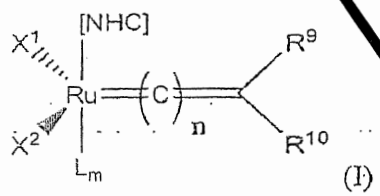
The claimed invention is:

1. A ruthenium alkylidene complex having an *N*-heterocyclic carbene ligand comprising a 5-membered heterocyclic ring having a carbenic carbon atom and at least one nitrogen atom contained within the 5-membered heterocyclic ring, wherein the nitrogen atom is directly attached to the carbenic carbon atom and is substituted by a phenyl ring, and wherein the phenyl ring has a hydrogen at either or both ortho positions and is substituted at at least one ortho or meta position.

2. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst of formula (I):



(I)

wherein:

X^1 and X^2 are independently anionic ligands;

n is 0, 1 or 2;

R^9 and R^{10} are each independently hydrogen or a substituted or unsubstituted substituent selected from the group consisting of C_1-C_{20} alkyl, C_2-C_{20} alkenyl, C_2-C_{20} alkynyl, aryl, C_1-C_{20} carboxylate, C_1-C_{20} alkoxy, C_2-C_{20} alkenyloxy, C_2-C_{20} alkynyloxy, aryloxy, C_2-C_{20} alkoxycarbonyl, C_1-C_{20} alkylthio, C_1-C_{20} alkylsulfonyl, and C_1-C_{20} alkylsulfinyl; or R^9 and R^{10} may optionally be linked together to form a cyclic structure via one of the listed substituents;

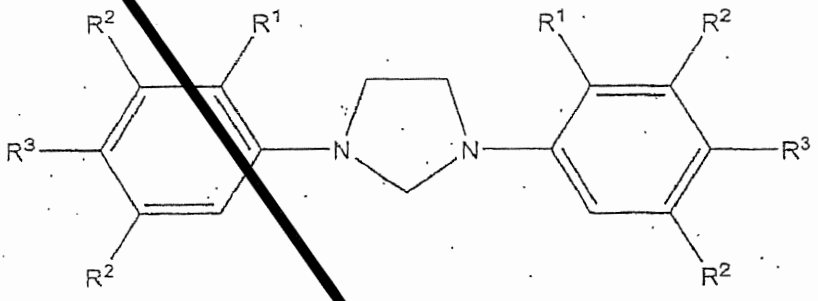
m is 1 or 2;

when m is 1, L is a neutral 2-electron donor ligand and may optionally be linked to R^{10} forming a chelating carbene ligand when n is zero;

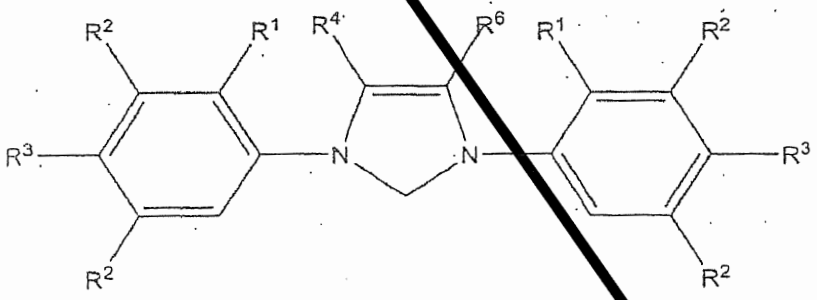
when m is 2, L is a heteroarene ligand; and

NHC is an *N*-heterocyclic carbene ligand comprising a 5-membered heterocyclic ring having a carbenic carbon atom and at least one nitrogen atom contained within the 5-membered heterocyclic ring, wherein the nitrogen atom is directly attached to the carbenic carbon atom and is substituted by a phenyl ring, and wherein the phenyl ring has a hydrogen at either or both ortho positions and is substituted at at least one ortho or meta position.

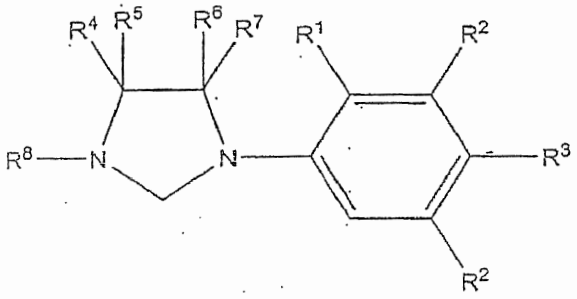
3. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 2, wherein the NHC ligand is selected from a ligand of formula of formulas (II)-(V):



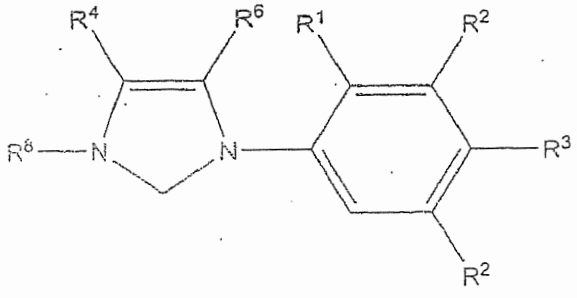
(II)



(III)



(IV)



(V)

wherein

R^1, R^2, and R^3 are either:

a) each R^1 is independently a primary or secondary C_1-C_4 alkyl group; each R^2 is independently H, a substituted or unsubstituted C_1-C_{10} alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl; and each R^3 is independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl, or a functional group selected from the group consisting of halo, hydroxyl, sulfhydryl, cyano, cyanato, thiocyanato, amino, nitro, nitroso, sulfo, sulfonato, boryl, borono, phosphono, phosphonato, phosphinato, phospho, phosphino, and silyloxy; or

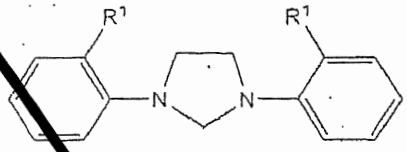
b) R^1 is H; each R^2 is independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl; and each R^3 is independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl or a functional group selected from the group consisting of halo, hydroxyl, sulfhydryl, cyano, cyanato, thiocyanato, amino, nitro, nitroso, sulfo, sulfonato, boryl, borono, phosphono, phosphonato, phosphinato, phospho, phosphino, and silyloxy; with the provisos that both R^2 substituents on the same phenyl ring are not H.

R^4 and R^6 are each independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted aryl, or in formulas (III) and (V) together with the carbons carrying them form a substituted or unsubstituted, fused 4-8 membered carbocylic ring or a substituted or unsubstituted, fused aromatic ring;

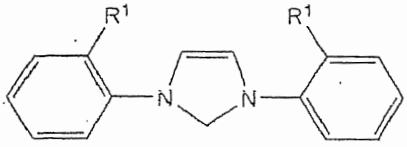
R^5 and R^7 are independently H, a substituted or unsubstituted C_1-C_8 alkyl group; and

R^8 is a C_1-C_{12} alkyl or a C_3-C_{12} cycloalkyl.

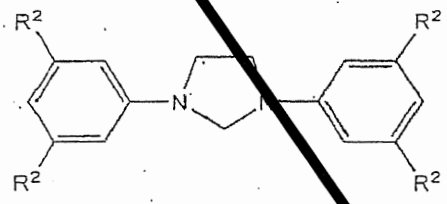
4. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 3, wherein the NHC ligand is selected from the group consisting of



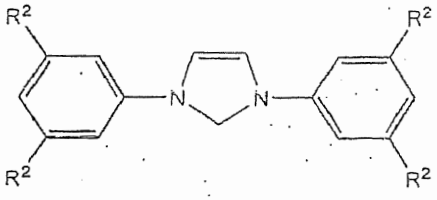
where R^1 is methyl, ethyl, propyl, or isopropyl;



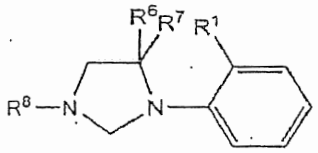
where R^1 ismethyl, ethyl, propyl, or isopropyl;



where R^2 is tert-butyl;

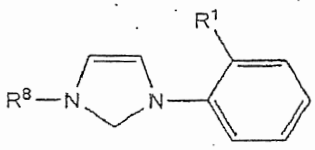


where R^2 is tert-butyl;



nd

where R^1 is methyl, ethyl, propyl,or isopropyl; R^6 and R^7 are hydrogen or methyl; and R^8 is methyl;



where R^1 is methyl, ethyl, propyl, or isopropyl; and R^8 is methyl.

5. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 2, 3, or 4, wherein:

X^1 and X^2 are halide, or a substituted or unsubstituted group selected from the group consisting of benzoate, C_1-C_5 carboxylate, C_1-C_5 alkyl, phenoxy, C_1-C_5 alkoxy, C_1-C_5 alkylthio, aryl, and C_1-C_5 alkyl sulfonate;

n is 0 or 1;

R^9 is hydrogen, C_1-C_5 alkyl or aryl;

R^{10} is a substituted or unsubstituted group selected from the group consisting of C_1-C_{20} alkyl, C_2-C_{20} alkenyl, and aryl;

m is 1; and

L is selected from the group consisting of phosphine, sulfonated phosphine, phosphite, phosphinite, phosphonite, arsine, stibine, ether, amine, amide, imine, sulfoxide, carboxyl,

nitrosyl, pyridine, and thioether, or is linked to R^{10} forming a chelating carbene ligand when n is 0.

6. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 5, wherein:

X^1 and X^2 are each halide, CF_3CO_2, CH_3CO_2, CFH_2CO_2, $(CH_3)_3CO$, $(CF_3)_2(CH_3)CO$, $(CF_3)(CH_3)_2CO$, PhO, MeO, EtO, tosylate, mesylate, or trifluoromethanesulfonate;

n is 0 or 1;

R^9 is hydrogen, C_1-C_5 alkyl or aryl;

R^{10} is a substituted or unsubstituted group selected from the group consisting of C_1-C_{20} alkyl, C_2-C_{20} alkenyl, and aryl;

m is 1; and

L is a phosphine of the formula PR'R''R''', where R', R'', and R''' are each independently aryl, C_1-C_{10} alkyl, or C_3-C_6 cycloalkyl, or is linked to R^{10} forming a chelating carbene ligand when n is 0.

7. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 6, wherein:

X^1 and X^2 are each chloride.

n is 0;

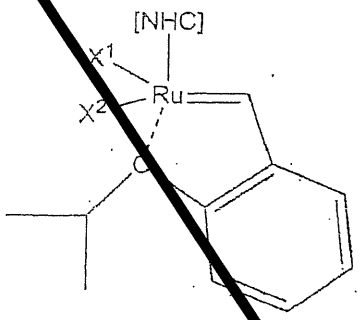
R^9 is hydrogen;

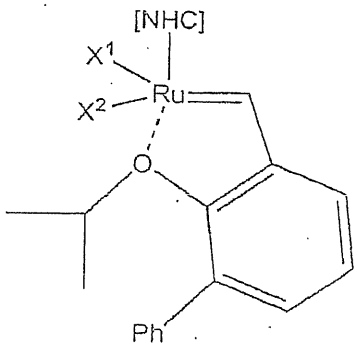
R^{10} is phenyl, vinyl or $-C=C(CH_3)_2$;

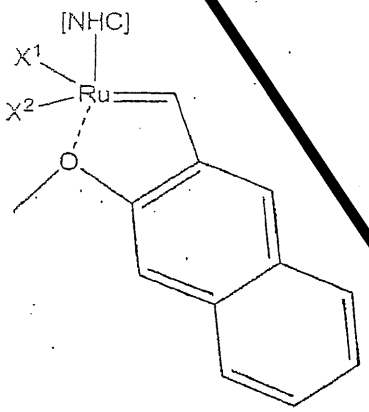
m is 1; and

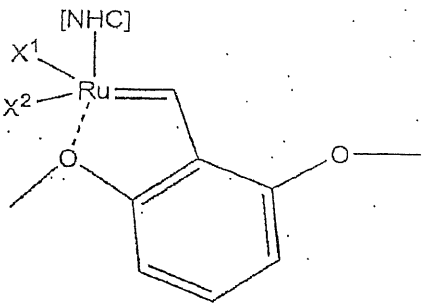
L is selected from the group consisting of P(cyclohexyl)$_3$, P(cyclopentyl)$_3$, P(isopropyl)$_3$, and P(phenyl)$_3$, or is linked to R^{10} forming a chelating carbene ligand.

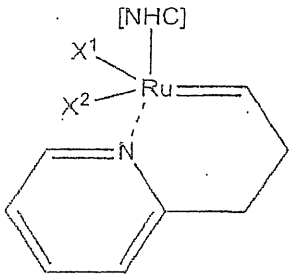
8. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 7, wherein the catalyst of formula (I) is selected from the group consisting of:

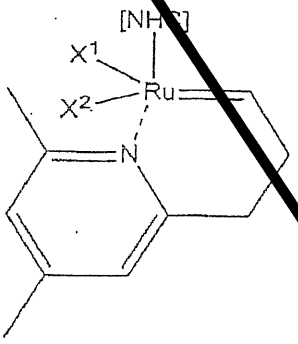




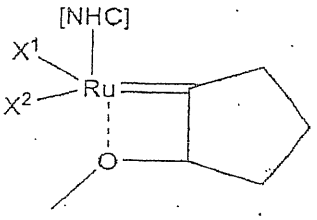




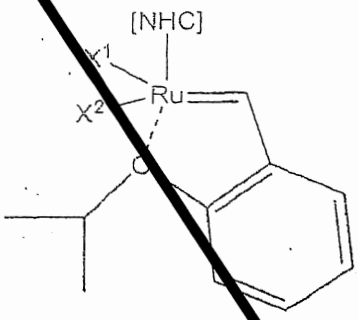


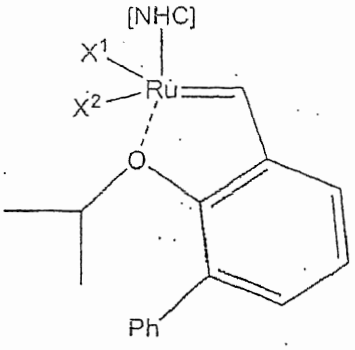


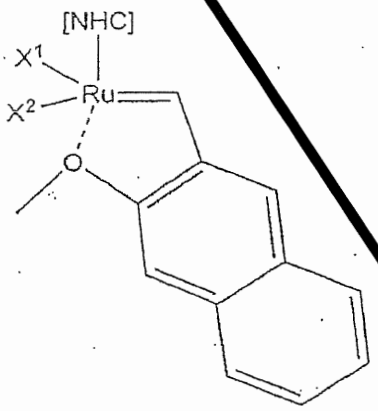
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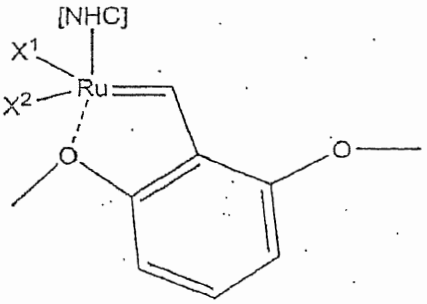


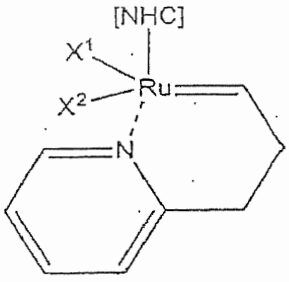
9. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 5, wherein the catalyst of formula (I) is selected from the group consisting of:

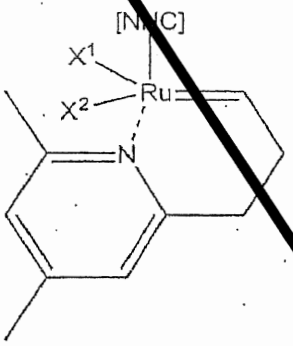




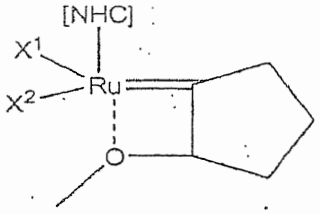








and



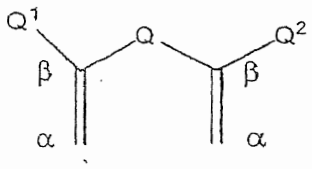
10. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 7, wherein L is selected from the group consisting of P(cyclohexyl)$_3$, P(cyclopentyl)$_3$, P(isopropyl)$_3$, and P(phenyl)$_3$.

11. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 5, wherein L is selected from the group consisting of P(cyclohexyl)$_3$, P(cyclopentyl)$_3$, P(isopropyl)$_3$, and P(phenyl)$_3$.

12. A ring-closing metathesis method for preparing a tetrasubstituted cyclic olefin comprising the step of:

contacting an olefinic compound having at least two terminal olefins which are substituted at the beta-carbon of each terminal olefin with an *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst of claims 1, 2, 3, or 4 under metathesis conditions to form a cyclic tetra-substituted olefin.

13. A ring-closing metathesis reaction of claim 12 wherein the olefinic compound is a compound of formula (VI)



(VI).

wherein

Q is selected from the group consisting of hydrocarbylene, substituted hydrocarbylene, heteroatom-containing hydrocarbylene, and substituted heteroatom-containing hydrocarbylene; and

Q^1 and Q^2 are independently selected from the group consisting of hydrocarbyl, substituted hydrocarbyl, heteroatom-containing hydrocarbyl, substituted heteroatom-containing hydrocarbyl, halide, hydroxyl, sulfhydryl, cyano, cyanato, thiocyanato, amino, nitro, nitroso, sulfo, sulfonato, boryl, borono, phosphono, phosphonato, phosphinato, phospho, phosphino, and silyloxy, wherein the substituted hydrocarbyl and substituted heteroatom-containing hydrocarbyl are substituted with at least one member selected from the group consisting of alkyl, aryl, halide, hydroxyl, sulfhydryl, cyano, cyanato, thiocyanato, amino, nitro, nitroso, sulfo, sulfonato, boryl, borono, phosphono, phosphonato, phosphinato, phospho, phosphino, and silyloxy.

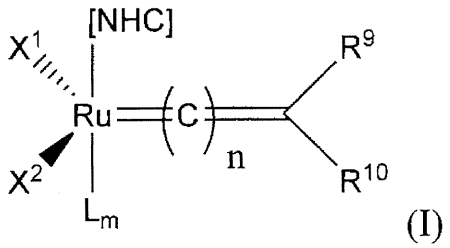
14 An olefin metathesis reaction comprising the step of:

contacting an olefin with an *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 1, 2, 3, or 4 under metathesis conditions.

15 A cross-metathesis reaction comprising the step of contacting an olefin and a tri-substituted olefin or a di-substituted olefin having further substitution at the allylic carbon with an *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim which claims 1, 2, 3, or 4 under metathesis conditions.

CLAIMS

1. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst of formula (I):



(I)

wherein:

X^1 and X^2 are independently anionic ligands;

n is 0, 1 or 2;

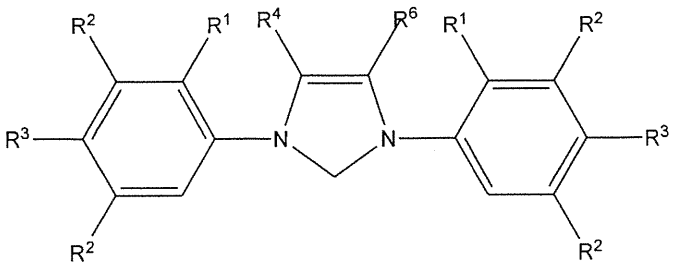
R^9 and R^{10} are each independently hydrogen or a substituted or unsubstituted substituent selected from the group consisting of C_1-C_{20} alkyl, C_2-C_{20} alkenyl, C_2-C_{20} alkynyl, aryl, C_1-C_{20} carboxylate, C_1-C_{20} alkoxy, C_2-C_{20} alkenyloxy, C_2-C_{20} alkynyloxy, aryloxy, C_2-C_{20} alkoxycarbonyl, C_1-C_{20} alkylthio, C_1-C_{20} alkylsulfonyl and C_1-C_{20} alkylsulfinyl; or R^9 and R^{10} may optionally be linked together to form a cyclic structure via one of the listed substituents;

m is 1 or 2;

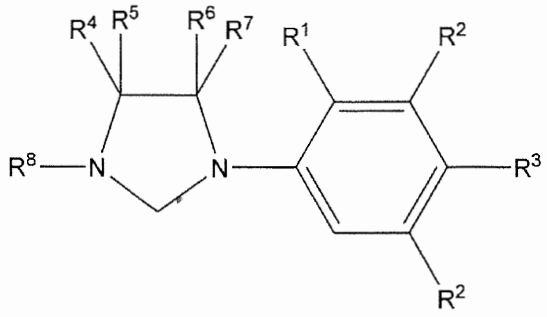
when m is 1, L is a neutral 2-electron donor ligand and may optionally be linked to R^{10} forming a chelating carbene ligand when n is zero;

when m is 2, L is a heteroarene ligand; and

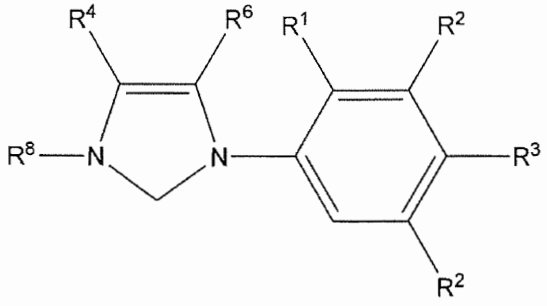
NHC is an N-heterocyclic carbene ligand selected from formulas (III)-(V):



(III)



(IV)



(V)

wherein

R^1, R^2, and R^3 are either:

a) each R^1 is independently a primary or secondary C_1-C_4 alkyl group; each R^2 is independently H, a substituted or unsubstituted C_1-C_{10} alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl; and each R^3 is independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl, or a functional group selected from the group consisting of halo, hydroxyl, sulfhydryl, cyano, cyanato, thiocyanato, amino, nitro, nitroso, sulfo, sulfonato, boryl, borono, phosphono, phosphonato, phosphinato, phospho, phosphino, and silyloxy; or

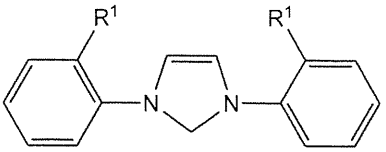
b) R^1 is H; each R^2 is independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl; and each R^3 is independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl or a functional group selected from the group consisting of halo, hydroxyl, sulfhydryl, cyano, cyanato, thiocyanato, amino, nitro, nitroso, sulfo, sulfonato, boryl, borono, phosphono, phosphonato, phosphinato, phospho, phosphino, and silyloxy; with the provisos that both R^2 substituents on the same phenyl ring are not H;

R^4 and R^6 are each independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted aryl, or in formulas (III) and (V), together with the carbons carrying them, form a substituted or unsubstituted, fused 4-8 membered carbocylic ring or a substituted or unsubstituted, fused aromatic ring;

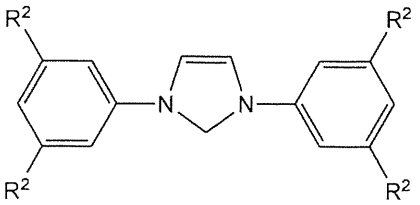
R^5 and R^7 are independently H, a substituted or unsubstituted C_1-C_8 alkyl group; and

R^8 is a C_1-C_{12} alkyl or a C_3-C_{12} cycloalkyl.

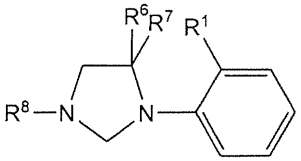
2. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 1, wherein the NHC ligand is selected from the group consisting of



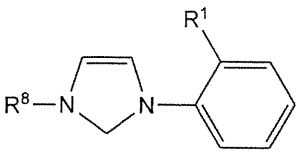
where R^1 ismethyl, ethyl, propyl, or isopropyl;



where R^2 is tert-butyl;



and



where R^1 is methyl, ethyl, propyl or isopropyl; R^6 and R^7 are hydrogen or methyl; and R^8 is methyl;

where R^1 is methyl, ethyl, propyl, or isopropyl; and R^8 is methyl.

3. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claims 1 or 2, wherein:

X^1 and X^2 are halide, or a substituted or unsubstituted group selected from the group consisting of benzoate, C_1-C_5 carboxylate, C_1-C_5 alkyl, phenoxy, C_1-C_5 alkoxy, C_1-C_5 alkylthio, aryl, and C_1-C_5 alkyl sulfonate;

n is 0 or 1;

R^9 is hydrogen, C_1-C_5 alkyl or aryl;

R^{10} is a substituted or unsubstituted group selected from the group consisting of C_1-C_{20} alkyl, C_2-C_{20} alkenyl, and aryl;

m is 1; and

L is selected from the group consisting of phosphine, sulfonated phosphine, phosphite, phosphinite, phosphonite, arsine, stibine, ether, amine, amide, imine, sulfoxide, carboxyl, nitrosyl, pyridine, and thioether, or is linked to R^{10} forming a chelating carbene ligand when n is 0.

4. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 3, wherein:

X^1 and X^2 are each halide, CF_3CO_2, CH_3, CO_2, CFH_2CO_2, $(CH_3)_3CO$, $(CF_3)_2$ $(CH_3)CO$, $(CF_3)(CH_3)_2CO$, PhO, MeO, EtO, tosylate, mesylate, or trifluoromethanesulfonate;

n is 0 or 1;

R^9 is hydrogen, C_1-C_5 alkyl or aryl;

R^{10} is a substituted or unsubstituted group selected from the group consisting of C_1-C_{20} alkyl, C_2-C_{20} alkenyl, and aryl;

m is 1; and

L is a phosphine of the formula PR′R″R‴, where R′, R″, and R‴ are each independently aryl, C_1-C_{10} alkyl, or C_3-C_6 cycloalkyl, or is linked to R^{10} forming a chelating carbene ligand when n is 0.

5. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 4, wherein:

X^1 and X^2 are each chloride;

n is 0;

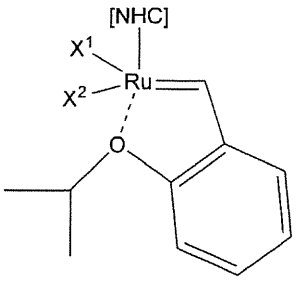
R^9 is hydrogen;

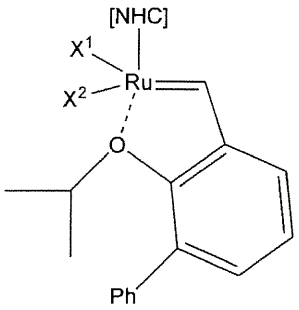
R^{10} is phenyl, vinyl or —C=C$(CH_3)_2$;

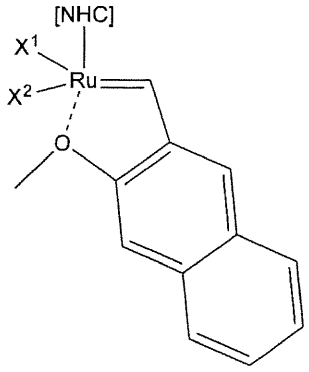
m is 1; and

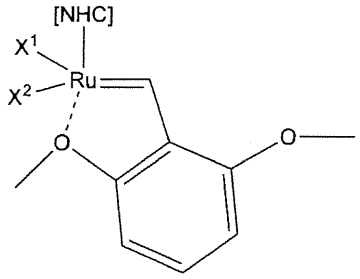
L is selected from the group consisting of P(cyclohexyl)$_3$, P(cyclopentyl)$_3$, P(isopropyl)$_3$, and P(phenyl)$_3$, or is linked to R^{10} forming a chelating carbene ligand.

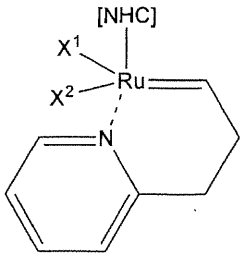
6. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 5, wherein the catalyst of formula (I) is selected from the group consisting of:

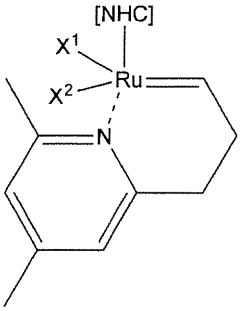




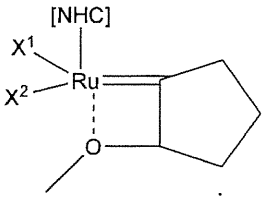




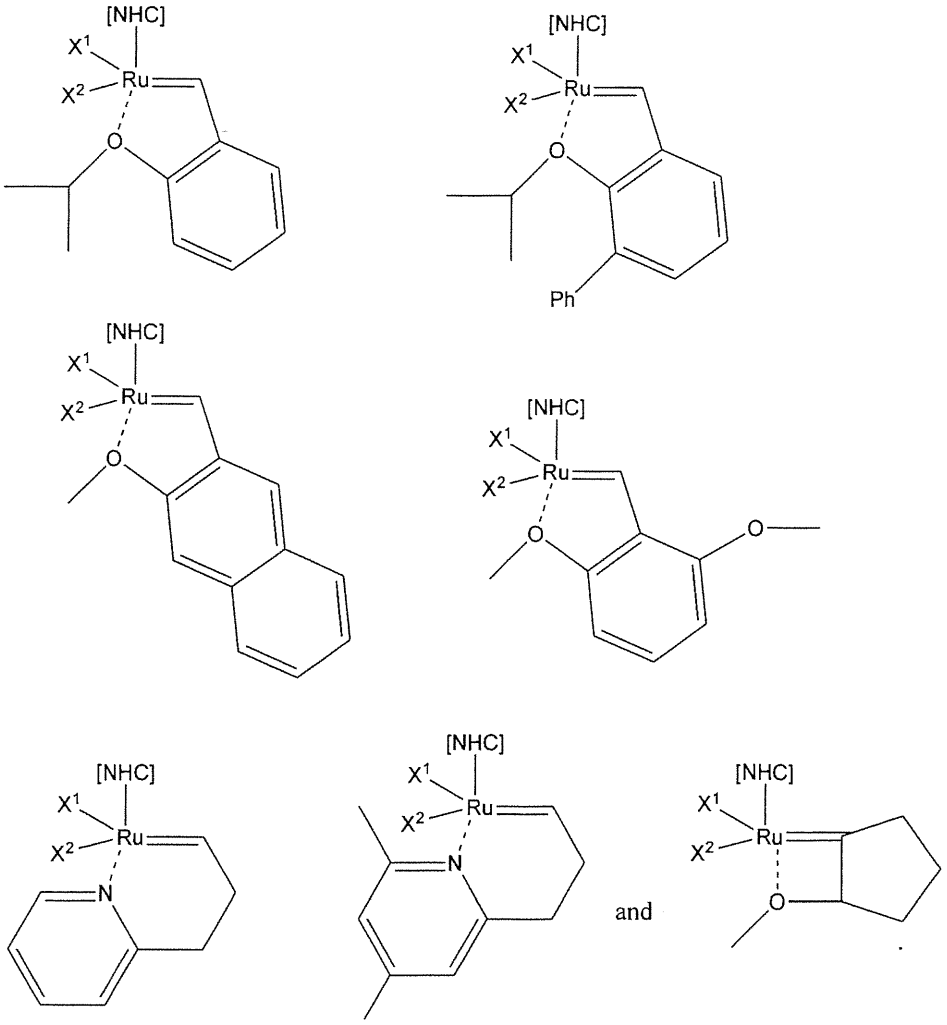




and



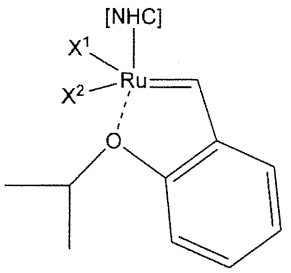
7. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 3, wherein the catalyst of formula (I) is selected from the group consisting of:

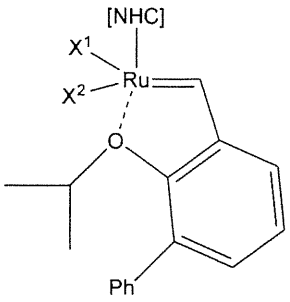


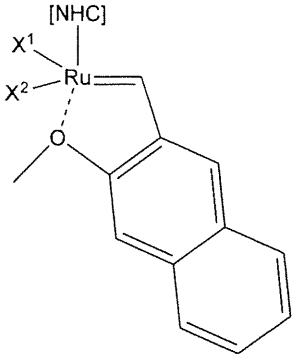
8. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 5, wherein L is selected from the group consisting of P(cyclohexyl)$_3$, P(cyclopentyl)$_3$, P(isopropyl)$_3$, and P(phenyl)$_3$.

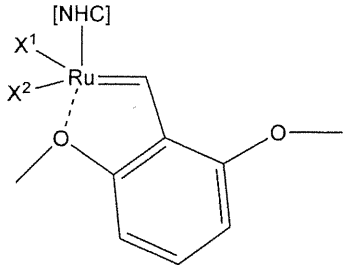
9. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 3, wherein L is selected from the group consisting of P(cyclohexyl)$_3$, P(cyclopentyl)$_3$, P(isopropyl)$_3$, and P(phenyl)$_3$.

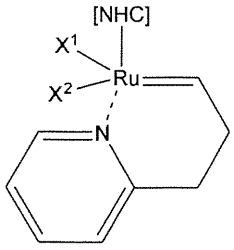
10. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst selected from the group consisting of:

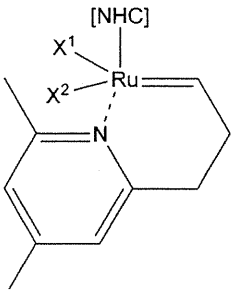




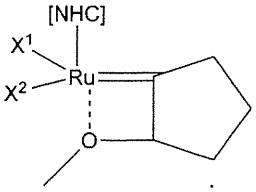








and



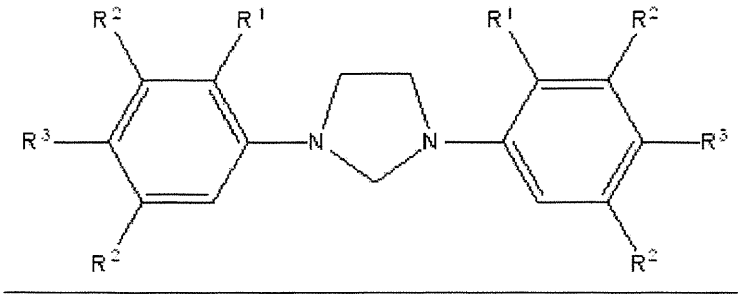
wherein:

X^1 and X^2 are independently anionic ligands;

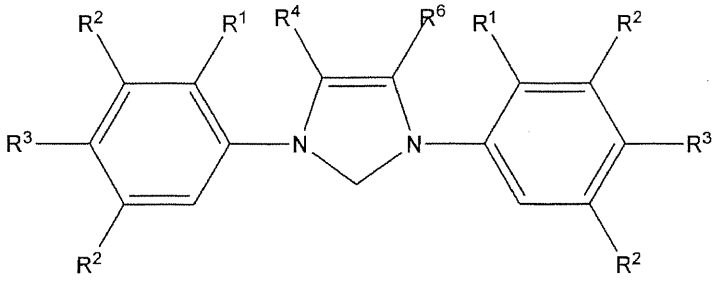
n is 0, 1 or 2; and

NHC is an *N*-heterocyclic carbene ligand comprising a 5-membered heterocyclic ring having a carbenic carbon atom and at least one nitrogen atom contained within the 5-membered heterocyclic ring, wherein the nitrogen atom is directly attached to the carbenic carbon atom and is substituted by a phenyl ring, and wherein the phenyl ring has a hydrogen at either or both ortho positions and is substituted at at least one ortho or meta position.

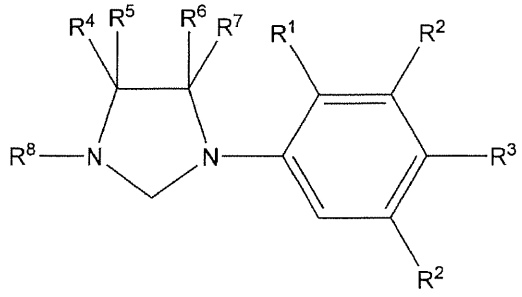
11. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 10, wherein the NHC ligand is selected from a ligand of formula of formulas (II)-(V):



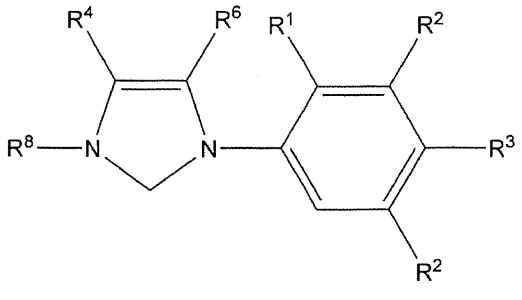
(II)



(III)



(IV)



(V)

wherein

R^1, R^2, and R^3 are either:

a) each R^1 is independently a primary or secondary C_1-C_4 alkyl group; each R^2 is independently H, a substituted or unsubstituted C_1-C_{10} alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl; and each R^3 is independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted

anthracenyl, or a functional group selected from the group consisting of halo, hydroxyl, sulfhydryl, cyano, cyanato, thiocyanato, amino, nitro, nitroso, sulfo, sulfonato, boryl, borono, phosphono, phosphonato, phosphinato, phospho, phosphino, and silyloxy; or

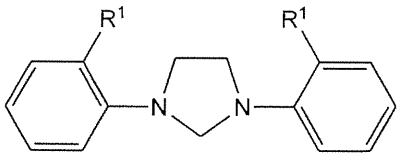
b) R^1 is H; each R^2 is independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl; and each R^3 is independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted phenyl, substituted or unsubstituted naphthyl, or substituted or unsubstituted anthracenyl or a functional group selected from the group consisting of halo, hydroxyl, sulfhydryl, cyano, cyanato, thiocyanato, amino, nitro, nitroso, sulfo, sulfonato, boryl, borono, phosphono, phosphonato, phosphinato, phospho, phosphino, and silyloxy; with the provisos that both R^2 substituents on the same phenyl ring are not H;

R^4 and R^6 are each independently H, a substituted or unsubstituted C_1-C_8 alkyl group, substituted or unsubstituted aryl, or, in formulas (III) and (V), together with the carbons carrying them, form a substituted or unsubstituted, fused 4-8 membered carbocylic ring or a substituted or unsubstituted, fused aromatic ring;

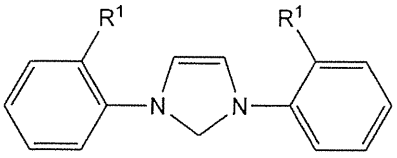
R^5 and R^7 are independently H, a substituted or unsubstituted C_1-C_8 alkyl group; and

R^8 is a C_1-C_{12} alkyl or a C_3-C_{12} cycloalkyl.

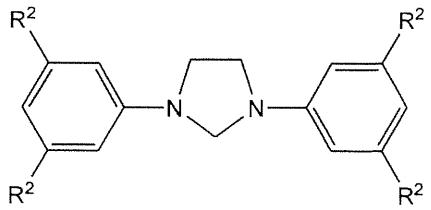
12. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 11, wherein the NHC ligand is selected from the group consisting of



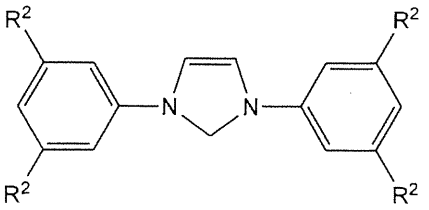
where $R^1$is methyl, ethyl, propyl, or isopropyl;



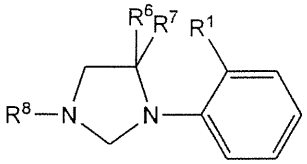
where R^1 ismethyl, ethyl, propyl, or isopropyl;



where R^2 is tert-butyl;

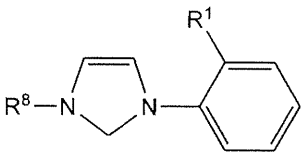


where R^2 is tert-butyl;



where R^1 is methyl, ethyl, propyl,or isopropyl; R^6 and R^7 are hydrogen or methyl; and R^8 is methyl;

and



where R^1 is methyl, ethyl, propyl, or isopropyl; and R^8 is methyl.

13. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 10, 11, or 12, wherein X^1 and X^2 are each halide, CF_3CO_2, CH_3,CO_2, CFH_2 CO_2, $(CH_3)_3CO$, $(CF_3)_2$ $(CH_3)CO$, $(CF_3)(CH_3)_2CO$, PhO, MeO, EtO, tosylate, mesylate, or trifluoromethanesulfonate.

14. An *N*-heterocyclic carbene (NHC) ruthenium olefin metathesis catalyst according to claim 13, wherein X^1 and X^2 are each chloride.