SUMMARY

[0009] In some embodiments, methods for producing metal nanoparticles are described herein. In some embodiments, the methods include providing a first metal salt in a solvent; converting the first metal salt into an insoluble compound that constitutes a plurality of nanoparticle seeds; and after forming the plurality of nanoparticle seeds, reacting a reducing agent with at least a portion of a second metal salt in the presence of at least one surfactant and the plurality of nanoparticle seeds to form a plurality of metal nanoparticles. Each metal nanoparticle includes a metal shell formed around a nucleus derived from a nanoparticle seed, and the metal shell includes a metal from the second metal salt.

[0009a] In some embodiments, there is provided a method comprising:

providing a first metal salt in a solvent;

converting the first metal salt into an insoluble compound by reducing the first metal salt with a first portion of a second metal salt, the insoluble compound comprising a plurality of nanoparticle seeds;

wherein the first metal salt and the second metal salt are different; and

after forming the plurality of nanoparticle seeds, reacting a reducing agent with a second portion of the second metal salt in the presence of at least one surfactant and the plurality of nanoparticle seeds to form a plurality of metal nanoparticles, each metal nanoparticle comprising a metal shell formed around a nucleus derived from a nanoparticle seed, and the metal shell comprising a metal from the second metal salt.

[0009b] In some embodiments, there is provided a method comprising:

providing a first metal salt in a solvent;

converting the first metal salt into an insoluble compound, the insoluble compound comprising a plurality of nanoparticle seeds;

wherein the insoluble compound comprises a metal carboxylate, a metal sulfide, a metal hydroxide, a metal chalcogenide, or a metal complex of the first metal salt; and

after forming the plurality of nanoparticle seeds, reacting a reducing agent with at least a portion of a second metal salt in the presence of at least one surfactant and the plurality of nanoparticle seeds to form a plurality of metal nanoparticles, each metal nanoparticle comprising a metal shell formed around a nucleus derived from a nanoparticle seed, and the metal shell comprising a metal from the second metal salt.

[0010] In some embodiments, methods for producing metal nanoparticles can include providing a first metal salt in a solvent, the first metal salt containing a copper (II) salt; reducing the first metal salt to form an insoluble copper (I) compound that constitutes a plurality of nanoparticle seeds; and after forming the plurality of nanoparticle seeds, reacting a reducing agent with a second metal salt in the presence of at least one surfactant and the plurality of nanoparticle seeds to form a plurality of metal nanoparticles. Each metal nanoparticle includes a metal shell formed around a nucleus derived from a nanoparticle seed, and the metal shell includes a metal from the second metal salt.

[0011] In some embodiments, methods for producing copper nanoparticles can include providing a copper (II) salt in a solvent; reducing the copper (II) salt to an insoluble copper (I) salt having a particle size of about 10 nm or less; after forming the insoluble copper (I) salt, adding at least one surfactant and a reducing agent thereto; and reacting the reducing agent with the insoluble copper (I) salt in the presence of at least one surfactant to form a plurality of copper nanoparticles.

[0011a] In some embodiments, there is provided a method comprising:

providing a copper (II) salt in a solvent;

reducing the copper (II) salt with a first reducing agent to form an insoluble copper (I) salt having a particle size of about 10 nm or less;

after forming the insoluble copper (I) salt, adding at least one surfactant and a second reducing agent thereto; and

reacting the second reducing agent with the insoluble copper (I) salt in the presence of the at least one surfactant to form a plurality of copper nanoparticles.

[0012] In some embodiments, metal nanoparticle compositions are described herein. In some embodiments metal nanoparticle compositions can include metal nanoparticles containing a metal shell formed around a nucleus derived from a copper (I) nanoparticle seed, and a surfactant coating disposed on the metal shell, where the surfactant coating includes at least one surfactant.

[0013] The foregoing has outlined rather broadly the features of the present disclosure in order that the detailed description that follows can be better understood. Additional

CLAIMS

What is claimed is the following:

1. A method comprising:

providing a first metal salt in a solvent;

converting the first metal salt into an insoluble compound, the insoluble compound comprising a plurality of nanoparticle seeds; and

after forming the plurality of nanoparticle seeds, reacting a reducing agent with at least a portion of a second metal salt in the presence of at least one surfactant and the plurality of nanoparticle seeds to form a plurality of metal nanoparticles, each metal nanoparticle comprising a metal shell formed around a nucleus derived from a nanoparticle seed, and the metal shell comprising a metal from the second metal salt.

2. The method of claim 1, wherein converting the first metal salt into an insoluble compound comprises reducing the first metal salt to form the insoluble compound.

3. The method of claim 2, wherein the first metal salt and the second metal salt are the same.

4. The method of claim 2, wherein the first metal salt and the second metal salt are different.

5. The method of claim 2, wherein at least the first metal salt comprises a copper (II) salt.

6. The method of claim 5, wherein the first metal salt and the second metal salt each comprise a copper (II) salt.

7. The method of claim 2, wherein the first metal salt is reduced by a first portion of the second metal salt.

8. The method of claim 2, wherein the first metal salt is reduced by a sugar comprising an oxidizable group.

9. The method of claim 2, wherein the first metal salt is reduced by a third metal salt.

10. The method of claim 9, further comprising:

separating the insoluble compound from the third metal salt or an oxidation product thereof, prior to reacting the reducing agent with the second metal salt.

11. The method of claim 1, wherein the first metal salt is present in an amount ranging between about 0.05 and about 0.25 stoichiometric equivalents relative to the second metal salt.

12. The method of claim 1, wherein the nanoparticle seeds are converted to a zero-valent metal while reacting the second metal salt with the reducing agent.

13. The method of claim 1, wherein converting the first metal salt into an insoluble compound comprises forming a metal carboxylate, a metal sulfide, colloidal sulfur, a metal hydroxide, a metal chalcogenide, or a metal complex from the first metal salt.

14. The method of claim 1, wherein the second metal salt comprises a mixture of two or more metal salts and the plurality of metal nanoparticles produced therefrom comprises alloy nanoparticles.

15. A method comprising:

providing a first metal salt in a solvent, the first metal salt comprising a copper (II) salt;

reducing the first metal salt to form an insoluble copper (I) compound, the insoluble copper (I) compound comprising a plurality of nanoparticle seeds; and

after forming the plurality of nanoparticle seeds, reacting a reducing agent with a second metal salt in the presence of at least one surfactant and the plurality of nanoparticle seeds to form a plurality of metal nanoparticles, each metal nanoparticle comprising a metal shell formed around a nucleus derived from a nanoparticle seed, and the metal shell comprising a metal from the second metal salt.

16. The method of claim 15, wherein the first metal salt is reduced by a first portion of the second metal salt.

17. The method of claim 15, wherein the first metal salt is reduced by a third metal salt.

18. The method of claim 17, further comprising:

separating the insoluble copper (I) compound from the third metal salt or an oxidation product thereof, prior to reacting the reducing agent with the second metal salt.

19. The method of claim 17, wherein the second metal salt comprises a copper (II) salt.

20. The method of claim 15, wherein the first metal salt is present in an amount ranging between about 0.05 and about 0.25 stoichiometric equivalents relative to the second metal salt.

21. The method of claim 15, wherein the nanoparticle seeds are converted to a zero-valent metal while reacting the second metal salt with the reducing agent.

22. A method comprising:

providing a copper (II) salt in a solvent;

reducing the copper (II) salt to form an insoluble copper (I) salt having a particle size of about 10 nm or less;

after forming the insoluble copper (I) salt, adding at least one surfactant and a reducing agent thereto; and

reacting the reducing agent with the insoluble copper (I) salt in the presence of the at least one surfactant to form a plurality of copper nanoparticles.

23. A metal nanoparticle composition comprising:

metal nanoparticles comprising a metal shell formed around a nucleus derived from a copper (I) nanoparticle seed; and

a surfactant coating disposed on the metal shell, the surfactant coating comprising at least one surfactant.

24. The metal nanoparticle composition of claim 23, wherein the metal shell comprises copper.

25. The metal nanoparticle composition of claim 24, wherein the at least one surfactant comprises a first surfactant comprising a C6-C18 primary alkylamine and a second surfactant comprising an N,N'-dialkylethylenediamine.

26. The metal nanoparticle composition of claim 24, wherein the metal nanoparticles range from about 1 nm to about 10 nm in size.

CLAIMS

1. A method comprising:

providing a first metal salt in a solvent;

converting the first metal salt into an insoluble compound by reducing the first metal salt with a first portion of a second metal salt, the insoluble compound comprising a plurality of nanoparticle seeds;

wherein the first metal salt and the second metal salt are different; and

after forming the plurality of nanoparticle seeds, reacting a reducing agent with a second portion of the second metal salt in the presence of at least one surfactant and the plurality of nanoparticle seeds to form a plurality of metal nanoparticles, each metal nanoparticle comprising a metal shell formed around a nucleus derived from a nanoparticle seed, and the metal shell comprising a metal from the second metal salt.

2. The method of claim 1, wherein the first metal salt comprises a copper (II) salt.

3. The method of claim 1, wherein the first metal salt is present in an amount ranging between about 0.05 and about 0.25 stoichiometric equivalents relative to the second metal salt.

4. The method of claim 1, wherein the nanoparticle seeds are converted to a zero-valent metal while reacting the second portion of the second metal salt with the reducing agent.

5. A method comprising:

providing a first metal salt in a solvent;

converting the first metal salt into an insoluble compound, the insoluble compound comprising a plurality of nanoparticle seeds;

wherein the insoluble compound comprises a metal carboxylate, a metal sulfide, a metal hydroxide, a metal chalcogenide, or a metal complex of the first metal salt; and

after forming the plurality of nanoparticle seeds, reacting a reducing agent with at least a portion of a second metal salt in the presence of at least one surfactant and the plurality of nanoparticle seeds to form a plurality of metal nanoparticles, each metal nanoparticle comprising a metal shell formed around a nucleus derived from a nanoparticle seed, and the metal shell comprising a metal from the second metal salt.

6. The method of claim 1, wherein the second metal salt comprises a mixture of two or more metal salts and the plurality of metal nanoparticles produced therefrom comprises alloy nanoparticles.

7. A method comprising:

providing a first metal salt in a solvent, the first metal salt comprising a copper (II) salt;

reducing the first metal salt to form an insoluble copper (I) compound, the insoluble copper (I) compound comprising a plurality of nanoparticle seeds; and

after forming the plurality of nanoparticle seeds, reacting a reducing agent with a second metal salt in the presence of at least one surfactant and the plurality of nanoparticle seeds to form a plurality of metal nanoparticles, each metal nanoparticle comprising a metal shell formed around a nucleus derived from a nanoparticle seed, and the metal shell comprising a metal from the second metal salt.

8. The method of claim 7, wherein the first metal salt is reduced by a first portion of the second metal salt.

9. The method of claim 7, wherein the first metal salt is reduced by a third metal salt.

10. The method of claim 9, further comprising:

separating the insoluble copper (I) compound from the third metal salt or an oxidation product thereof, prior to reacting the reducing agent with the second metal salt.

11. The method of claim 9, wherein the second metal salt comprises a copper (II) salt.

12. The method of claim 7, wherein the first metal salt is present in an amount ranging between about 0.05 and about 0.25 stoichiometric equivalents relative to the second metal salt.

13. The method of claim 7, wherein the nanoparticle seeds are converted to a zero-valent metal while reacting the second metal salt with the reducing agent.

14. A method comprising:

providing a copper (II) salt in a solvent;

reducing the copper (II) salt with a first reducing agent to form an insoluble copper (I) salt having a particle size of about 10 nm or less;

after forming the insoluble copper (I) salt, adding at least one surfactant and a second reducing agent thereto; and

reacting the second reducing agent with the insoluble copper (I) salt in the presence of the at least one surfactant to form a plurality of copper nanoparticles.

15. A metal nanoparticle composition comprising:

metal nanoparticles comprising a metal shell formed around a nucleus derived from a copper (I) nanoparticle seed; and

a surfactant coating disposed on the metal shell, the surfactant coating comprising at least one surfactant.

16. The metal nanoparticle composition of claim 15, wherein the metal shell comprises copper.

17. The metal nanoparticle composition of claim 16, wherein the at least one surfactant comprises a first surfactant comprising a C6-C18 primary alkylamine and a second surfactant comprising an N,N'-dialkylethylenediamine.

18. The metal nanoparticle composition of claim 16, wherein the metal nanoparticles range from about 1 nm to about 10 nm in size.

19. The method of claim 7, wherein the first metal salt is reduced by a sugar comprising an oxidizable group.