AuSn, since they provide an initial low fusion temperature and a significantly higher reflow temperature thereafter.

[0007] Although copper nanoparticles are of significant interest due to their compatibility with existing soldering methods, the formation of monodisperse copper nanoparticles remains synthetically challenging, particularly at bulk scales required for commercial production. Further, it can be difficult to reversibly protect copper nanoparticles in order to prevent their agglomeration with one another. Protection can sometimes be accomplished with a thin oxide coating or a surfactant, including polymers such as polyvinylpyrrolidone, but oftentimes these agents cannot be effectively removed in order that the copper nanoparticles can function as desired in soldering applications. In addition, these agents can introduce contaminants or can themselves be considered contaminants that detrimentally impact the properties of copper nanoparticles. Properties that can be impacted can include, for example, electrical and thermal conductivity, mechanical strength, brittleness and fracture toughness.

[0008] In view of the foregoing, scaleable processes for the synthesis of monodisperse metal nanoparticles, particularly copper nanoparticles having a size of 10 nm or less, would be of substantial benefit in the art. The present invention satisfies this need and provides related advantages as well.

SUMMARY

[0008a] In one embodiment, there is provided a process comprising:

reacting an insoluble complex of a metal salt with a reducing agent in a reaction mixture comprising a solvent, a first surfactant, a second surfactant, and a third surfactant so as to form metal nanoparticles;

wherein the first surfactant comprises a primary amine, the second surfactant comprises a secondary amine, and the third surfactant comprises a chelating agent comprising an N,N'-dialkylethylenediamine, wherein the insoluble complex comprises a coordination compound of the metal salt with at least one of the first surfactant, the second surfactant, and the third surfactant.

[0008b] In one embodiment, there is provided a process comprising:

forming a first solution comprising a copper salt, a first surfactant, a second surfactant, and third surfactant;

wherein the first surfactant comprises a primary amine, the second surfactant comprises a secondary amine, and the third surfactant comprises a chelating agent comprising an N,N'-dialkylethylenediamine;

allowing an insoluble complex of the copper salt to form from the first solution;

combining a second solution comprising a reducing agent with the insoluble complex, thereby forming a reaction mixture; and

forming copper nanoparticles from the insoluble complex;

wherein the insoluble complex comprises a coordination compound of the copper salt and at least one of the first surfactant, the second surfactant, and the third surfactant.

[0008c] In one embodiment, there is provided copper nanoparticles prepared by the process as defined above and having a fusion temperature of about 200°C or lower, wherein the copper nanoparticles comprise at least some of the first surfactant, the second surfactant, and the third surfactant.

[0009] In various embodiments, processes described herein include reacting an insoluble complex of a metal salt with a reducing agent in a reaction mixture containing a first surfactant, a second surfactant, and a third surfactant so as to form metal nanoparticles. The first surfactant contains a primary amine. The second surfactant contains a secondary amine. The third surfactant contains a diamine chelating agent.

[0010] In other various embodiments, processes described herein include forming a first solution containing a copper salt, a first surfactant, a second surfactant, and a third surfactant; allowing an insoluble complex of the copper salt to form from the first solution; combining a second solution containing a reducing agent with the insoluble complex, thereby forming a reaction mixture; and forming copper nanoparticles from the