Claims

1. An aqueous platinum electroplating bath comprising:

a) at least one platinum plating salt or complex; and

b) a source of borate ions

wherein the platinum plating salt or complex is a platinum borate salt or complex or is selected from the group consisting of diammine dinitroplatinum(II), tetraammineplatinum(II) hydrogen orthophosphate, tetraammineplatinum(II) hydrogen carbonate, tetraammineplatinum(II) hydroxide, tetraammineplatinum(II) sulphate and tetraammineplatinum(II) nitrate,

and wherein the bath has a pH in the range from 6 to 9 when it is in use or ready for use.

2. A bath according to any one of the preceding claims, wherein the source of borate ions

(a) is boron-containing acid optionally in combination with at least one borate salt, wherein the boron-containing acid is optionally selected from the group consisting of boric acid, tetraboric acid and pyroboric acid; or

(b) is a metaborate salt optionally in combination with at least one other borate salt;

wherein the borate salt is optionally selected from the group consisting of alkali metal metaborates, alkali metal tetraborates, alkali metal biborates, alkali metal pentaborates, alkaline earth metal metaborates, alkaline earth metal tetraborates, alkaline earth metal biborates and alkaline earth metal pentaborates.

3. A bath according to any one of the preceding claims, wherein the platinum ion concentration is about 0.1 to about 30 g/litre, and/or wherein the borate ion concentration is about 0.1 to about 90 g/litre.

4. A bath according to any one of the preceding claims further comprising at least one leveller.

5. A bath according to claim 12, wherein the leveller comprises at least one unsaturated carbon-carbon or unsaturated carbon-heteroatom bond.

6. A bath according to claim 4 or claim 5, wherein the leveller is selected from the group consisting of at least one:

a) substituted or unsubstituted saccharine or salt thereof;

b) substituted or unsubstituted benzopyranone;

c) substituted or unsubstituted benzaldehyde or derivative thereof;

d) substituted or unsubstituted alkene provided the alkene is not ethylene;

e) substituted or unsubstituted alkyne provided the alkyne is not acetylene;

f) substituted or unsubstituted alkylnitrile;

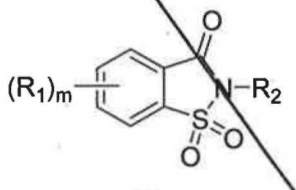
g) substituted or unsubstituted pyridine or addition salt thereof;

h) substituted or unsubstituted triazole; and

i) substituted or unsubstituted pyridinium salt.

7. A bath according to any one of the claims 4 to 6 wherein the leveller is:

(i) a compound of formula (1) or salts thereof:



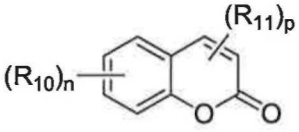
(1)

wherein m is 0, 1, 2, 3 or 4;

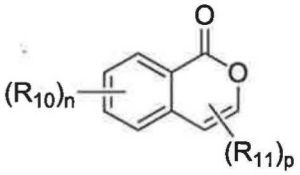
each R_1 is independently an unsubstituted C_1-C_{10} alkyl group;

R_2 is selected from the group consisting of H, unsubstituted C_1-C_{10} alkyl, an alkali metal ion and an alkaline earth metal ion;

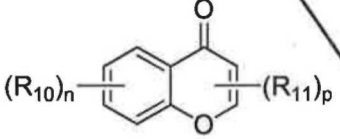
(ii) a compound of formula (2a), (2b) or (2c):



(2a)



(2b)



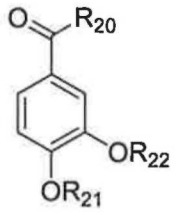
(2c)

wherein n is 0, 1, 2, 3 or 4;

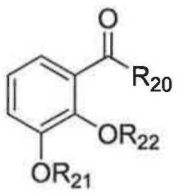
p is 0, 1 or 2;

each R_{10} and R_{11} is independently selected from an unsubstituted C_1-C_{10} alkyl group;

(iii) a compound of formula (3a) or (3b):



(3a)



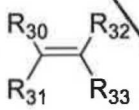
(3b)

wherein R_{20} is selected from the group consisting of H and -OR_{23} ; and

R_{21} and R_{22} are independently selected from the group consisting of H, -$C(O)R_{24}$ and unsubstituted C_1-C_{10}-alkyl; and

R_{23} and R_{24} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

(iv) a compound of formula (4):



(4)

wherein each R_{30}, R_{31}, R_{32} and R_{33} is independently selected from the group consisting of H, unsubstituted C_1-C_{10}-alkyl, substituted C_1-C_{10}-alkyl, -CO_2R_{34}, -$NR_{34}R_{35}$, -$CONR_{34}R_{35}$ and –CN, provided that R_{30}, R_{31}, R_{32} and R_{33} are not all H,

wherein the substituents are selected from the group consisting of at least one -OH, -CO_2R_{36}, -$OC(O)R_{36}$, -$NR_{36}R_{37}$, -$CONR_{36}R_{37}$, -CN, $-SO_3^-Na^+$ and $-SO_3^-K^+$;

R_{34} and R_{35} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl; and

R_{36} and R_{37} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

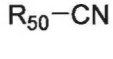
(v) a compound of formula (5):



(5)

wherein R_{40} and R_{41} are independently selected from the group consisting of H, unsubstituted C_1-C_{10}-alkyl and substituted C_1-C_{10}-alkyl, provided that R_{40} and R_{41} are not both H,
wherein the substituents are selected from the group consisting of at least one of -OH, $-CO_2R_{42}$, $-OC(O)R_{42}$, $-NR_{42}R_{43}$, $-CONR_{42}R_{43}$, -CN, $-SO_3^-Na^+$ and $-SO_3^-K^+$;
R_{42} and R_{43} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

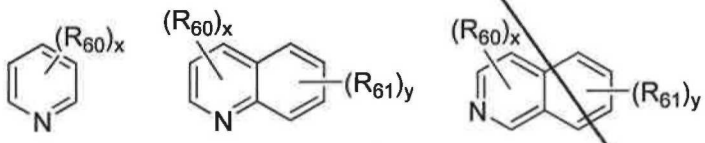
(vi) a compound of formula (6):



(6)

wherein R_{50} is a substituted or unsubstituted C_1-C_{10}-alkyl, and the substituents are selected from the group consisting of at least one of $-OR_{51}$, $-CO_2R_{51}$, $-OC(O)R_{51}$, $-NR_{51}R_{52}$ and -CN; and wherein R_{51} and R_{52} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

(vii) a compound of formula (7a), (7b) or (7c):



(7a) (7b) (7c)

wherein R_{60} and R_{61} are independently selected from the group consisting of –OH, –CN, $-CONR_{62}R_{63}$, $-CO_2R_{62}$, $-COR_{63}$, *N*-(unsubstituted C_1-C_{10}-alkyl)-pyrrolidinyl, unsubstituted C_1-C_{10}-alkyl, substituted C_1-C_{10}-alkyl, unsubstituted C_2-C_{10}-alkenyl, substituted C_2-C_{10}-alkenyl, $-SO_2R_{63}$, -N=N-(unsubstituted C_6-C_{10}-aryl), -N=N-(substituted C_6-C_{20}-aryl), unsubstituted pyridyl, substituted pyridyl,

wherein the substituents are independently selected from the group consisting of at least one of –CN, -$CONR_{64}R_{65}$, -COR_{65}, -CO_2R_{64}, -OH, -$NR_{64}R_{65}$ and =NR_{64};

R_{62} is selected from the group consisting of H, -OH and unsubstituted C_1-C_{10}-alkyl;

R_{63} is selected from the group consisting of H, -OH, unsubstituted C_1-C_{10}-alkyl, unsubstituted C_1-C_{10}-alkyl-CO_2H, -NH_2, -NH(unsubstituted C_1-C_{10}-alkyl), -N(unsubstituted C_1-C_{10}-alkyl)$_2$;

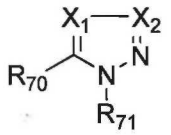
R_{64} is selected from the groups defined for R_{62};

R_{65} is selected from the groups defined for R_{63};

each x is 0, 1, 2 or 3; and

each y is 0, 1, 2, 3 or 4;

(viii) a compound of formula (8):



(8)

wherein R_{70} is selected from a group consisting of H, -CO_2R_{72} and –$NR_{72}R_{73}$;

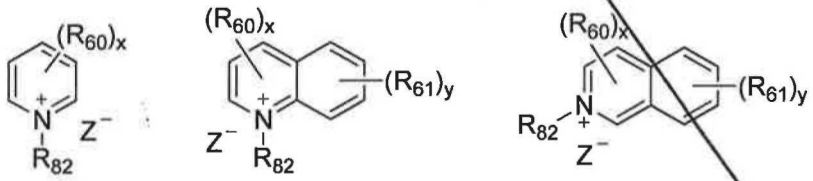
R_{71} is selected from a group consisting of H and unsubstituted C_1-C_{10}-alkyl;

R_{72} and R_{73} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

one of X_1 and X_2 is C-R_{74} and the other of X_1 and X_2 is N; and

R_{74} is selected from a group as defined for R_{70}; or

(ix) a compound of formula (9a), (9b) or (9c):



(9a) (9b) (9c)

wherein R_{60} and R_{61} are independently selected from the group consisting of –OH, –CN, -$CONR_{62}R_{63}$, -CO_2R_{62}, -COR_{63}, , *N*-(unsubstituted C_1-C_{10}-alkyl)-pyrrolidinyl, unsubstituted C_1-C_{10}-alkyl, substituted C_1-C_{10}-alkyl, unsubstituted C_2-C_{10}-alkenyl, substituted C_2-C_{10}-alkenyl, -SO_2-R_{63}, -N=N-(unsubstituted C_6-C_{10}-aryl), -N=N-(substituted C_6-C_{20}-aryl), unsubstituted pyridyl, substituted pyridyl,

wherein the substituents are independently selected from the group consisting of at least one –CN, $-CONR_{64}R_{65}$, $-COR_{65}$, $-CO_2R_{64}$, -OH, $-NR_{64}R_{65}$ and $=NR_{64}$;

R_{62} is selected from the group consisting of H, -OH and unsubstituted C_1-C_{10}-alkyl;

R_{63} is selected from the group consisting of H, -OH, unsubstituted C_1-C_{10}-alkyl, unsubstituted C_1-C_{10}-alkyl-CO_2H, $-NH_2$, -NH(unsubstituted C_1-C_{10}-alkyl), -N(unsubstituted C_1-C_{10}-alkyl)$_2$;

R_{64} is selected from the groups defined for R_{62};

R_{65} is selected from the groups defined for R_{63};

R_{82} is selected from the group consisting of $-O^-$ and unsubstituted C_1-C_{10}-alkyl;

Z is a counterion when R_{82} is an unsubstituted C_1-C_{10}-alkyl;

each x is 0, 1, 2 or 3; and

each y is 0, 1, 2, 3 or 4.

8. A bath according to claim 4 wherein the leveller is at least one substituted or unsubstituted polyalkyleneimines.

9. A bath according to any one of the preceding claims, further comprising one or more other platinum group metal or base metal plating salts or complexes.

10. A bath according to any one of the preceding claims, wherein the rate of plating is about ≥0.5 microns thickness of platinum or platinum alloy per hour.

11. A bath according to any one of the preceding claims, wherein the bath is used at temperatures from about room temperature to about 100°C.

12. A bath according to any one of the preceding claims further comprising one or more brighteners, surfactants or wetting agents.

13. The use of an aqueous platinum electroplating bath as defined in any one of claims 1 to 12 for plating platinum or a platinum alloy onto a substrate.

Claims

1. An aqueous platinum electroplating bath comprising:
   a) at least one platinum plating salt or complex; and
   b) a source of borate ions

wherein the platinum plating salt or complex is a platinum borate salt or complex or is selected from the group consisting of diammine dinitroplatinum(II), tetraammineplatinum(II) hydrogen orthophosphate, tetraammineplatinum(II) hydrogen carbonate, tetraammineplatinum(II) hydroxide, tetraammineplatinum(II) sulphate and tetraammineplatinum(II) nitrate,
wherein the source of borate ions is boron-containing acid, optionally in combination with at least one borate salt,
and wherein the bath has a pH in the range from 6 to 9.

2. A bath according to claim 1 wherein the boron-containing acid is selected from boric acid, tetraboric acid and pyroboric acid.

3. A bath according to any one of the preceding claims, wherein the source of borate ions is boron-containing acid in combination with at least one borate salt, and

wherein the borate salt is selected from the group consisting of alkali metal metaborates, alkali metal tetraborates, alkali metal biborates, alkali metal pentaborates, alkaline earth metal metaborates, alkaline earth metal tetraborates, alkaline earth metal biborates and alkaline earth metal pentaborates.

4. A bath according to any one of the preceding claims, wherein the platinum ion concentration is 0.1 to 30 g/litre, and/or wherein the borate ion concentration is 0.1 to 90 g/litre.

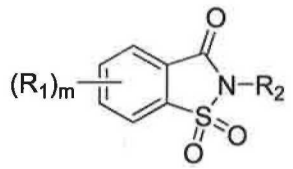
5. A bath according to any one of the preceding claims further comprising at least one leveller.

6. A bath according to claim 5, wherein the leveller comprises at least one unsaturated carbon-carbon or unsaturated carbon-heteroatom bond.

7. A bath according to claim 5 or claim 6, wherein the leveller is selected from the group consisting of at least one:
   a) substituted or unsubstituted saccharine or salt thereof;
   b) substituted or unsubstituted benzopyranone;
   c) substituted or unsubstituted benzaldehyde or derivative thereof;
   d) substituted or unsubstituted alkene provided the alkene is not ethylene;
   e) substituted or unsubstituted alkyne provided the alkyne is not acetylene;
   f) substituted or unsubstituted alkylnitrile;
   g) substituted or unsubstituted pyridine or addition salt thereof;
   h) substituted or unsubstituted triazole; and
   i) substituted or unsubstituted pyridinium salt.

8. A bath according to claim 5 wherein the leveller is:

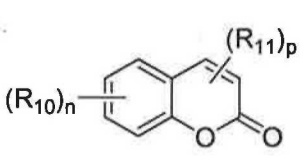
(i) a compound of formula (1) or salts thereof:



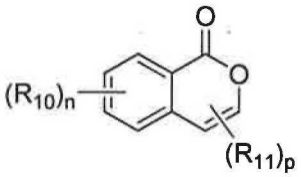
(1)

wherein m is 0, 1, 2, 3 or 4;
each R_1 is independently an unsubstituted C_1-C_{10} alkyl group;
R_2 is selected from the group consisting of H, unsubstituted C_1-C_{10} alkyl, an alkali metal ion and an alkaline earth metal ion;

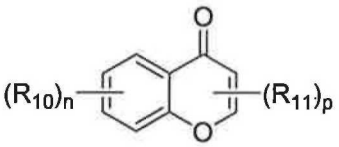
(ii) a compound of formula (2a), (2b) or (2c):



(2a)



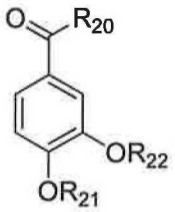
(2b)



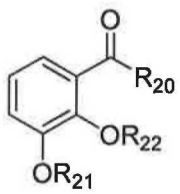
(2c)

wherein n is 0, 1, 2, 3 or 4;
p is 0, 1 or 2;
each R_{10} and R_{11} is independently selected from an unsubstituted C_1-C_{10} alkyl group;

(iii) a compound of formula (3a) or (3b):



(3a)



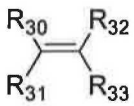
(3b)

wherein R_{20} is selected from the group consisting of H and -OR_{23} ; and

R_{21} and R_{22} are independently selected from the group consisting of H, $-C(O)R_{24}$ and unsubstituted C_1-C_{10}-alkyl; and

R_{23} and R_{24} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

(iv) a compound of formula (4):



(4)

wherein each R_{30}, R_{31}, R_{32} and R_{33} is independently selected from the group consisting of H, unsubstituted C_1-C_{10}-alkyl, substituted C_1-C_{10}-alkyl, $-CO_2R_{34}$, $-NR_{34}R_{35}$, $-CONR_{34}R_{35}$ and –CN, provided that R_{30}, R_{31}, R_{32} and R_{33} are not all H,

wherein the substituents are selected from the group consisting of at least one -OH, $-CO_2R_{36}$, $-OC(O)R_{36}$, $-NR_{36}R_{37}$, $-CONR_{36}R_{37}$, -CN, $-SO_3^-Na^+$ and $-SO_3^-K^+$;

R_{34} and R_{35} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl; and

R_{36} and R_{37} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

(v) a compound of formula (5):



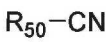
(5)

wherein R_{40} and R_{41} are independently selected from the group consisting of H, unsubstituted C_1-C_{10}-alkyl and substituted C_1-C_{10}-alkyl, provided that R_{40} and R_{41} are not both H,

wherein the substituents are selected from the group consisting of at least one of -OH, $-CO_2R_{42}$, $-OC(O)R_{42}$, $-NR_{42}R_{43}$, $-CONR_{42}R_{43}$, -CN, $-SO_3^-Na^+$ and $-SO_3^-K^+$;

R_{42} and R_{43} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

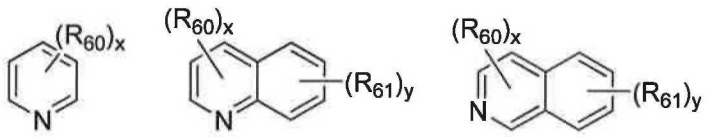
(vi) a compound of formula (6):



(6)

wherein R_{50} is a substituted or unsubstituted C_1-C_{10}-alkyl, and the substituents are selected from the group consisting of at least one of -OR_{51}, -CO_2R_{51}, -$OC(O)R_{51}$, -$NR_{51}R_{52}$ and -CN; and wherein R_{51} and R_{52} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

(vii) a compound of formula (7a), (7b) or (7c):



(7a) (7b) (7c)

wherein R_{60} and R_{61} are independently selected from the group consisting of –OH, –CN, -$CONR_{62}R_{63}$, -CO_2R_{62}, -COR_{63}, *N*-(unsubstituted C_1-C_{10}-alkyl)-pyrrolidinyl, unsubstituted C_1-C_{10}-alkyl, substituted C_1-C_{10}-alkyl, unsubstituted C_2-C_{10}-alkenyl, substituted C_2-C_{10}-alkenyl, -SO_2-R_{63}, -N=N-(unsubstituted C_6-C_{10}-aryl), -N=N-(substituted C_6-C_{20}-aryl), unsubstituted pyridyl, substituted pyridyl,

wherein the substituents are independently selected from the group consisting of at least one of –CN, -$CONR_{64}R_{65}$, -COR_{65}, -CO_2R_{64}, -OH, -$NR_{64}R_{65}$ and =NR_{64};

R_{62} is selected from the group consisting of H, -OH and unsubstituted C_1-C_{10}-alkyl;

R_{63} is selected from the group consisting of H, -OH, unsubstituted C_1-C_{10}-alkyl, unsubstituted C_1-C_{10}-alkyl-CO_2H, -NH_2, -NH(unsubstituted C_1-C_{10}-alkyl), -N(unsubstituted C_1-C_{10}-alkyl)$_2$;

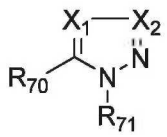
R_{64} is selected from the groups defined for R_{62};

R_{65} is selected from the groups defined for R_{63};

each x is 0, 1, 2 or 3; and

each y is 0, 1, 2, 3 or 4;

(viii) a compound of formula (8):



(8)

wherein R_{70} is selected from a group consisting of H, -CO_2R_{72} and –$NR_{72}R_{73}$;

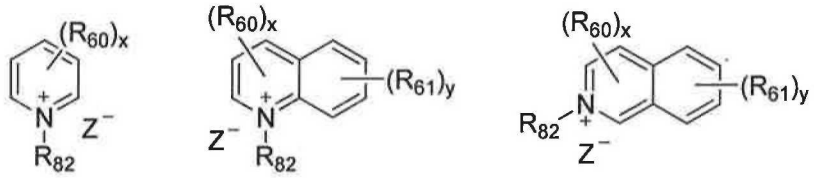
R_{71} is selected from a group consisting of H and unsubstituted C_1-C_{10}-alkyl;

R_{72} and R_{73} are independently selected from the group consisting of H and unsubstituted C_1-C_{10}-alkyl;

one of X_1 and X_2 is C-R_{74} and the other of X_1 and X_2 is N; and

R_{74} is selected from a group as defined for R_{70}; or

(ix) a compound of formula (9a), (9b) or (9c):



(9a) (9b) (9c)

wherein R_{60} and R_{61} are independently selected from the group consisting of –OH, –CN, -$CONR_{62}R_{63}$, -CO_2R_{62}, -COR_{63}, , *N*-(unsubstituted C_1-C_{10}-alkyl)-pyrrolidinyl, unsubstituted C_1-C_{10}-alkyl, substituted C_1-C_{10}-alkyl, unsubstituted C_2-C_{10}-alkenyl, substituted C_2-C_{10}-alkenyl, -SO_2-R_{63}, -N=N-(unsubstituted C_6-C_{10}-aryl), -N=N-(substituted C_6-C_{20}-aryl), unsubstituted pyridyl, substituted pyridyl,

wherein the substituents are independently selected from the group consisting of at least one –CN, -$CONR_{64}R_{65}$, -COR_{65}, -CO_2R_{64}, -OH, -$NR_{64}R_{65}$ and =NR_{64};

R_{62} is selected from the group consisting of H, -OH and unsubstituted C_1-C_{10}-alkyl;

R_{63} is selected from the group consisting of H, -OH, unsubstituted C_1-C_{10}-alkyl, unsubstituted C_1-C_{10}-alkyl-CO_2H, -NH_2, -NH(unsubstituted C_1-C_{10}-alkyl), -N(unsubstituted C_1-C_{10}-alkyl)$_2$;

R_{64} is selected from the groups defined for R_{62};

R_{65} is selected from the groups defined for R_{63};

R_{82} is selected from the group consisting of $–O^-$ and unsubstituted C_1-C_{10}-alkyl;

Z is a counterion when R_{82} is an unsubstituted C_1-C_{10}-alkyl;

each x is 0, 1, 2 or 3; and

each y is 0, 1, 2, 3 or 4.

9. A bath according to claim 5 wherein the leveller is at least one substituted or unsubstituted polyalkyleneimines.

10. A bath according to any one of the preceding claims, further comprising one or more other platinum group metal or base metal plating salts or complexes.

11. A bath according to any one of the preceding claims, wherein the rate of plating is ≥0.5 microns thickness of platinum or platinum alloy per hour.

12. A bath according to any one of the preceding claims, wherein the bath is used at temperatures from room temperature to 100°C.

13. A bath according to any one of the preceding claims further comprising one or more brighteners, surfactants or wetting agents.

14. The use of an aqueous platinum electroplating bath as defined in any one of claims 1 to 13 for plating platinum or a platinum alloy onto a substrate.