nanoparticles having irregular shape, wide size ranges, and/or nanoparticle sizes that are much larger than 20 nm. Furthermore, many methods for synthesizing copper nanoparticles are not readily amenable to scale up.

[0006] Only a limited number of scalable processes are available for producing monodisperse copper nanoparticles having small nanoparticle sizes. One readily scalable procedure for synthesizing copper nanoparticles having nanoparticle sizes below about 20 nm, more particularly below about 10 nm, involves heating a copper salt solution, a bidentate diamine (*e.g.*, a N,N'-dialkylethylenediamine), and one or more C6 – C18 alkylamines. Copper nanoparticles produced by this method have a fusion temperature of less than about 200°C, with the fusion temperature decreasing as a function of nanoparticle size. Copper nanoparticles in this size range have also been produced by the reduction of a copper salt in the presence of ascorbic acid. Although copper nanoparticles in this size range can be isolated, characterized and utilized, they do have a somewhat limited shelf life. Further, rapid oxidation of copper can take place if the copper nanoparticles are incompletely fused after heating.

[0007] In view of the foregoing, facile utilization of copper nanoparticles having nanoparticle sizes of less than about 20 nm would be of substantial benefit in the art. The present invention satisfies this need and provides related advantages as well.

SUMMARY

[0007a] In one embodiment, there is provided an article comprising:

a matrix material selected from the group consisting of a polymer matrix, a rubber matrix, a ceramic matrix, a metal matrix and a glass matrix; and

a plurality of copper nanoparticles in the matrix material that have been at least partially fused together;

wherein the plurality of copper nanoparticles are less than 20 nm in size.

[0007b] In one embodiment, there is provided an article comprising:

a matrix material;

a plurality of copper nanoparticles in the matrix material that have been at least partially fused together;

wherein the plurality of copper nanoparticles are less than 20 nm in size;

and a filler material.

[0007c] In one embodiment, there is provided a method comprising:

providing a plurality of copper nanoparticles;

wherein the plurality of copper nanoparticles are less than 20 nm in size;

mixing the plurality of copper nanoparticles with a matrix material selected from the group consisting of polymer matrix, a rubber matrix, a ceramic matrix, a metal matrix and a glass matrix; and

applying pressure to at least partially fuse the plurality of copper nanoparticles together.

[0007d] In one embodiment, there is provided a method comprising:

providing an article comprising:

a matrix material selected from the group consisting of polymer matrix, a rubber matrix, a ceramic matrix and a glass matrix;

a plurality of copper nanoparticles that have been at least partially fused together in the matrix material;

wherein the plurality of copper nanoparticles are less than 20 nm in size; and

a filler material; and

placing the article in thermal contact with a heat source.

[0007e] In one embodiment, there is provided a composition comprising:

a plurality of copper nanoparticles that are less than 20 nm in size that further comprise a surfactant system comprising a bidentate diamine and one or more C6 – C18 alkylamines; and

a matrix material selected from the group consisting of a polymer matrix, a rubber matrix, a ceramic matrix, a metal matrix, and a glass matrix.

[0007f] In one embodiment, there is provided a method comprising:

providing a plurality of copper nanoparticles that are mixed with a matrix material to form a paste;

wherein the matrix material is selected from the group consisting of a polymer matrix, a rubber matrix, a ceramic matrix, a metal matrix and a glass matrix; and

wherein the plurality of copper nanoparticles are less than 20 nm in size and further comprise a surfactant system comprising a bidentate diamine and one or more C6 – C18 alkylamines;

placing the paste in a joint between a first member and a second member; and

joining the first member to the second member by at least partially fusing the plurality of copper nanoparticles together.

[0008] In various embodiments, articles containing a matrix material and a plurality of copper nanoparticles in the matrix material are described herein. The copper nanoparticles are at least partially fused together and are less than about 20 nm in size.

[0009] In other various embodiments, compositions of the present disclosure include a plurality of copper nanoparticles that are less than about 20 nm in size and further contain a surfactant system having a bidentate diamine and one or more C6 – C18 alkylamines, and a matrix material selected from the group consisting of a polymer matrix, a rubber matrix, a ceramic matrix, a metal matrix, and a glass matrix.