nanoparticles have a surfactant coating thereon, and the surfactant coating contains one or more surfactants.

[0012a] In one embodiment, there is provided a nanoparticle paste formulation comprising: an organic matrix comprising a hydrocarbon, an alcohol, an amine, and an organic acid; and a plurality of metal nanoparticles dispersed in the organic matrix, the plurality of metal nanoparticles comprising about 30% to about 90% of the nanoparticle paste formulation by weight; wherein the nanoparticle paste formulation maintains a fluid state and is dispensable through a micron-size aperture.

[0012b] In one embodiment, there is provided a nanoparticle paste formulation comprising: an organic matrix comprising a hydrocarbon, an alcohol, an amine, and an organic acid; and a plurality of metal nanoparticles dispersed in the organic matrix, the plurality of metal nanoparticles comprising about 30% to about 90% of the nanoparticle paste formulation by weight; wherein the metal nanoparticles have a surfactant coating thereon, the surfactant coating comprising one or more surfactants.

[0013] In some embodiments, the present disclosure describes methods including providing a plurality of metal nanoparticles having a surfactant coating thereon, and combining the plurality of metal nanoparticles with an organic matrix to form a nanoparticle paste formulation. The plurality of metal nanoparticles forms about 30% to about 90% of the nanoparticle paste formulation by weight. The organic matrix contains one or more organic solvents, where the one or more organic solvents are a hydrocarbon, an alcohol, an amine, and an organic acid.

[0014] In some embodiments, the present disclosure describes methods including providing a nanoparticle paste formulation containing an organic matrix and a plurality of metal nanoparticles dispersed in the organic matrix, dispensing the nanoparticle paste formulation onto a surface, and at least partially consolidating the metal nanoparticles with one another by heating the dispensed nanoparticle paste formulation at a temperature at or above a fusion temperature of the metal nanoparticles. The plurality of metal nanoparticles forms about 30% to about 90% of the nanoparticle paste formulation by weight. The organic matrix contains one or more organic solvents, where the one or more organic solvents are a hydrocarbon, an alcohol, an amine, and an organic acid.

[0015] [0014a] In one embodiment, there is provided a method comprising: providing a plurality of metal nanoparticles having a surfactant coating thereon; and combining the plurality of metal nanoparticles with an organic matrix to form a nanoparticle paste formulation; wherein the plurality of metal nanoparticles comprise about 30% to about 90% of the nanoparticle paste formulation by weight; and wherein the organic matrix comprises a hydrocarbon, an alcohol, an amine, and an organic acid.

[0014b] In one embodiment, there is provided a method comprising: providing a nanoparticle paste formulation comprising an organic matrix and a plurality of metal nanoparticles dispersed in the organic matrix, the plurality of metal nanoparticles comprising about 30% to about 90% of the nanoparticle paste formulation by weight and the organic matrix comprising a hydrocarbon, an alcohol, an amine, and an organic acid; dispensing the nanoparticle paste formulation onto a substrate; and at least partially consolidating the metal nanoparticles with one another by heating the dispensed nanoparticle paste formulation at a temperature at or above a fusion temperature of the metal nanoparticles.

[0016] 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 features and advantages of the disclosure will be described hereinafter, which form the subject of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following descriptions to be taken in conjunction with the accompanying drawings describing specific embodiments of the disclosure, wherein:

CLAIMS

What is claimed is the following:

1. A nanoparticle paste formulation comprising:

an organic matrix; and

a plurality of metal nanoparticles dispersed in the organic matrix, the plurality of metal nanoparticles comprising about 30% to about 90% of the nanoparticle paste formulation by weight;

wherein the nanoparticle paste formulation maintains a fluid state and is dispensable through a micron-size aperture.

2. The nanoparticle paste formulation of claim 1, wherein the metal nanoparticles have a surfactant coating thereon, the surfactant coating comprising one or more surfactants.

3. The nanoparticle paste formulation of claim 2, wherein the organic matrix comprises one or more organic solvents.

4. The nanoparticle paste formulation of claim 3, wherein the organic matrix comprises a hydrocarbon, an alcohol, an amine, and an organic acid.

5. The nanoparticle paste formulation of claim 4, wherein the organic matrix comprises more than one hydrocarbon, more than one alcohol, more than one amine, and more than one organic acid.

6. The nanoparticle paste formulation of claim 5, wherein each hydrocarbon has a boiling point that differs by about 20°C to about 50°C from other hydrocarbons in the organic matrix, each alcohol has a boiling point that differs by about 20°C to about 50°C from other alcohols in the organic matrix, each amine has a boiling point that differs by about 20°C to about 50°C from other amines in the organic matrix, and each organic acid has a boiling point that differs by about 20°C to about 50°C from other organic acids in the organic matrix.

7. The nanoparticle paste formulation of claim 6, wherein the organic matrix comprises four or more hydrocarbons, four or more alcohols, four or more amines, and four or more one organic acids.

8. The nanoparticle paste formulation of claim 4, further comprising:

micron-scale metal particles comprising about 0.01% to about 15% of the nanoparticle paste formulation by weight.

9. The nanoparticle paste formulation of claim 3, further comprising:

micron-scale metal particles comprising about 0.01% to about 15% of the nanoparticle paste formulation by weight.

10. The nanoparticle paste formulation of claim 3, further comprising:

one or more additives selected from the group consisting of a rheology control aid, a thickening agent, a micron-scale conductive additive, a nanoscale conductive additive, and any combination thereof.

11. The nanoparticle paste formulation of claim 3, wherein the nanoparticle paste formulation has a maximum particle size of about 30 microns or less.

12. A nanoparticle paste formulation comprising:

an organic matrix comprising one or more organic solvents, the one or more organic solvents comprising a hydrocarbon, an alcohol, an amine, and an organic acid; and

a plurality of metal nanoparticles dispersed in the organic matrix, the plurality of metal nanoparticles comprising about 30% to about 90% of the nanoparticle paste formulation by weight;

wherein the metal nanoparticles have a surfactant coating thereon, the surfactant coating comprising one or more surfactants.

13. The nanoparticle paste formulation of claim 12, wherein the organic matrix comprises more than one hydrocarbon, more than one alcohol, more than one amine, and more than one organic acid.

14. The nanoparticle paste formulation of claim 13, wherein each hydrocarbon has a boiling point that differs by about 20°C to about 50°C from other hydrocarbons in the organic matrix, each alcohol has a boiling point that

differs by about 20°C to about 50°C from other alcohols in the organic matrix, each amine has a boiling point that differs by about 20°C to about 50°C from other amines in the organic matrix, and each organic acid has a boiling point that differs by about 20°C to about 50°C from other organic acids in the organic matrix.

15. The nanoparticle paste formulation of claim 14, wherein the organic matrix comprises four or more hydrocarbons, four or more alcohols, four or more amines, and four or more one organic acids.

16. The nanoparticle paste formulation of claim 12, further comprising:

micron-scale metal particles comprising about 0.01% to about 15% of the nanoparticle paste formulation by weight.

17. The nanoparticle paste formulation of claim 12, further comprising:

one or more additives selected from the group consisting of a rheology control aid, a thickening agent, a micron-scale conductive additive, a nanoscale conductive additive, and any combination thereof.

18. A method comprising:

providing a plurality of metal nanoparticles having a surfactant coating thereon; and

combining the plurality of metal nanoparticles with an organic matrix to form a nanoparticle paste formulation;

wherein the plurality of metal nanoparticles comprise about 30% to about 90% of the nanoparticle paste formulation by weight; and

wherein the organic matrix comprises one or more organic solvents, the one or more organic solvents comprising a hydrocarbon, an alcohol, an amine, and an organic acid.

19. The method of claim 18, wherein combining the plurality of metal nanoparticles with an organic matrix comprises dispersing the plurality of metal nanoparticles in the organic matrix.

20. The method of claim 19, wherein dispersing the plurality of metal nanoparticles in the organic matrix comprises homogenizing the plurality of

metal nanoparticles in the organic matrix such that the nanoparticle paste formulation has a maximum particle size of about 30 microns or less.

21. A method comprising:

providing a nanoparticle paste formulation comprising an organic matrix and a plurality of metal nanoparticles dispersed in the organic matrix, the plurality of metal nanoparticles comprising about 30% to about 90% of the nanoparticle paste formulation by weight and the organic matrix comprising one or more organic solvents;

wherein the one or more organic solvents comprise a hydrocarbon, an alcohol, an amine, and an organic acid;

dispensing the nanoparticle paste formulation onto a substrate; and

at least partially consolidating the metal nanoparticles with one another by heating the dispensed nanoparticle paste formulation at a temperature at or above a fusion temperature of the metal nanoparticles.

22. The method of claim 21, further comprising:

heating the dispensed nanoparticle paste formulation at least at a first temperature plateau, the first temperature plateau having a temperature below the fusion temperature of the metal nanoparticles.

23. The method of claim 22, further comprising:

heating the dispensed nanoparticle paste formulation at a second temperature plateau, the second temperature plateau having a temperature that is higher than that of the first temperature plateau and below the fusion temperature of the metal nanoparticles.

24. The method of claim 22, wherein the organic matrix comprises more than one hydrocarbon, more than one alcohol, more than one amine, and more than one organic acid;

wherein each hydrocarbon has a boiling point that differs by about 20°C to about 50°C from other hydrocarbons in the organic matrix, each alcohol has a boiling point that differs by about 20°C to about 50°C from other alcohols in the organic matrix, each amine has a boiling point that differs by about 20°C to about 50°C from other amines in the organic matrix, and each

organic acid has a boiling point that differs by about 20°C to about 50°C from other organic acids in the organic matrix.

25. The method of claim 24, wherein the organic matrix comprises four or more hydrocarbons, four or more alcohols, four or more amines, and four or more one organic acids.

CLAIMS

1. A nanoparticle paste formulation comprising:

an organic matrix comprising a hydrocarbon, an alcohol, an amine, and an organic acid; and

a plurality of metal nanoparticles dispersed in the organic matrix, the plurality of metal nanoparticles comprising about 30% to about 90% of the nanoparticle paste formulation by weight;

wherein the nanoparticle paste formulation maintains a fluid state and is dispensable through a micron-size aperture.

2. The nanoparticle paste formulation of claim 1, wherein the metal nanoparticles have a surfactant coating thereon, the surfactant coating comprising one or more surfactants.

3. The nanoparticle paste formulation of claim 1, wherein the organic matrix comprises more than one hydrocarbon, more than one alcohol, more than one amine, and more than one organic acid.

4. The nanoparticle paste formulation of claim 3, wherein each hydrocarbon has a boiling point that differs by about 20°C to about 50°C from other hydrocarbons in the organic matrix, each alcohol has a boiling point that differs by about 20°C to about 50°C from other alcohols in the organic matrix, each amine has a boiling point that differs by about 20°C to about 50°C from other amines in the organic matrix, and each organic acid has a boiling point that differs by about 20°C to about 50°C from other organic acids in the organic matrix.

5. The nanoparticle paste formulation of claim 4, wherein the organic matrix comprises four or more hydrocarbons, four or more alcohols, four or more amines, and four or more one organic acids.

6. The nanoparticle paste formulation of claim 1, further comprising:

micron-scale metal particles comprising about 0.01% to about 15% of the nanoparticle paste formulation by weight.

7. The nanoparticle paste formulation of claim 1, further comprising:

one or more additives selected from the group consisting of a rheology control aid, a thickening agent, a micron-scale conductive additive, a nanoscale conductive additive, and any combination thereof.

8. The nanoparticle paste formulation of claim 1, wherein the nanoparticle paste formulation has a maximum particle size of about 30 microns or less.

9. A nanoparticle paste formulation comprising:

an organic matrix comprising a hydrocarbon, an alcohol, an amine, and an organic acid; and

a plurality of metal nanoparticles dispersed in the organic matrix, the plurality of metal nanoparticles comprising about 30% to about 90% of the nanoparticle paste formulation by weight;

wherein the metal nanoparticles have a surfactant coating thereon, the surfactant coating comprising one or more surfactants.

10. The nanoparticle paste formulation of claim 9, wherein the organic matrix comprises more than one hydrocarbon, more than one alcohol, more than one amine, and more than one organic acid.

11. The nanoparticle paste formulation of claim 10, wherein each hydrocarbon has a boiling point that differs by about 20°C to about 50°C from other hydrocarbons in the organic matrix, each alcohol has a boiling point that differs by about 20°C to about 50°C from other alcohols in the organic matrix, each amine has a boiling point that differs by about 20°C to about 50°C from other amines in the organic matrix, and each organic acid has a boiling point that differs by about 20°C to about 50°C from other organic acids in the organic matrix.

12. The nanoparticle paste formulation of claim 11, wherein the organic matrix comprises four or more hydrocarbons, four or more alcohols, four or more amines, and four or more one organic acids.

13. The nanoparticle paste formulation of claim 9, further comprising:

micron-scale metal particles comprising about 0.01% to about 15% of the nanoparticle paste formulation by weight.

14. The nanoparticle paste formulation of claim 9, further comprising:

one or more additives selected from the group consisting of a rheology control aid, a thickening agent, a micron-scale conductive additive, a nanoscale conductive additive, and any combination thereof.

15. A method comprising:

providing a plurality of metal nanoparticles having a surfactant coating thereon; and

combining the plurality of metal nanoparticles with an organic matrix to form a nanoparticle paste formulation;

wherein the plurality of metal nanoparticles comprise about 30% to about 90% of the nanoparticle paste formulation by weight; and

wherein the organic matrix comprises a hydrocarbon, an alcohol, an amine, and an organic acid.

16. The method of claim 15, wherein combining the plurality of metal nanoparticles with an organic matrix comprises dispersing the plurality of metal nanoparticles in the organic matrix.

17. The method of claim 16, wherein dispersing the plurality of metal nanoparticles in the organic matrix comprises homogenizing the plurality of metal nanoparticles in the organic matrix such that the nanoparticle paste formulation has a maximum particle size of about 30 microns or less.

18. A method comprising:

providing a nanoparticle paste formulation comprising an organic matrix and a plurality of metal nanoparticles dispersed in the organic matrix, the plurality of metal nanoparticles comprising about 30% to about 90% of the nanoparticle paste formulation by weight and the organic matrix comprising a hydrocarbon, an alcohol, an amine, and an

organic acid;

dispensing the nanoparticle paste formulation onto a substrate; and

at least partially consolidating the metal nanoparticles with one another by heating the dispensed nanoparticle paste formulation at a temperature at or above a fusion temperature of the metal nanoparticles.

19. The method of claim 18, further comprising:

heating the dispensed nanoparticle paste formulation at least at a first temperature plateau, the first temperature plateau having a temperature below the fusion temperature of the metal nanoparticles.

20. The method of claim 19, further comprising:

heating the dispensed nanoparticle paste formulation at a second temperature plateau, the second temperature plateau having a temperature that is higher than that of the first temperature plateau and below the fusion temperature of the metal nanoparticles.

21. The method of claim 19, wherein the organic matrix comprises more than one hydrocarbon, more than one alcohol, more than one amine, and more than one organic acid;

wherein each hydrocarbon has a boiling point that differs by about 20°C to about 50°C from other hydrocarbons in the organic matrix, each alcohol has a boiling point that differs by about 20°C to about 50°C from other alcohols in the organic matrix, each amine has a boiling point that differs by about 20°C to about 50°C from other amines in the organic matrix, and each organic acid has a boiling point that differs by about 20°C to about 50°C from other organic acids in the organic matrix.

22. The method of claim 21, wherein the organic matrix comprises four or more hydrocarbons, four or more alcohols, four or more amines, and four or more one organic acids.