WHAT IS CLAIMED IS:

1. A method of detecting an analyte of interest in a sample, comprising

a. contacting a first complex that comprises (A) a first detectable label, wherein the first detectable label is an electrochemiluminescent (ECL) label, and (B) the analyte of interest, with:

(I) a signal amplification reagent that specifically binds to the first detectable label and that comprises a binding moiety, and

(II) a detectable moiety comprising (1) a binding partner of the binding moiety, and (2) one or more of a second detectable label; and

b. measuring (I) the second detectable label or (II) the first and second detectable labels, thereby detecting the analyte of interest;

or

c. contacting a first complex that comprises (A) a first detectable label, wherein the first detectable label is an ECL label, and (B) the analyte of interest, with:

(I) a signal amplification reagent that specifically binds to the first detectable label and that comprises an enzyme, and

(II) a substrate of the enzyme; and

d. measuring enzyme activity, thereby detecting the analyte of interest;

or

e. contacting a first complex that comprises (A) a first detectable label, wherein the first detectable label is an ECL label, and (B) the analyte of interest, with a signal amplification reagent that specifically binds to the first detectable label and that optionally comprises a second detectable label; and

f. measuring (I) the first detectable label; (II) the second detectable label; or (III) the first and second detectable labels, thereby detecting the analyte of interest;

or

g. contacting a first complex that comprises (A) a first detectable label, wherein the first detectable label is an electrochemiluminescent (ECL) label, and (B) the analyte of interest, with a signal amplification reagent that specifically binds to the first detectable label, wherein the signal amplification reagent comprises a nucleic acid probe, thereby

forming a second complex comprising the first complex and the signal amplification reagent;

h. extending the nucleic acid probe to form an extended sequence; and

i. measuring the amount of extended sequence, thereby detecting the analyte of interest.

2. The method of claim 1, wherein the first complex of (a)-(i) is on a surface, optionally wherein the surface comprises a particle or a well of a multi-well plate.

3. The method of claim 2, wherein the first complex comprises a capture reagent that specifically binds to the analyte, wherein the capture reagent is immobilized on the surface prior to the contacting of (a), (c), (e), or (g); and a detection reagent that specifically binds to the analyte and that comprises the first detectable label, optionally wherein the first detectable label is linked to the detection reagent via a conjugation linker.

4. The method of claim 3, wherein the detection reagent is a first detection reagent, and wherein the first complex further comprises a second detection reagent that specifically binds to the analyte, wherein the second detection reagent comprises a first detectable label, optionally wherein the first detectable label is linked to the second detection reagent via a conjugation linker, and wherein the signal amplification reagent is capable of being bound simultaneously to the first detectable label on the first detection reagent and to the first detectable label on the second detection reagent.

5. The method of any one of claims 1 to 4, wherein the contacting of (a) comprises contacting the first complex with (I) a signal amplification reagent that specifically binds to the first detectable label and that comprises a binding moiety, and (II) a detectable moiety comprising (1) a binding partner of the binding moiety, and (2) one or more of a second detectable label,

wherein the first complex is first contacted with the signal amplification reagent, then contacted with the detectable moiety, or wherein the first complex is contacted with the signal amplification reagent and the detectable moiety simultaneously or substantially simultaneously, and

wherein the measuring of (b) comprises measuring the second detectable label, or wherein the measuring of (b) comprises measuring the first and second detectable labels;

or wherein the contacting of (a) comprises (I) forming a signal amplification complex comprising the signal amplification reagent and the detectable moiety, and (II) contacting the first complex with the signal amplification complex,

optionally wherein the detectable moiety comprises multiple binding sites for the binding moiety and/or the binding moiety comprises multiple binding sites for the detectable moiety, wherein the signal amplification complex comprises a plurality of signal amplification reagents, and wherein each signal amplification reagent is bound to one or more detectable moieties,

and optionally wherein the binding moiety and the detectable moiety comprise complementary oligonucleotides, a receptor-ligand pair, an antigen-antibody pair, a hapten-antibody pair, an epitope-antibody pair, a mimotope-antibody pair, an aptamer-target molecule pair, or an intercalator-target molecule pair, and

when the binding moiety comprises an oligonucleotide, the detectable moiety comprises a complementary oligonucleotide and one or more of a second detectable label;

when the binding moiety comprises biotin, the detectable moiety comprises avidin or streptavidin and one or more of a second detectable label; and

when the binding moiety comprises avidin or streptavidin, the detectable moiety comprises biotin and one or more of a second detectable label.

6. The method of any one of claims 1 to 5, wherein the first complex is contacted with (I) a signal amplification reagent that specifically binds to the first detectable label and that comprises an enzyme, and (II) a substrate of the enzyme.

7. The method of any one of claims 1 to 5, wherein the first complex is contacted with a signal amplification reagent that specifically binds to the first detectable label and that optionally comprises a second detectable label, and wherein the measuring of (f) comprises:

when the signal amplification reagent does not comprise the second detectable label, measuring the first detectable label;

when the signal amplification reagent comprises the second detectable label, measuring the first detectable label, the second detectable label, or both.

8. The method of any one of claims 1 to 5, wherein the first complex is contacted with a signal amplification reagent that specifically binds to the first detectable label and that comprises a nucleic acid probe, thereby forming a second complex comprising the first complex and the signal amplification reagent,

optionally wherein the extending of (h) comprises polymerase chain reaction (PCR), ligase chain reaction (LCR), strand displacement amplification (SDA), self-sustained synthetic reaction (3SR), isothermal amplification, or combination thereof; and

when the extending of (h) comprises PCR, the extending comprises binding the nucleic acid probe to a template oligonucleotide and extending the nucleic acid probe by PCR;

when the extending of (h) comprises isothermal amplification, the extending comprises binding the nucleic acid probe to a template oligonucleotide, forming a circular template, and extending the nucleic acid probe by rolling circle amplification (RCA).

9. The method of any one of claims 1 to 5, wherein the first complex comprises at least two first detectable labels;

wherein the signal amplification reagent is a first signal amplification reagent, and the contacting of (g) further comprises contacting the first complex with a second signal amplification reagent that comprises a nucleic acid probe, wherein the first and second signal amplification reagents each binds to a distinct first detectable label, and the second complex comprises the first complex and the first and second signal amplification reagents; and

wherein the extending of (h) comprises extending one or both of the nucleic acid probes of the first and second signal amplification reagent to form the extended sequence, optionally wherein the extending comprises:

binding one or both of the nucleic acid probes of the first and second signal amplification reagents to a template oligonucleotide, forming a circular template, and extending one or both nucleic acid probes by RCA, wherein:

each nucleic acid probe is bound to a distinct template oligonucleotide; a circular template is formed from each template oligonucleotide; and each nucleic acid probe is extended by RCA; or

both nucleic acid probes are contacted with two template oligonucleotides, wherein each template oligonucleotide binds to a portion of each nucleic acid probe; the two template oligonucleotides are ligated to form a circular template; and one or both of the nucleic acid probes are extended by RCA,

optionally wherein the nucleic acid probes of the first and second signal amplification reagents comprise or consist of a same sequence.

10. The method of claim 8 or 9, wherein the first complex is on a surface, and wherein the surface comprises an anchoring reagent that is immobilized on the surface prior to or during the extending of (h), wherein the anchoring reagent binds to an anchoring region of the extended sequence, optionally wherein the anchoring reagent and the anchoring region comprise complementary oligonucleotides, and

wherein the measuring of (i) comprises measuring the amount of extended sequence bound to the surface via the anchoring reagent, optionally wherein the measuring comprises binding the extended sequence to a labeled probe comprising a second detectable label and measuring the amount of (I) the second detectable label or (II) the first and second detectable labels on the surface.

11. The method of any one of claims 2 to 11, wherein the surface comprises an electrode, and the measuring further comprises applying a voltage form to the electrode to generate an electrochemiluminescence signal; or

wherein the surface comprises a particle, and the method further comprises collecting the particle on an electrode, and the measuring further comprises applying a voltage waveform to the electrode to generate an electrochemiluminescence signal.

12. The method of any one of claims 1 to 11, wherein the method further comprises, prior to the contacting of (a), (c), (e), or (g), detecting the first complex, wherein detecting the first complex comprises measuring the amount of the first detectable label.

13. A method of detecting an analyte of interest in a sample, comprising

a. forming a first complex on a surface comprising the analyte of interest, a capture reagent that specifically binds to the analyte, wherein the capture reagent is immobilized on the surface or wherein the capture reagent is capable of being

immobilized to the surface; and a detection reagent that specifically binds to the analyte and that comprises a first nucleic acid probe;

b. extending the first nucleic acid probe to form a first extended sequence comprising a first anchoring region, wherein the first anchoring region binds a first anchoring reagent that is immobilized on the surface;

c. binding the first extended sequence to a first labeled probe comprising a first detectable label, wherein the first detectable label is an electrochemiluminescent (ECL) label; and

d. contacting the first labeled probe bound to the first extended sequence with:
(I) a signal amplification reagent that specifically binds to the first detectable label and that comprises a binding moiety, and
(II) a detectable moiety comprising (1) a binding partner of the binding moiety and (2) one or more of a second detectable label; and

e. measuring (I) the second detectable label or (II) the first and second detectable labels, thereby detecting the analyte of interest;

or

f. contacting the first labeled probe bound to the first extended sequence with:
(I) a signal amplification reagent that specifically binds to the first detectable label and that comprises an enzyme, and
(II) a substrate of the enzyme; and

g. measuring enzyme activity, thereby detecting the analyte of interest;

or

h. contacting the first labeled probe bound to the first extended sequence with a signal amplification reagent that specifically binds to the first detectable label and that optionally comprises a second detectable label; and

i. measuring (I) the first detectable label; (II) the second detectable label; or (III) the first and second detectable labels, thereby detecting the analyte of interest;

or

j. contacting the first labeled probe bound to the first extended sequence with a signal amplification reagent that specifically binds to the first detectable label, wherein the signal amplification reagent comprises a second nucleic acid probe, thereby forming a second complex comprising the signal amplification reagent and the first labeled probe;

k. extending the second nucleic acid probe to form a second extended sequence comprising a second anchoring region, wherein the second anchoring region binds a second anchoring reagent that is immobilized on the surface; and;

l. measuring the amount of (I) the second extended sequence or (II) the first extended sequence and the second extended sequence bound to the surface, thereby detecting the analyte of interest.

14. The method of any one of claims 3 to 13, wherein the capture reagent, the detection reagent, and the signal amplification reagent each comprises an antibody or antigen-binding fragment thereof, antigen, ligand, receptor, oligonucleotide, hapten, epitope, mimotope, or aptamer, preferably wherein the capture reagent, the detection reagent, and the signal amplification reagent each comprises an antibody or antigen-binding fragment thereof.

15. The method of any one of claims 1 to 14, wherein the signal amplification reagent is an antibody or antigen-binding fragment thereof comprising an antigen binding domain specific to an electrochemiluminescent (ECL) label or to an ECL label and a conjugation linker.

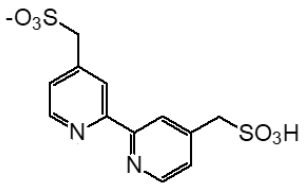
16. The method of any one of claims 1 to 15, wherein the first detectable label comprises an ECL label, and the second detectable label is capable of being measured using light scattering, optical absorbance, fluorescence, chemiluminescence, electrochemiluminescence, bioluminescence, phosphorescence, radioactivity, magnetic field, or combinations thereof, optionally wherein the second detectable label comprises an ECL label that is a same ECL label or a different ECL label as the first detectable label.

17. The method of claim 16, wherein the ECL label of the first and/or the second detectable label comprises an organometallic complex comprising at least one substituted bipyridine ligand, wherein the substituted bipyridine ligand comprises at least one sulfonate group, optionally wherein:

the organometallic complex comprises at least two substituted bipyridine ligands, wherein each substituted bipyridine ligand comprises at least one sulfonate group;

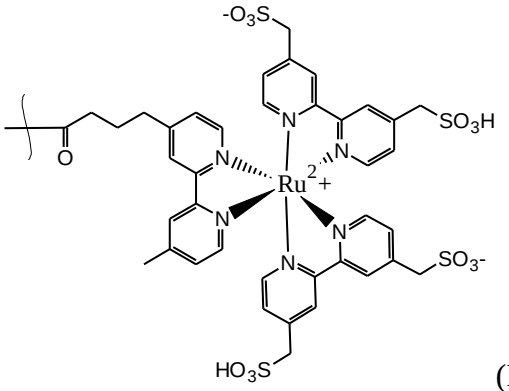
the organometallic complex comprises ruthenium, osmium, or rhenium; and/or

the substituted bipyridine ligand is a compound of Formula I:



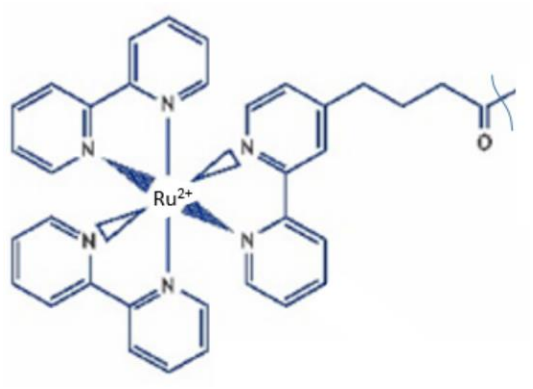
(I).

18. The method of claim 17, wherein the ECL label of the first and the second detectable label is a compound of Formula II:

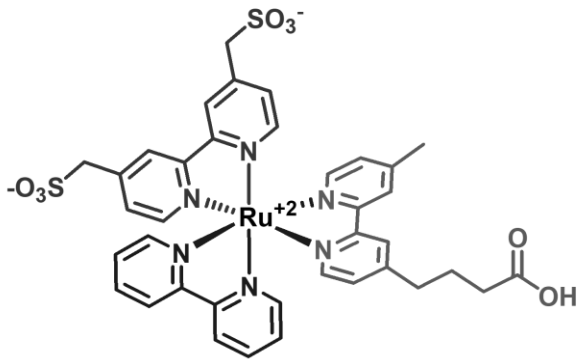


(II); or

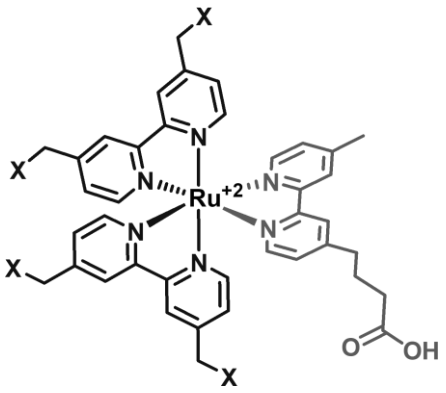
wherein the first detectable label comprises a compound of Formula II, and the second detectable label comprises a compound of any one of Formulas III, IV, V, or VI:



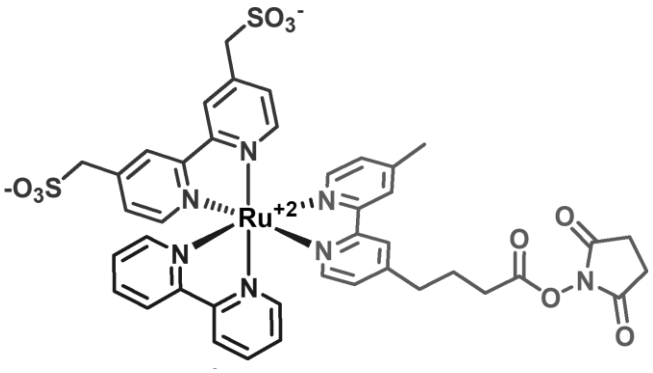
(III);



(IV);



(V), wherein X is a phosphate, a carbonate, a borate, or combination thereof;



(VI); or

wherein the first detectable label comprises a compound of Formula III, and the second detectable label comprises a compound of any one of Formulas II, IV, V, or VI; or

wherein the first detectable label comprises a compound of Formula IV, and the second detectable label comprises a compound of any one of Formulas II, III, V, or VI; or

wherein the first detectable label comprises a compound of Formula V, and the second detectable label comprises a compound of any one of Formulas II, III, IV, or VI; or

wherein the first detectable label comprises a compound of Formula VI, and the second detectable label comprises a compound of any one of Formulas II, III, IV, or V.

19. A kit for detecting an analyte of interest in a sample comprising, in one or more vials, containers, or compartments:

a. a capture reagent that specifically binds to the analyte;

b. one of (b.1) or (b.2):

(b.1) a detection reagent that specifically binds to the analyte, wherein the detection reagent comprises a first detectable label, wherein the first detectable label is an electrochemiluminescent (ECL) label;

(b.2) a detection reagent that specifically binds to the analyte, wherein the detection reagent comprises a first nucleic acid probe; and a first labeled probe comprising a first detectable label, wherein the first detectable label is an electrochemiluminescent (ECL) label; and

c. a signal amplification reagent that specifically binds to the first detectable label.

20. An antibody or antigen-binding fragment thereof comprising an antigen binding domain specific to an electrochemiluminescent (ECL) label or to an ECL label and a conjugation linker, optionally wherein the antibody or antigen-binding fragment comprises a detectable label, a nucleic acid probe, an enzyme, or a binding moiety.

21. A composition or kit comprising

the antibody or antigen-binding fragment of claim 20; and

when the antibody or antigen binding fragment comprises the nucleic acid probe, the composition or kit further comprises a template oligonucleotide that is capable of binding to the nucleic acid probe;

when the antibody or antigen binding fragment comprises the enzyme, the composition or kit further comprises a substrate of the enzyme;

when the antibody or antigen binding fragment comprises the binding moiety, the composition or kit further comprises a detectable moiety comprising (I) a binding partner of the binding moiety and (II) one or more detectable labels.

22. An assay system or one or more non-transitory computer-readable media, wherein the assay system comprises:

at least one memory unit;

at least one processing unit programmed according to instructions on the at least one memory unit; and

at least one assay system component configured to be controlled by the at least one processing unit, wherein the at least one processing unit is configured to:

control the at least one assay system component to perform one of (1) and (2):

(1) one or both of: a first measurement of a higher abundance analyte in a sample; and a second measurement of a lower abundance analyte in the sample,

wherein the higher abundance analyte is present in the sample at approximately 10 to 100000 higher-fold than the lower abundance analyte,

wherein the higher abundance analyte is detected using a detection reagent comprising an ECL label,

and wherein the lower abundance analyte is detected using (i) a detection reagent comprising an ECL label and (ii) a signal amplification reagent that specifically binds to the ECL label;

(2) a measurement of an analyte in a sample, wherein the analyte is capable of being detected in the sample when present at a concentration from about 0.0001 to about 100000 pg/mL using a single detection reagent comprising an ECL label;

and wherein the one or more non-transitory computer-readable media comprises instructions stored thereon that, when executed by the at least one processing unit, causes the at least one processing unit to:

perform, via control of the assay system, one or both of the first measurement and the second measurement.