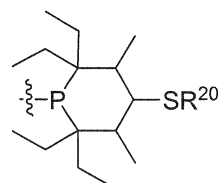
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1-17



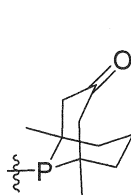
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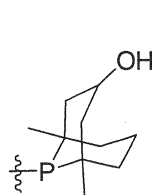
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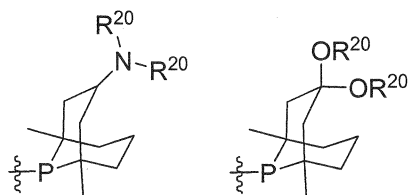
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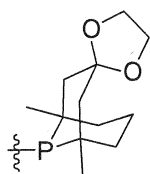
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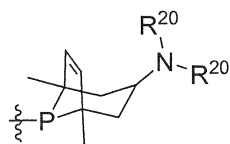
1-22



1-23



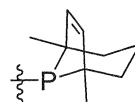
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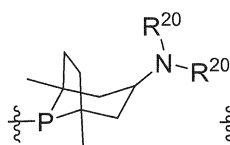


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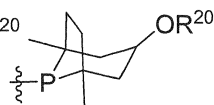
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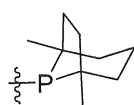
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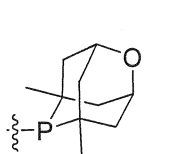
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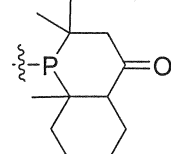
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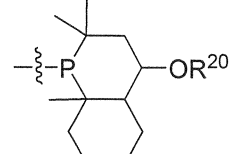
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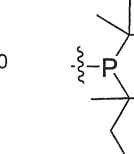
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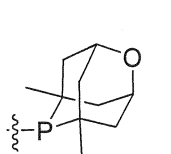
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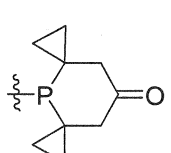
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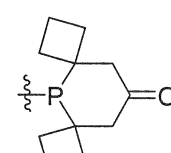
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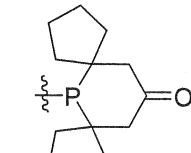
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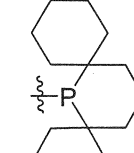
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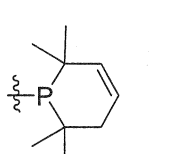
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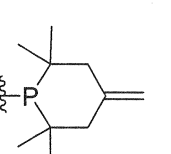
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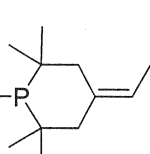
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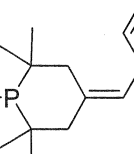
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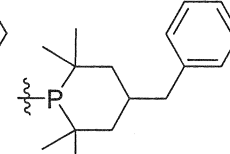
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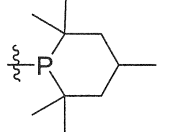
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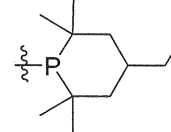
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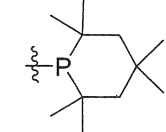
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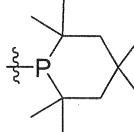
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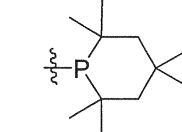
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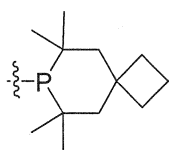
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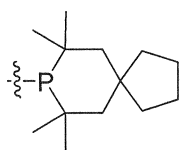
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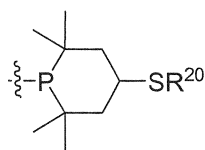
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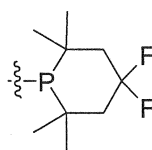
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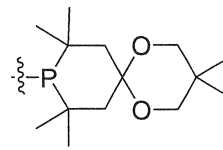
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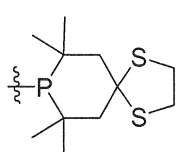
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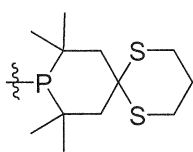
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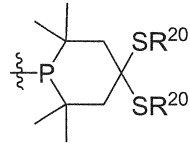
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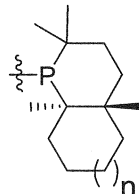
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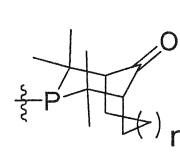
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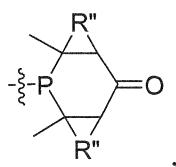
1-63



1-64



1-65



1-66



1-67



1-68



1-69, and

1-70

or a salt thereof, wherein R'' is selected from the group consisting of oxygen, NR²⁰, and C(R²⁰)₂;

R²⁰ is hydrogen, alkyl, aryl, heteroaryl, arylalkyl or heteroarylalkyl, wherein the aryl, heteroaryl, aryl of arylalkyl and heteroaryl of heteroarylalkyl are optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; and

n is 0, 1, or 2.

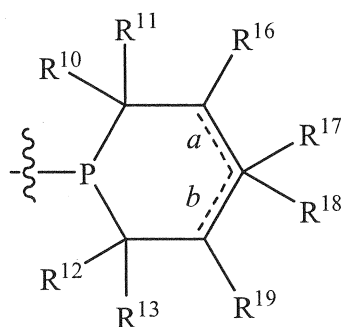
9. The compound of claim 1, wherein Ar¹ and Ar² are each aryl.

10. The compound of claim 1, wherein Ar¹ is substituted with two R¹ and Ar² is substituted with three R².

11. The compound of claim 1, wherein R¹ is alkyloxy and wherein R² is alkyl.

12. The compound of claim 1, wherein R² is isopropyl.

13. The compound of claim 1, wherein X is a phosphine of formula (Id):



(Id)

wherein each of R¹⁰, R¹¹, R¹², R¹³ is alkyl;

R¹⁷ and R¹⁸ are each independently selected from the group consisting of hydrogen, or R¹⁷ together with R¹⁸ optionally form a carbonyl or a 3- to 7-membered spiro ring containing zero, one, or two heteroatoms;

each of R¹⁶ and R¹⁹ is hydrogen; and

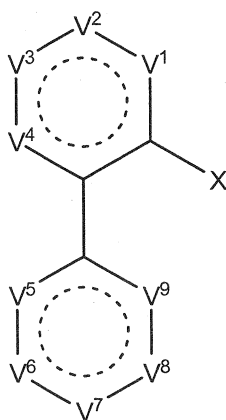
each of bonds a and b is a single bond.

14. The compound of claim 13, wherein R¹⁷ together with R¹⁸ form a 5-membered spiro ring containing two heteroatoms.

15. The compound of claim 14, wherein the two heteroatoms are each oxygen.

16. The compound of claim 1, wherein R¹⁰, R¹¹, R¹², and R¹³ are each methyl.

17. The compound of claim 2, said compound having the structure corresponding to formula (I-1)



(I-1)

wherein

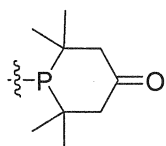
V^1 and V^4 are each CR^1 , wherein R^1 at each occurrence is alkoxy;

V^2 and V^3 are each CR^1 , wherein R^1 at each occurrence is hydrogen;

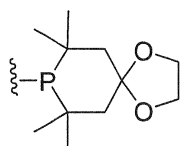
V^5 , V^7 and V^9 are each CR^2 , wherein R^2 at each occurrence is alkyl;

V^6 and V^8 are each CR^2 , wherein R^2 at each occurrence is hydrogen; and

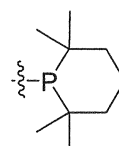
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3 and 1-5.



1-1

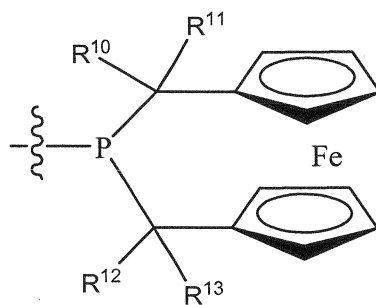


1-3



1-5

18. The compound according to claim 1 or claim 2, wherein X is a phosphine of formula (Ib),



(Ib)

or a salt thereof,

wherein

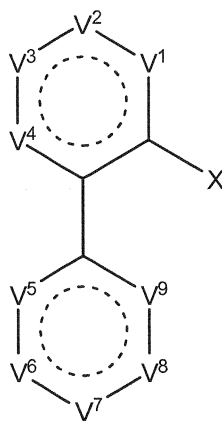
R^{10} , R^{11} , R^{12} , and R^{13} are, at each occurrence, independently selected from the group consisting of alkyl, aryl, heteroaryl, and a ring formed by joining together R^{10} or R^{11} with R^{12} or R^{13} .

19. The compound of claim 18, wherein X is attached to an atom of Ar^1 adjacent to

the atom bonded to Ar^2 .

20. The compound of claim 2, said compound having a structure corresponding to any of formulae (I-1) - (I-42), wherein X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae (Ia) and (Ib).

21. The compound of claim 20, said compound having a structure corresponding to formula (I-1),



(I-1)

or a salt thereof,

wherein

V^1 and V^4 are CR^1 , wherein R^1 is independently, at each occurrence, hydrogen or alkoxy;

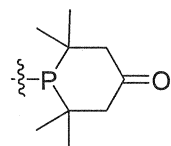
V^2 and V^3 are CR^1 , wherein R^1 is independently, at each occurrence, hydrogen or alkoxy;

V^5 and V^9 are CR^2 , wherein R^2 is independently, at each occurrence, selected from the group consisting of hydrogen, alkoxy, alkyl, and dialkylamino;

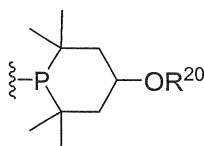
V^6 and V^8 are CR^2 , wherein R^2 is independently, at each occurrence, hydrogen or alkoxy;

V^7 is CR^2 , wherein R^2 is hydrogen or alkyl; and

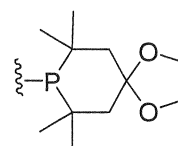
X is selected from the group consisting of phosphines of formulae 1-1, 1-2, 1-3, 1-4, 1-5, and 1-64.



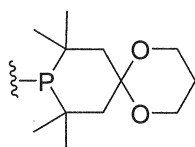
1-1



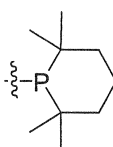
1-2



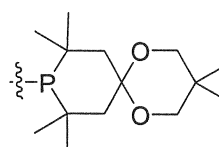
1-3



1-4



1-5



1-64

22. The compound of claim 21, wherein the compound is selected from the group consisting of:

2,2,6,6-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphinane;

2,2,6,6-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphinan-4-one;

2,2,6,6-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphinan-4-ol;

7,7,9,9-tetramethyl-8-(2',4',6'-triisopropylbiphenyl-2-yl)-1,4-dioxa-8-phosphaspiro[4.5]decane;

8,8,10,10-tetramethyl-9-(2',4',6'-triisopropylbiphenyl-2-yl)-1,5-dioxa-9-phosphaspiro[5.5]undecane;

3,3,8,8,10,10-hexamethyl-9-(2',4',6'-triisopropylbiphenyl-2-yl)-1,5-dioxa-9-phosphaspiro[5.5]undecane;

1-(2'-(dimethylamino)-6'-methoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2',6'-bis(dimethylamino)biphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2',6'-dimethoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2',6'-diisopropoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2'-(dimethylamino)biphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(biphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(3,6-dimethoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

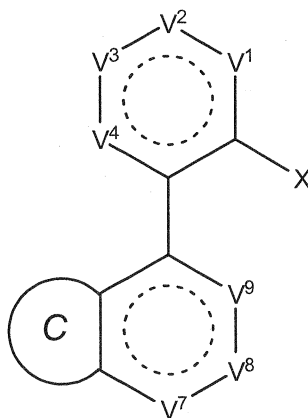
1-(3,6-dimethoxy-2',4',6'-trimethylbiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;
 2,2,6,6-tetramethyl-1-(2',4',6'-triisopropyl-3,6-dimethoxybiphenyl-2-yl)phosphinan-4-one;
 2,2,6,6-tetramethyl-1-(2',4',6'-triisopropyl-4,5-dimethoxybiphenyl-2-yl)phosphinan-4-one;
 1-(3',5'-dimethoxybiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;
 1-(4'-*tert*-butylbiphenyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;
 6-methoxy-*N,N*-dimethyl-2'-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)biphenyl-2-amine;
*N*²,*N*²,*N*⁶,*N*⁶-tetramethyl-2'-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)biphenyl-2,6-diamine;
 8-(2',6'-dimethoxybiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
 8-(2',6'-diisopropoxybiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
N,N-dimethyl-2'-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)biphenyl-2-amine;
 8-(biphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
 8-(3,6-dimethoxybiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
 8-(3,6-dimethoxy-2',4',6'-trimethylbiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
 7,7,9,9-tetramethyl-8-(2',4',6'-triisopropyl-3,6-dimethoxybiphenyl-2-yl)-1,4-dioxo-8-phosphaspiro[4.5]decane;
 7,7,9,9-tetramethyl-8-(2',4',6'-triisopropyl-4,5-dimethoxybiphenyl-2-yl)-1,4-dioxo-8-phosphaspiro[4.5]decane;

8-(3',5'-dimethoxybiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;

8-(4'-*tert*-butylbiphenyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane;
and

2,2,6,6-tetramethyl-1-(2',4',6'-triisopropyl-3,6-dimethoxybiphenyl-2-yl)phosphinane.

23. The compound of claim 20, said compound having a structure corresponding to formula (I-8),



(I-8)

or a salt thereof,

wherein

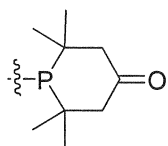
V¹ and V² are each CR¹, wherein R¹ is, at each occurrence, hydrogen;

V⁷ and V⁸ are each CR², wherein R² is, at each occurrence, hydrogen;

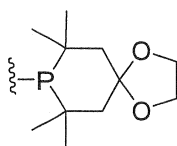
V⁹ is CR², wherein R² is hydrogen;

ring C at each occurrence is an unsubstituted fused-phenyl; and

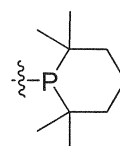
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3 and 1-5.



1-1



1-3



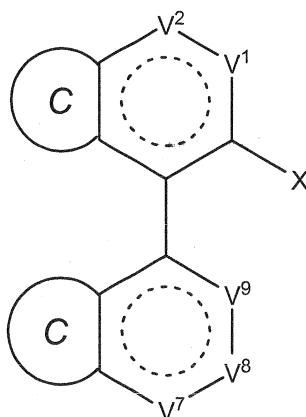
1-5

24. The compound of claim 23, wherein said compound is selected from the group consisting of:

2,2,6,6-tetramethyl-1-(2-(naphthalen-1-yl)phenyl)phosphinan-4-one; and

7,7,9,9-tetramethyl-8-(4-methyl-2-(naphthalen-1-yl)phenyl)-1,4-dioxo-8-phosphaspiro[4.5]decane.

25. The compound of claim 20, said compound having a structure corresponding to formula (I-10),



(I-10)

or a salt thereof,

wherein

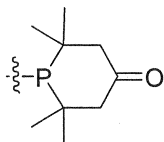
V^1 and V^2 are each CR^1 , wherein R^1 is, at each occurrence, hydrogen;

V^7 and V^8 are each CR^2 , wherein R^2 is, at each occurrence, hydrogen;

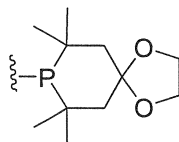
V^9 is CR^2 , wherein R^2 is hydrogen or alkoxy;

ring C at each occurrence is an unsubstituted fused-phenyl; and

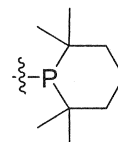
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3, and 1-5.



1-1



1-3



1-5

26. The compound of claim 25, wherein said compound is selected from the group consisting of:

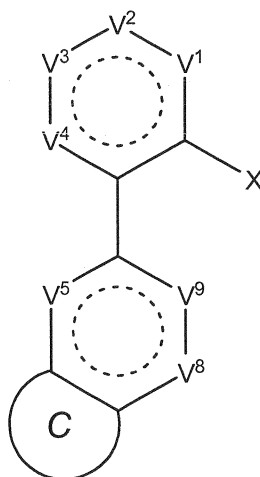
1-(1,1'-binaphthyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2'-methoxy-1,1'-binaphthyl-2-yl)-2,2,6,6-tetramethylphosphinan-4-one;

8-(1,1'-binaphthyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane; and

8-(2'-methoxy-1,1'-binaphthyl-2-yl)-7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decane.

27. The compound of claim 20, said compound having a structure corresponding to formula (I-9),



(I-9)

or a salt thereof,

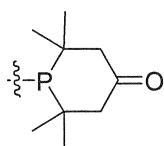
wherein

V^1 , V^2 , V^3 , and V^4 are each CR^1 , wherein R^1 , at each occurrence, is hydrogen;

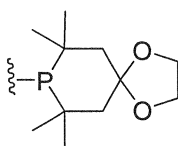
V^5 , V^8 and V^9 are each CR^2 , wherein R^2 , at each occurrence, is hydrogen;

ring *C* is an unsubstituted fused-phenyl; and

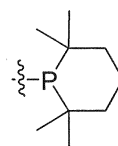
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3, and 1-5.



1-1



1-3



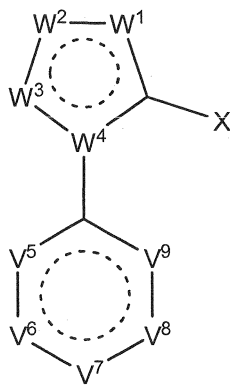
1-5

28. The compound of claim 27, wherein said compound is selected from the group consisting of:

2,2,6,6-tetramethyl-1-(2-(naphthalen-2-yl)phenyl)phosphinan-4-one; and

7,7,9,9-tetramethyl-8-(2-(naphthalen-2-yl)phenyl)-1,4-dioxaspiro[4.5]decane.

29. The compound of claim 20, said compound having a structure corresponding to formula (I-2),



(I-2)

or a salt thereof,

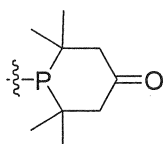
wherein

W^1 and W^2 are each CR^1 , wherein R^1 , at each occurrence, is hydrogen;

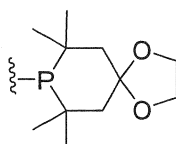
W^3 and W^4 are each N;

V^5 , V^6 , V^7 , V^8 , and V^9 are each CR^2 , wherein R^2 , at each occurrence, is hydrogen; and

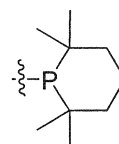
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3 and 1-5.



1-1



1-3



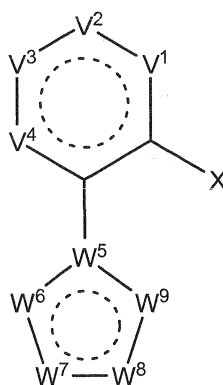
1-5

30. The compound of claim 29, wherein said compound is selected from the group consisting of:

2,2,6,6-tetramethyl-1-(1-phenyl-1*H*-pyrazol-5-yl)phosphinan-4-one; and

1-phenyl-5-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)-1*H*-pyrazole.

31. The compound of claim 20, said compound having a structure corresponding to formula (I-3),



(I-3)

or a salt thereof,

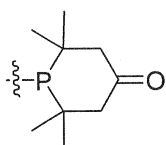
wherein

V^1 , V^2 , V^3 and V^4 are each CR^1 , wherein R^1 , at each occurrence, is hydrogen;

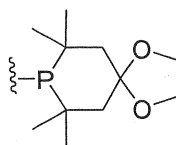
W^6 , W^7 , W^8 and W^9 are each CR^2 , wherein R^2 , at each occurrence, is hydrogen;

W⁵ is N; and

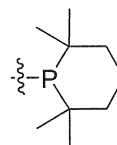
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3 and 1-5.



1-1



1-3



1-5

32. The compound of claim 31, wherein said compound is selected from the group consisting of:

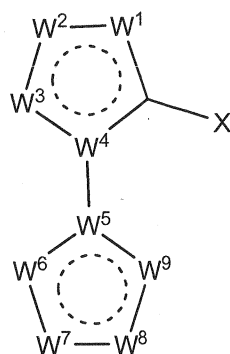
1-(2-(1*H*-pyrrol-1-yl)phenyl)-2,2,6,6-tetramethylphosphinan-4-one;

1-(2-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)phenyl)-1*H*-pyrrole;

and

1-(2-(2,2,6,6-tetramethylphosphinan-1-yl)phenyl)-1*H*-pyrrole.

33. The compound of claim 20, said compound having a structure corresponding to formula (I-4),



(I-4)

or a salt thereof, wherein

W¹ and W² are each CR¹, wherein R¹, at each occurrence, is hydrogen;

W³ and W⁴ are each N;

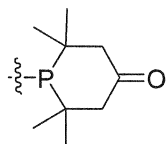
W⁵ is C;

W⁶ and W⁹ are each CR², wherein R², at each occurrence, is substituted or unsubstituted phenyl;

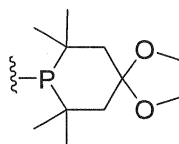
W⁷ is N;

W⁸ is NR², wherein R², at each occurrence, is phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; and

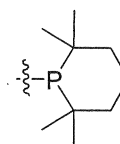
X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 1-1, 1-3 and 1-5.



1-1



1-3



1-5

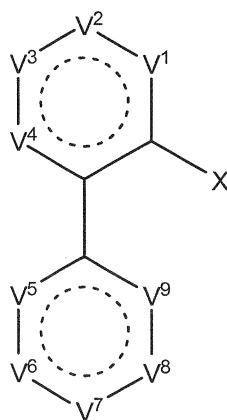
34. The compound of claim 33, wherein said compound is selected from the group consisting of:

2,2,6,6-Tetramethyl-1-(1',3',5'-triphenyl-1'*H*-1,4'-bipyrazol-5-yl)phosphinan-4-one;

1'1',3',5'-Triphenyl-5-(7,7,9,9-tetramethyl-1,4-dioxo-8-phosphaspiro[4.5]decan-8-yl)-1'*H*-1,4'-bipyrazole; and

1',3',5'-Triphenyl-5-(2,2,6,6-tetramethylphosphinan-1-yl)-1'*H*-1,4'-bipyrazole.

35. A compound having a structure corresponding to formula (I-1),



(I-1)

or a salt thereof,

wherein

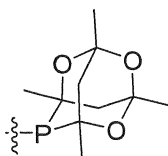
V^1 , V^2 , V^3 and V^4 are each CR^1 , wherein R^1 is, at each occurrence, hydrogen;

V^5 and V^9 are CR^2 , wherein R^2 is independently, at each occurrence, hydrogen or alkyl;

V^6 and V^8 are CR^2 , wherein R^2 , at each occurrence, is hydrogen;

V^7 is CR^2 , wherein R^2 is hydrogen or alkyl; and

X is a phosphine of formula 1-37.



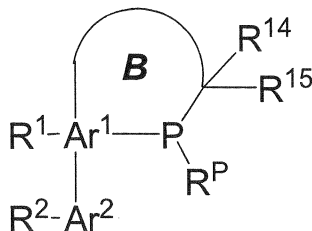
1-37

36. The compound of claim 35, wherein the compound is selected from the group consisting of:

1,3,5,7-tetramethyl-8-(2',4',6'-triisopropylbiphenyl-2-yl)-2,4,6-trioxa-8-phosphatricyclo[3.3.1.1^{3,7}]decane; and

8-(biphenyl-2-yl)-1,3,5,7-tetramethyl-2,4,6-trioxa-8-phosphatricyclo[3.3.1.1^{3,7}]decane.

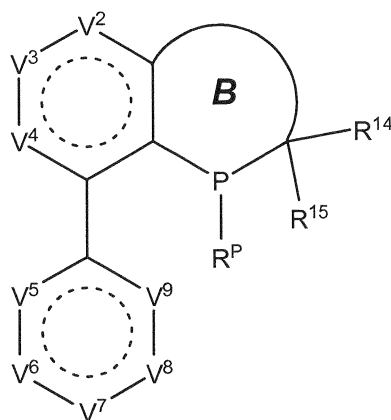
37. The compound of claim 1, said compound having a structure corresponding to formula (Ic), or a salt thereof,



(Ic)

38. The compound of claim 37, said compound having a structure corresponding

to formula (Ic-1),



(Ic-1)

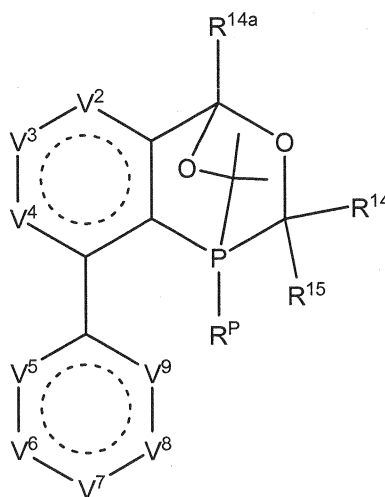
or a salt thereof,

wherein,

V^2 , V^3 , and V^4 are each independently CR^1 or N; and

V^5 , V^6 , V^7 , V^8 and V^9 are each independently CR^2 or N.

39. The compound of claim 38, said compound having a structure corresponding to formula (Ic-1a), or a salt thereof,

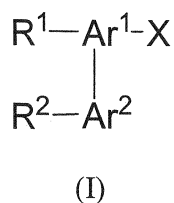


(Ic-1a)

wherein,

R^{14a} is selected from the group consisting of alkenyl; alkoxy; alkoxyalkyl; alkyl; *N*-alkylamino; alkylthio; alkynyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; substituted or unsubstituted arylalkyl; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; dialkylamino; halo; haloalkyl; fluoroalkyl; heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxy; hydroxyalkyl; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; $L^1-C(O)-OR^{1'}$, $L^1-P(O)-(OR^{1'})_2$, or $L^1-S(O)_2-OR^{1'}$, wherein L^1 is a bond or alkylene, and $R^{1'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^2-O-C(O)-R^{2'}$, wherein L^2 is a bond or alkylene, and $R^{2'}$ is alkyl or hydroxyalkyl; $L^3-C(O)-NR^{3'}R^{4'}$, wherein L^3 is a bond or alkylene, and $R^{3'}$ and $R^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $L^4-NR^{5'}-C(O)-R^{6'}$, wherein L^4 is a bond or alkylene, $R^{5'}$ is hydrogen and alkyl, and $R^{6'}$ is alkyl or hydroxyalkyl; and $L^7-NR^{8'}-S(O)_2-R^{9'}$, wherein L^7 is a bond or alkylene, $R^{8'}$ is hydrogen or alkyl, and $R^{9'}$ is alkyl or hydroxyalkyl.

40. A compound having a structure corresponding to formula (I),



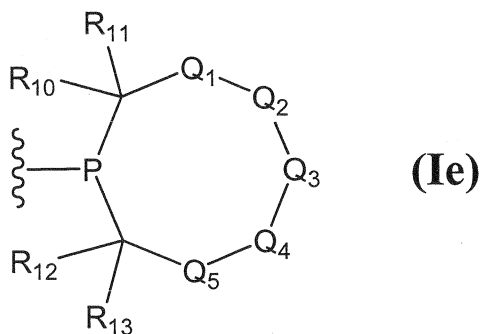
wherein

Ar^1 and Ar^2 are each independently aryl or heteroaryl, and wherein Ar^1 and Ar^2 are each independently optionally substituted with one or more R^1 and R^2 , respectively;

R^1 and R^2 are independently selected at each occurrence from the group consisting of hydrogen; amino; hydroxyl; cyano; halo; alkyl; alkenyl; alkynyl; haloalkyl; haloalkoxy; oxoalkyl; alkoxy; aryloxy; heteroaryloxy; arylamino; heteroarylamino; alkylamino; dialkylamino; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; cycloalkyloxy optionally substituted with alkyl, alkenyl, alkynyl,

alkoxy, cyano, halo, haloalkyl or haloalkoxy; 5- or 6-membered heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; hydroxyalkoxy; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; $L^1-C(O)-OR^{1'}$, $L^1-P(O)-(OR^{1'})_2$, or $L^1-S(O)_2-OR^{1'}$, wherein L^1 is a bond or alkylene, and $R^{1'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^2-O-C(O)-R^{2'}$, wherein L^2 is a bond or alkylene, and $R^{2'}$ is alkyl or hydroxyalkyl; $L^3-C(O)-NR^{3'}R^{4'}$, wherein L^3 is a bond or alkylene, and $R^{3'}$ and $R^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $L^4-NR^{5'}-C(O)-R^{6'}$, wherein L^4 is a bond or alkylene, $R^{5'}$ is hydrogen or alkyl, and $R^{6'}$ is alkyl or hydroxyalkyl; sulfamoyl; *N*-(alkyl)sulfamoyl; *N,N*-(dialkyl)sulfamoyl; sulfonamide; sulfate; alkylthio; thioalkyl; and a ring containing an alkylene or $-O-(CH_2)_m-O-$ formed by the joining together of any two R^1 or any two R^2 or an R^1 and an R^2 , wherein m is 1, 2, 3 or 4;

X is a phosphine of formula (Ie), or a salt thereof,



wherein

Q^1 is selected from the group consisting of a bond; $-O-$, $-S-$, $-N(R^{21})-$, $=C(R^{22})-$, and $-C(R^{23})(R^{24})-$;

Q^2 is selected from the group consisting of a bond, $-O-$, $-S-$, $-N(R^{25})-$, $=C(R^{26})-$, and $-C(R^{27})(R^{28})-$;

Q^3 is selected from the group consisting of a bond, $-O-$, $-S-$, $-N(R^{29})-$, $=C(R^{30})-$, and $-C(R^{32})(R^{30})-$;

Q^4 is selected from the group consisting of a bond, $-O-$, $-S-$, $-N(R^{33})-$, $=C(R^{34})-$, and $-C(R^{35})(R^{36})-$;

Q^5 is selected from the group consisting of a bond, $-O-$, $-S-$, $-N(R^{37})-$, $=C(R^{38})-$, and $-C(R^{39})(R^{40})-$; and at least one of Q^1 , Q^2 , Q^3 , Q^4 , and Q^5 is not a bond; or

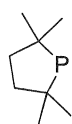
two of Q^1 , Q^2 , Q^3 , Q^4 , or Q^5 together form a carbonyl; an exocyclic double bond optionally substituted with alkyl, alkenyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; or a 3-8-membered spiro ring containing zero, one, or two hetero ring atoms, optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy;

as to R^{10} , R^{11} , R^{12} , and R^{13} ,

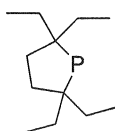
- i. R^{10} or R^{11} together with R^{12} or R^{13} form a ring; or
- ii. R^{10} and R^{11} together with the carbon atom to which they are attached form a spirocyclic ring and/or R^{12} and R^{13} together with the carbon atom to which they are attached form a spirocyclic ring; or
- iii. one or more of R^{10} , R^{11} , R^{12} and R^{13} form a ring together with a ring substituent of ring A; or
- iv. R^{10} , R^{11} , R^{12} , and R^{13} do not form a ring, wherein R^{10} , R^{11} , R^{12} and R^{13} are each independently selected from the group consisting of alkyl; alkenyl; haloalkyl; alkynyl; oxoalkyl; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocyclyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; thioalkyl; $L^{13}-C(O)-OR^{14'}$, $L^{13}-P(O)-(OR^{14'})_2$, or $L^{13}-S(O)_2-OR^{14'}$, wherein L^{13} is a bond or alkylene, and $R^{14'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^{15}-O-C(O)-R^{16'}$, wherein L^{15} is alkylene and $R^{16'}$ is alkyl or hydroxyalkyl; $L^{17}-C(O)-NR^{18'}R^{19'}$, wherein L^{17} is a bond or alkylene, and $R^{18'}$ and $R^{19'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; and $L^{20}-NR^{21'}-C(O)-R^{22'}$, wherein L^{20} is alkylene, $R^{21'}$ is hydrogen or alkyl, and $R^{22'}$ is alkyl or hydroxyalkyl; and

$R^{21}-R^{40}$ are, at each occurrence, independently selected from the group consisting of hydrogen, halo, fluoro, alkyl, haloalkyl, fluoroalkyl, alkenyl, alkynyl, alkyloxy, *N*-alkylamino, *N,N*-dialkylamino, *N,N,N*-trialkylammoniumalkyl; substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted heteroaryl, substituted or unsubstituted phenyl; hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; $L^1-C(O)-OR^{1'}$, $L^1-P(O)-(OR^{1'})_2$, or $L^1-S(O)_2-OR^{1'}$ where $R^{1'}$ is hydrogen, alkyl or hydroxyalkyl and L^1 is a bond or alkylene; $L^2-O-C(O)-R^{2'}$ where $R^{2'}$ is alkyl or hydroxyalkyl and L^2 is a bond or alkylene; $L^3-C(O)-NR^{3'}R^{4'}$ where $R^{3'}$ and $R^{4'}$ are independently selected from H, alkyl, and hydroxyalkyl and wherein L^3 is a bond or alkylene; $L^4-NR^{5'}-C(O)-R^{6'}$ wherein $R^{5'}$ is selected from H and alkyl, $R^{6'}$ is selected from alkyl and hydroxyalkyl, and L^4 is a bond or alkylene; and alkylthio; or additionally one or more of $R^{21}-R^{40}$ form a ring with another of R^{10} , R^{11} , R^{12} , R^{13} , and $R^{21}-R^{40}$.

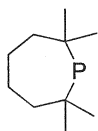
41. The compound according to claim 40, wherein X comprises a 4-membered ring.
42. The compound according to claim 40, wherein X comprises a 5-membered ring.
43. The compound according to claim 40, wherein X comprises a 7-membered ring or an 8-membered ring.
44. The compound according to claim 40, wherein R^{10} , R^{11} , R^{12} , and R^{13} are selected from the group consisting of alkyl, phenyl, and heteroaryl, or wherein R^{10} or R^{11} together with R^{12} or R^{13} form a ring.
45. The compound according to claim 40, wherein X is a phosphine having a structure corresponding to a formula selected from the group consisting of



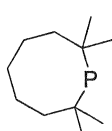
2-1



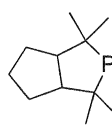
2-2



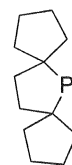
2-3



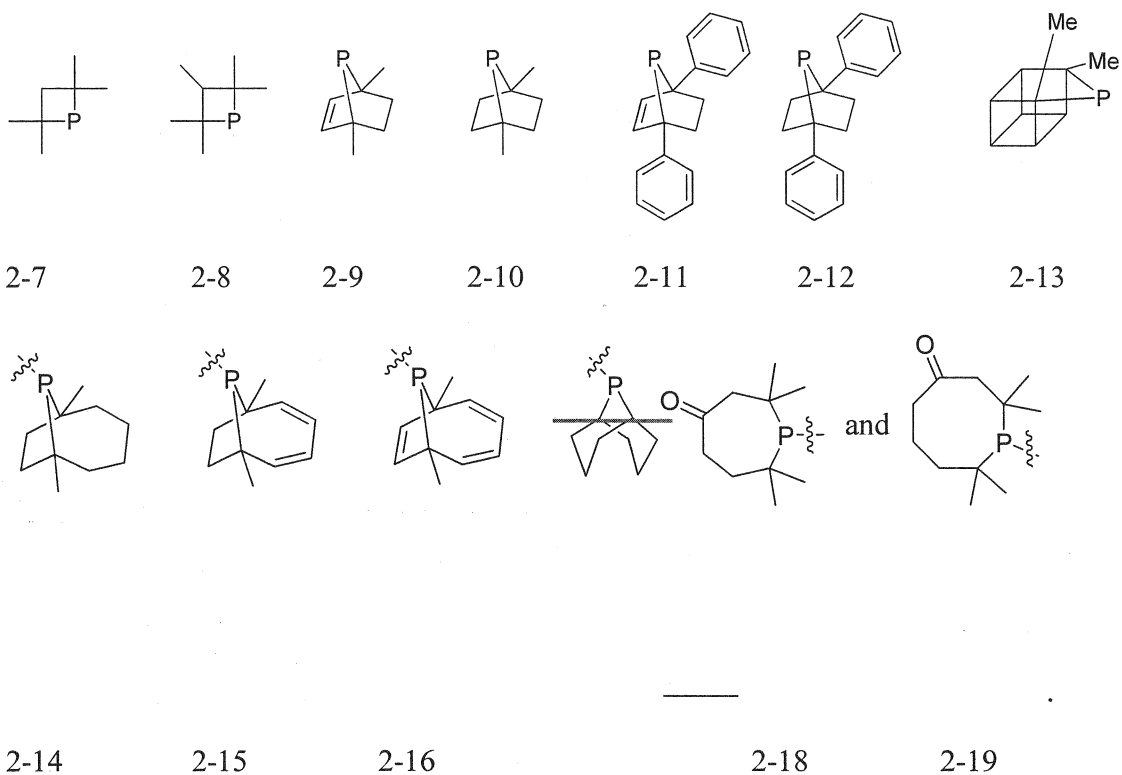
2-4



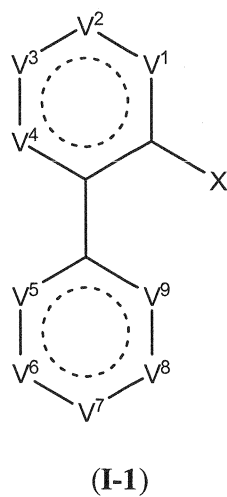
2-5



2-6



46. The compound of claim 40, said compound having a structure corresponding to formula (I-1),



or a salt thereof,

wherein

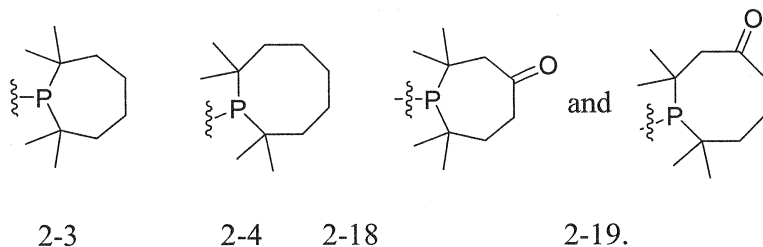
V^1 , V^2 , V^3 and V^4 are each CR^1 , wherein R^1 is, at each occurrence, hydrogen;

V⁵ and V⁹ are CR², wherein R² is independently, at each occurrence, hydrogen or alkyl;

V⁶ and V⁸ are CR², wherein R², at each occurrence, is hydrogen;

V⁷ is CR², wherein R² is hydrogen or alkyl; and

X is a phosphine having a structure corresponding to a formula selected from the group consisting of formulae 2-3, 2-4, 2-18, and 2-19



47. The compound of claim 46, wherein the compound is selected from the group consisting of:

1-(biphenyl-2-yl)-2,2,7,7-tetramethylphosphhepan-4-one;

1-(biphenyl-2-yl)-2,2,7,7-tetramethylphosphhepane;

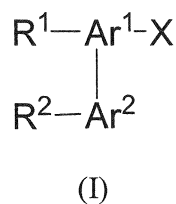
2,2,7,7-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphhepan-4-one;

2,2,7,7-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphhepane;

2,2,8,8-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphocan-4-one; and

2,2,8,8-tetramethyl-1-(2',4',6'-triisopropylbiphenyl-2-yl)phosphocane.

48. A compound having a structure corresponding to formula (I),



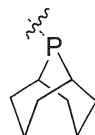
or a salt thereof,

wherein

Ar¹ and Ar² are each independently aryl or heteroaryl, and wherein Ar¹ and Ar² are each independently optionally substituted with one or more R¹ and R², respectively;

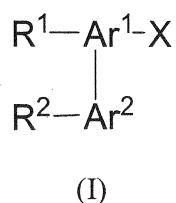
R^1 and R^2 are independently selected at each occurrence from the group consisting of hydrogen; amino; hydroxyl; cyano; halo; alkyl; alkenyl; alkynyl; haloalkyl; haloalkoxy; oxoalkyl; alkoxy; aryloxy; heteroaryloxy; arylamino; heteroarylamino; alkylamino; dialkylamino; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; cycloalkyloxy optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; 5- or 6-membered heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; hydroxyalkoxy; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; $L^1-C(O)-OR^{1'}$, $L^1-P(O)-(OR^{1'})_2$, or $L^1-S(O)_2-OR^{1'}$, wherein L^1 is a bond or alkylene, and $R^{1'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^2-O-C(O)-R^{2'}$, wherein L^2 is a bond or alkylene, and $R^{2'}$ is alkyl or hydroxyalkyl; $L^3-C(O)-NR^{3'}R^{4'}$, wherein L^3 is a bond or alkylene, and $R^{3'}$ and $R^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $L^4-NR^{5'}-C(O)-R^{6'}$, wherein L^4 is a bond or alkylene, $R^{5'}$ is hydrogen or alkyl, and $R^{6'}$ is alkyl or hydroxyalkyl; sulfamoyl; *N*-(alkyl)sulfamoyl; *N,N*-(dialkyl)sulfamoyl; sulfonamide; sulfate; alkylthio; thioalkyl; and a ring containing an alkylene or $-O-(CH_2)_m-O-$ formed by the joining together of any two R^1 or any two R^2 or an R^1 and an R^2 , wherein m is 1, 2, 3 or 4; and

X is a phosphine having a structure corresponding to formula 2-17



2-17.

49. A compound having a structure corresponding to formula (I),



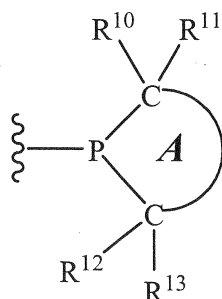
or a salt thereof,

wherein

Ar^1 and Ar^2 are each independently aryl or heteroaryl, and wherein Ar^1 and Ar^2 are each independently optionally substituted with one or more R^1 and R^2 , respectively;

R^1 and R^2 are independently selected at each occurrence from the group consisting of hydrogen; amino; hydroxyl; cyano; halo; alkyl; alkenyl; alkynyl; haloalkyl; haloalkoxy; oxoalkyl; alkoxy; aryloxy; heteroaryloxy; arylamino; heteroarylamino; alkylamino; dialkylamino; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; cycloalkyloxy optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; 5- or 6-membered heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; hydroxyalkoxy; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; $\text{L}^1\text{-C(O)-OR}^{1'}$, $\text{L}^1\text{-P(O)-(OR}^{1'})_2$, or $\text{L}^1\text{-S(O)}_2\text{-OR}^{1'}$, wherein L^1 is a bond or alkylene, and $\text{R}^{1'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $\text{L}^2\text{-O-C(O)-R}^{2'}$, wherein L^2 is a bond or alkylene, and $\text{R}^{2'}$ is alkyl or hydroxyalkyl; $\text{L}^3\text{-C(O)-NR}^{3'}\text{R}^{4'}$, wherein L^3 is a bond or alkylene, and $\text{R}^{3'}$ and $\text{R}^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $\text{L}^4\text{-NR}^{5'}\text{-C(O)-R}^{6'}$, wherein L^4 is a bond or alkylene, $\text{R}^{5'}$ is hydrogen or alkyl, and $\text{R}^{6'}$ is alkyl or hydroxyalkyl; sulfamoyl; *N*-(alkyl)sulfamoyl; *N,N*-(dialkyl)sulfamoyl; sulfonamide; sulfate; alkylthio; thioalkyl; and a ring containing an alkylene or $\text{-O-(CH}_2)_m\text{-O-}$ formed by the joining together of any two R^1 or any two R^2 or an R^1 and an R^2 , wherein m is 1, 2, 3 or 4;

X is a phosphine of formula (Ia):



wherein ring *A* includes 0 to 9 ring atoms in addition to the phosphorus and 2 carbon ring atoms of formula (Ia), wherein said ring atoms are each independently selected from the group consisting of carbon, oxygen, nitrogen, phosphorus and sulfur; and

wherein the ring atoms of ring *A* are each independently optionally substituted with one or more substituents selected from the group consisting of alkenyl; alkoxy; alkoxyalkyl; alkyl; alkylamino; alkylthio; alkynyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; arylalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; cycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; dialkylamino; halo; haloalkyl; fluoroalkyl; heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocycloalkyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxy; hydroxyalkyl; oxo; an exocyclic double bond optionally substituted with alkyl, alkenyl, alkynyl, aryl, cycloalkyl, heterocyclyl, or heteroaryl; a 3- to 7-membered spiro ring containing zero, one, or two heteroatoms; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; $L^1-C(O)-OR^{1'}$, $L^1-P(O)-(OR^{1'})_2$, or $L^1-S(O)_2-OR^{1'}$, wherein L^1 is a bond or alkylene, and $R^{1'}$ is selected from the group consisting of hydrogen, alkyl or hydroxyalkyl; $L^2-O-C(O)-R^{2'}$, wherein L^2 is a bond or alkylene, and $R^{2'}$ is alkyl or hydroxyalkyl; $L^3-C(O)-NR^{3'}R^{4'}$, wherein L^3 is a bond or alkylene, and $R^{3'}$ and $R^{4'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; $L^4-NR^{5'}-C(O)-R^{6'}$, wherein L^4 is a bond or alkylene, $R^{5'}$ is hydrogen or alkyl, and $R^{6'}$ is alkyl or hydroxyalkyl; and $L^7-NR^{8'}-S(O)_2-R^{9'}$, wherein L^7 is a bond or alkylene, $R^{8'}$ is hydrogen or alkyl, and $R^{9'}$ is alkyl or hydroxyalkyl; and

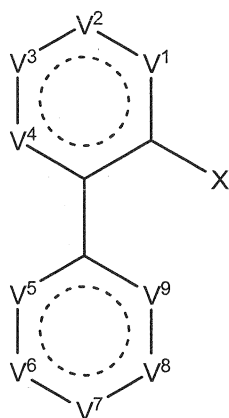
as to R^{10} , R^{11} , R^{12} , and R^{13} ,

- i. R^{10} or R^{11} together with R^{12} or R^{13} form a ring; or
- ii. R^{10} and R^{11} together with the carbon atom to which they are attached form a spirocyclic ring and/or R^{12} and R^{13} together with the carbon atom to which they are attached form a spirocyclic ring;

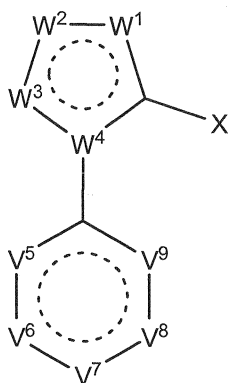
wherein, any of substituents R^{10} , R^{11} , R^{12} , and R^{13} that do not form the ring set forth in (i) or (ii) are each independently selected from the group consisting of hydrogen; alkyl; alkenyl; haloalkyl; alkynyl; oxoalkyl; cycloalkyl optionally substituted with alkyl,

alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heterocyclyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; heteroaryl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; phenyl optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy; hydroxyalkyl; alkoxyalkyl; aminoalkyl; *N*-alkylaminoalkyl; *N,N*-dialkylaminoalkyl; *N,N,N*-trialkylammoniumalkyl; thioalkyl; $L^{13}-C(O)-OR^{14'}$, $L^{13}-P(O)-(OR^{14'})_2$, or $L^{13}-S(O)_2-OR^{14'}$, wherein L^{13} is a bond or alkylene, and $R^{14'}$ is selected from the group consisting of hydrogen, alkyl and hydroxyalkyl; $L^{15}-O-C(O)-R^{16'}$, wherein L^{15} is alkylene and $R^{16'}$ is alkyl or hydroxyalkyl; $L^{17}-C(O)-NR^{18'}R^{19'}$, wherein L^{17} is a bond or alkylene, and $R^{18'}$ and $R^{19'}$ are each independently selected from the group consisting of hydrogen, alkyl, and hydroxyalkyl; and $L^{20}-NR^{21'}-C(O)-R^{22'}$, wherein L^{20} is alkylene, $R^{21'}$ is hydrogen or alkyl, and $R^{22'}$ is alkyl or hydroxyalkyl.

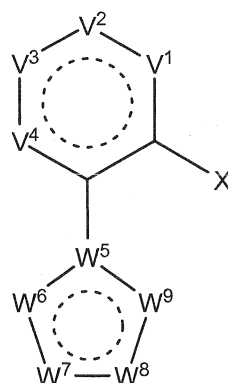
50. The compound according to claim 49, said compound having a structure corresponding to a structure of a formula selected from the group consisting of formulae (I-1) - (I-42), or a salt thereof:



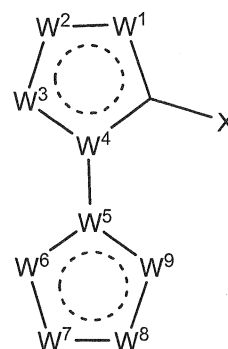
(I-1)



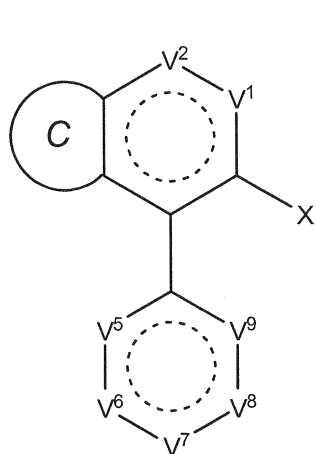
(I-2)



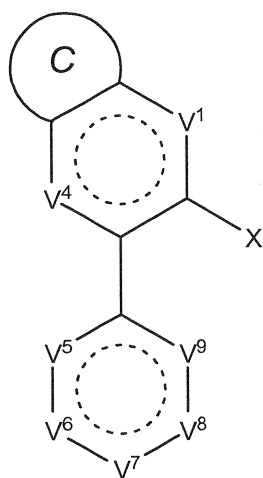
(I-3)



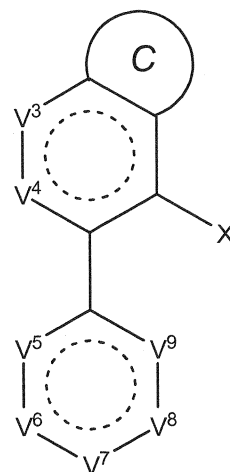
(I-4)



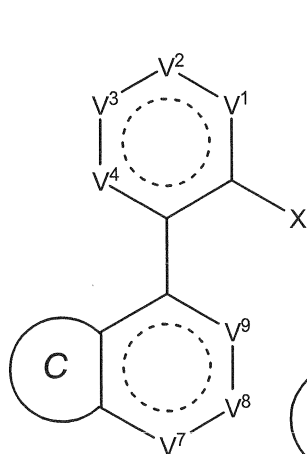
(I-5)



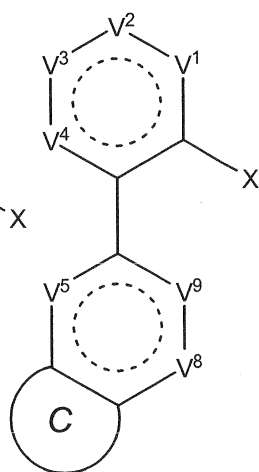
(I-6)



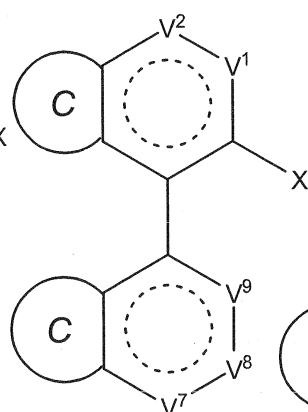
(I-7)



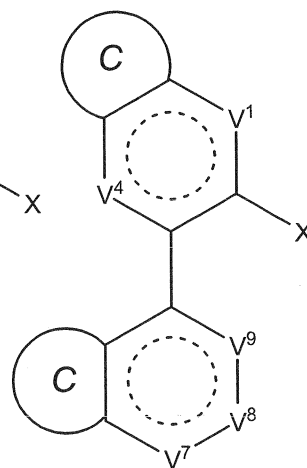
(I-8)



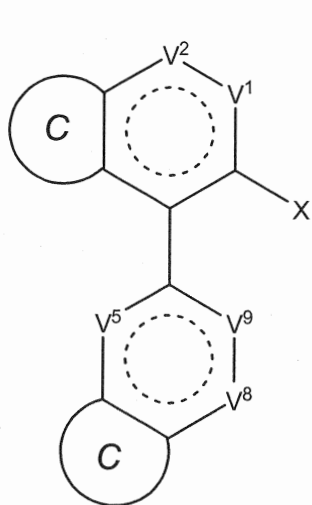
(I-9)



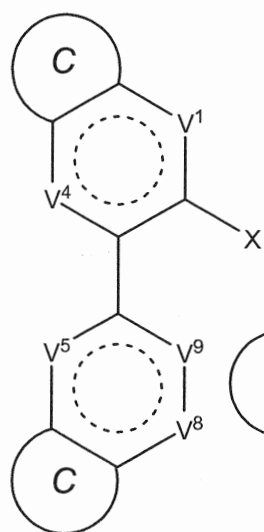
(I-10)



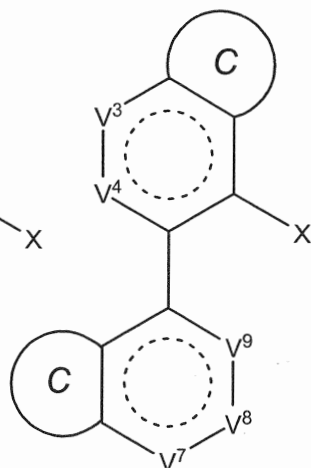
(I-11)



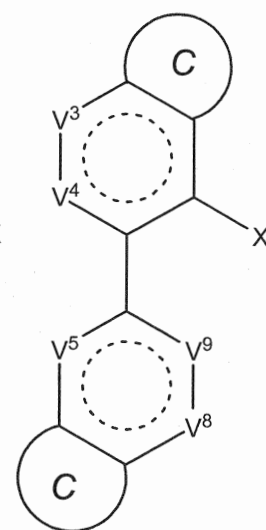
(I-12)



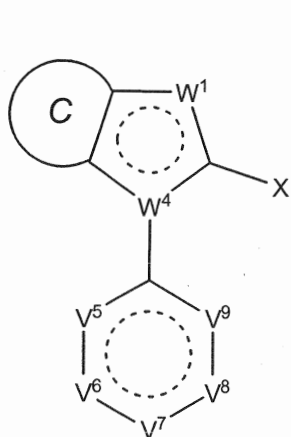
(I-13)



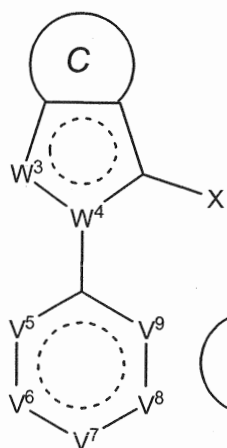
(I-14)



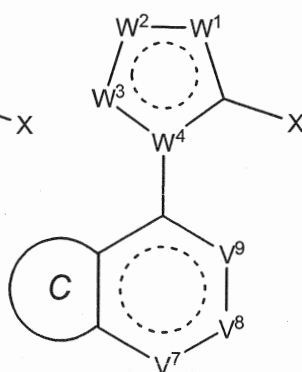
(I-15)



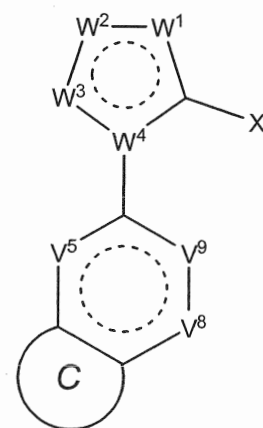
(I-16)



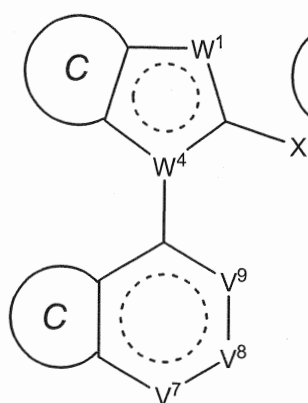
(I-17)



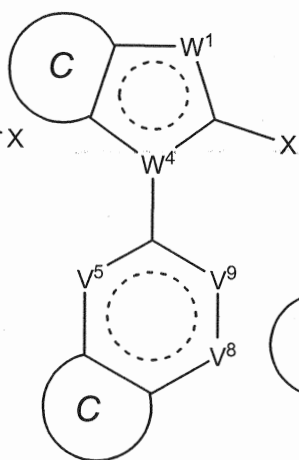
(I-18)



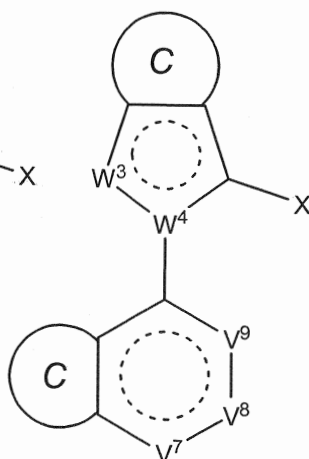
(I-19)



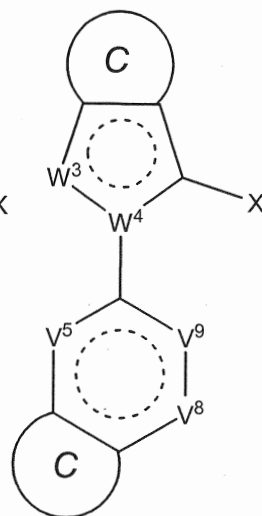
(I-20)



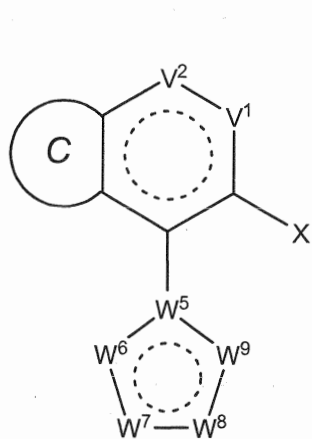
(I-21)



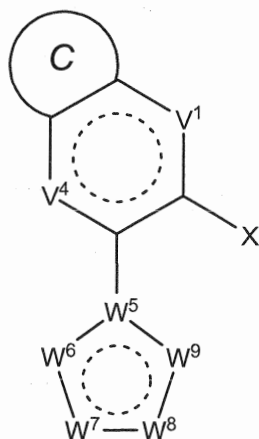
(I-22)



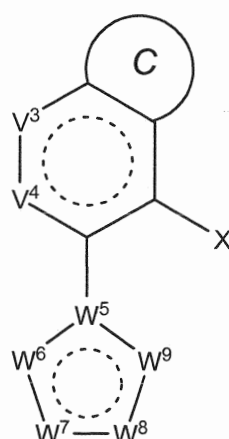
(I-23)



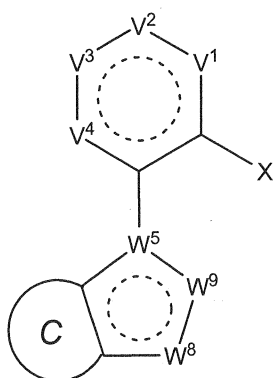
(I-24)



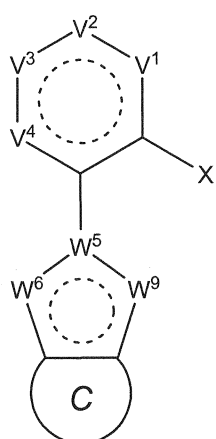
(I-25)



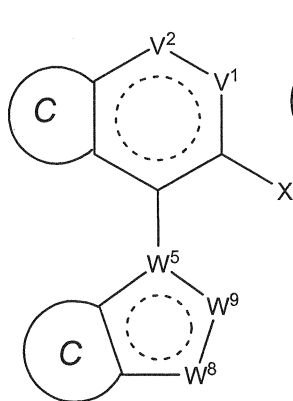
(I-26)



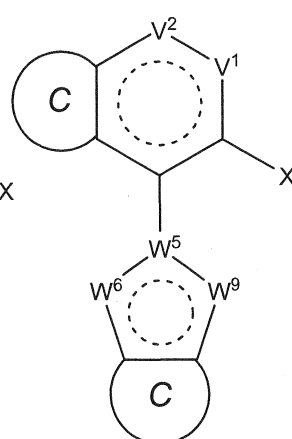
(I-27)



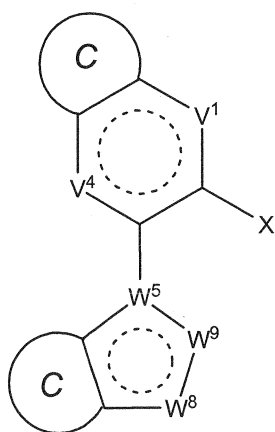
(I-28)



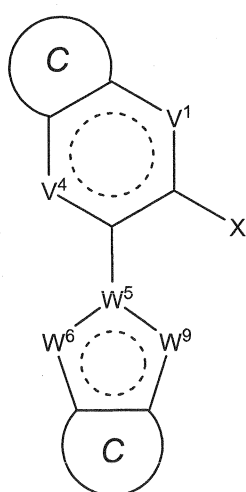
(I-29)



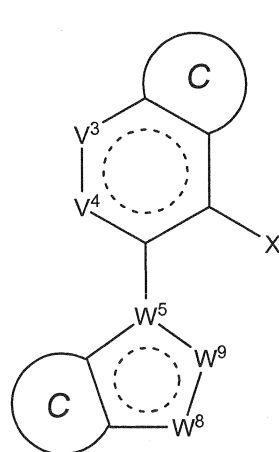
(I-30)



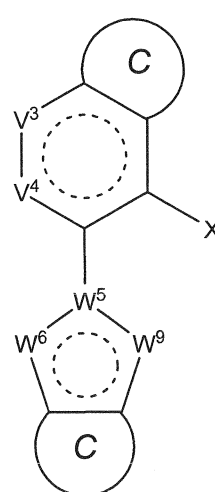
(I-31)



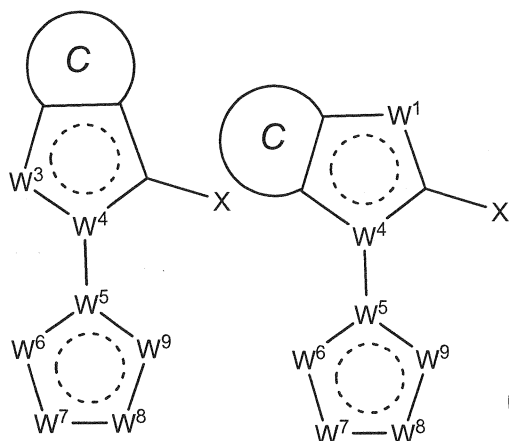
(I-32)



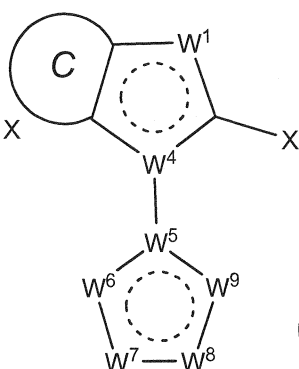
(I-33)



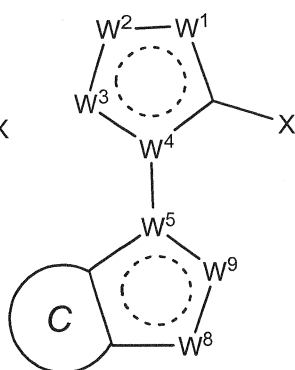
(I-34)



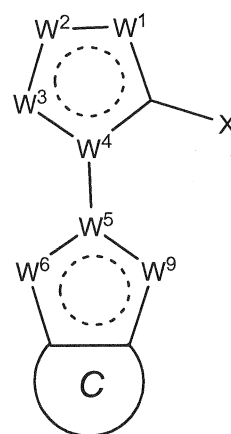
(I-35)



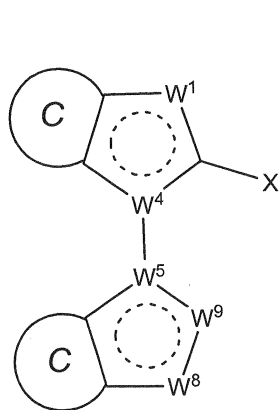
(I-36)



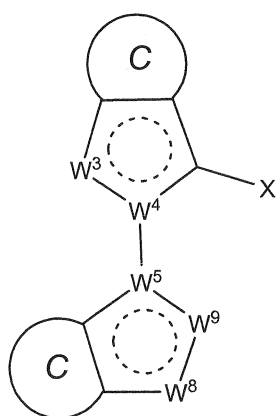
(I-37)



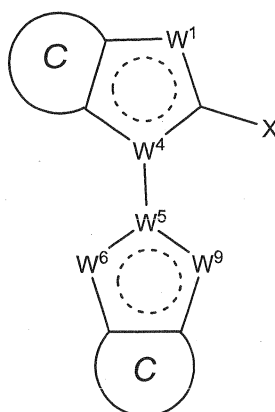
(I-38)



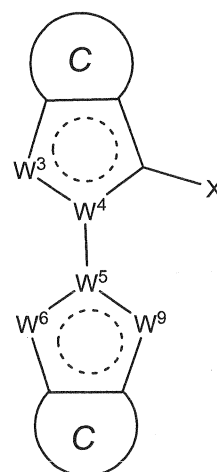
(I-39)



(I-40)



(I-41), and



(I-42)

wherein

V^1 , V^2 , V^3 , and V^4 are each independently CR^1 or N;

V^5 , V^6 , V^7 , V^8 and V^9 are each independently CR^2 or N;

W^1 , W^2 , and W^3 are each independently selected from the group consisting of CR^1 , NR^1 , N and O;

W^4 is C or N;

W^5 is C or N;

W^6 , W^7 , W^8 and W^9 are each independently selected from the group consisting of CR^2 , NR^2 , N and O; and

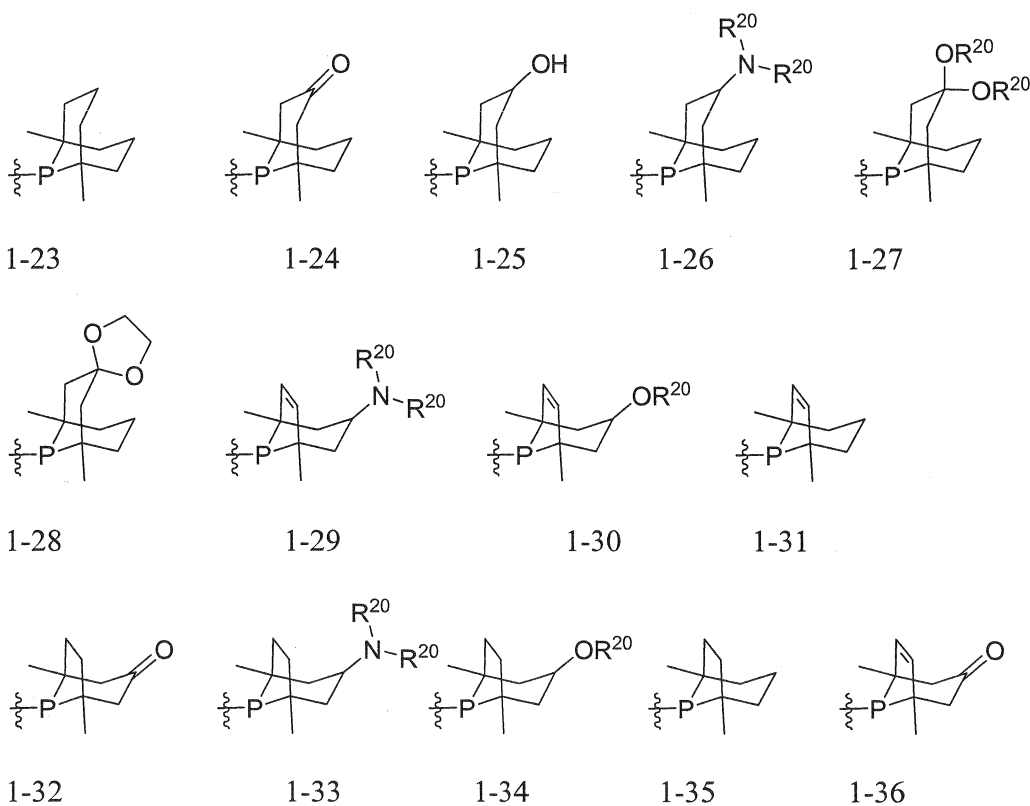
ring C, at each occurrence, is a fused-aryl or fused-heteroaryl and is optionally substituted with R^1 and R^2 .

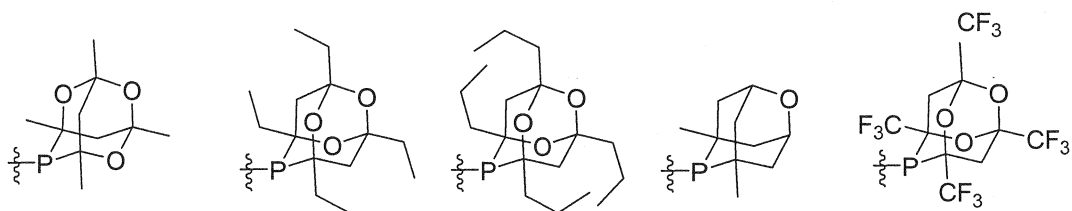
51. The compound according to any one of claims 49-50, wherein ring A is a 4-, 5-, 6-, 7-, or 8-membered ring, and wherein each of the ring atoms in addition to the phosphorus and 2 carbon ring atoms of formula (Ia) are carbon.

52. The compound according to claim 49, wherein ring A of formula (Ia) is bicyclic.

53. The compound according to claim 49, wherein ring A of formula (Ia) is tricyclic.

54. The compound according to claim 49, wherein X is a phosphine having a structure corresponding to a formula selected from the group consisting of:





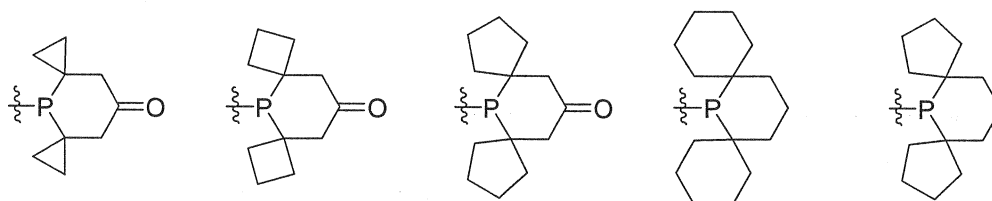
1-37

1-38

1-39

1-40

1-41



1-45

1-46

1-47

1-48, and

1-49

or a salt thereof, wherein R^{20} is hydrogen, alkyl, aryl, heteroaryl, arylalkyl or heteroarylalkyl, wherein the aryl, heteroaryl, aryl of arylalkyl and heteroaryl of heteroarylalkyl are optionally substituted with alkyl, alkenyl, alkynyl, alkoxy, cyano, halo, haloalkyl or haloalkoxy.

55. 7,7,9,9-tetramethyl-8-(2',4',6'-triisopropyl-3,6-dimethoxybiphenyl-2-yl)-1,4-dioxa-8-phospha-spiro[4.5]decane.

56. A catalyst composition comprising a transition metal catalyst precursor and a compound according to any one of claims 1-55.

57. The catalyst composition according to claim 56, wherein the transition metal catalyst precursor is selected from the group consisting of palladium, rhodium, ruthenium, platinum, gold, cobalt, iridium, copper and nickel.

58. The catalyst composition according to claim 57, wherein the transition metal catalyst precursor contains palladium.

59. A catalyst composition comprising a palladium catalyst precursor and a compound according to claim 8.

60. A catalyst composition comprising a palladium catalyst precursor and a compound according to claim 18.

61. A catalyst composition comprising a palladium catalyst precursor and a compound according to claim 37.

62. A catalyst composition comprising a palladium catalyst precursor and 7,7,9,9-tetramethyl-8-(2',4',6'-triisopropyl-3,6-dimethoxybiphenyl-2-yl)-1,4-dioxo-8-phosphaspiro[4.5]decane.

63. A heterogeneous catalyst composition comprising a compound according to any one of claims 1-55 covalently bonded to a solid catalyst support.

64. A method for synthesizing a secondary organic sulfonamide, comprising reacting an aryl nonaflate with a primary sulfonamide in the presence of a palladium catalyst precursor and at least one compound selected from the compounds of any one of claims 1-55.

65. A method of performing a bond-forming reaction comprising catalyzing said reaction with a compound of formula (I), wherein the bond-forming reaction is selected from the group consisting of carbon-nitrogen, carbon-oxygen, carbon-carbon, carbon-sulfur, carbon-phosphorus, carbon-boron, carbon-fluorine and carbon-hydrogen.

66. A method of forming a bond in a chemical reaction comprising catalyzing said reaction with a compound of formula (I), wherein the bond is selected from the group consisting of a carbon-nitrogen bond, a carbon-oxygen bond, a carbon-carbon bond, a carbon-sulfur bond, a carbon-phosphorus bond, a carbon-boron bond, a carbon-fluorine bond and a carbon-hydrogen bond.

67. A method of preparing phosphacycles of formula (I) comprising:
metalation of a biaryl halide to form a biaryl lithium species;
reacting a chlorophosphate with said biaryl lithium species to form a biaryl phosphonate;
reduction of second product to form primary phosphine; and
reacting primary phosphine with a divinylketone.