In the as yet unpublished European application 10188779.2, a description is given of the production of metal particle sols, in which the metal salt solution used for their production comprises ions selected from the group encompassing ruthenium, rhodium, palladium, osmium, iridium, and platinum, as a result of which the silver nanoparticles receive stabilizing doping with these ions. The silver nanoparticles described were stabilized sterically with Disperbyk 190 (Byk GmbH) or PVP as dispersing assistant, and doped in particular with Ru. In connection with the simultaneous combining of the reactant solutions employed, silver nanoparticles with doping of this kind enabled a significantly reduced sintering time and a significantly lower sintering temperature.

It was an object of the present ~~invention~~ embodiments disclosed herein to provide a further simple method for producing stable, or colloid-chemically stable, metal nanoparticle sols, and/or to further improve the colloid-chemical stability and/or the performance properties of the metal nanoparticle dispersions produced.

An alternative object of the present ~~invention~~ embodiments disclosed herein was to find a metal nanoparticle sol comprising metal nanoparticles, and also a method for producing it, with which the sintering times and/or sintering temperatures necessary in order to attain sufficient conductivities can be lowered in such a way that it is possible to reduce the thermal load, particularly in applications with plastics substrates.

The present ~~invention~~ disclosure provides a method for producing a metal nanoparticle sol that is simple to carry out and with which metal nanoparticle sols having improved performance properties can be obtained.

In one aspect, there is provided a method for producing a metal nanoparticle dispersion comprising metal nanoparticles stabilized with at least one dispersing assistant, characterized in that

a) a metal salt, at least one dispersing assistant comprising at least one free carboxylic acid group or salt thereof as functional group, and a reducing agent, optionally in the presence of hydroxide ions, are combined in solution and reacted with one another to form stabilized metal nanoparticles;

b) flocculation of the resultant metal nanoparticles is generated in the reaction mixture obtained in step a);

c) the floc obtained in step b) is separated from at least part of the rest of the reaction mixture;

d) the floc obtained in step c) is redispersed with addition of at least one dispersion medium, optionally with addition of a base;

e) the metal nanoparticle dispersion obtained in step d) is optionally purified; and

f) the desired concentration of stabilized metal nanoparticles for the metal nanoparticle dispersion obtained in step d) or e) is set.

In another aspect, there is provided a metal nanoparticle dispersion produced by a method as defined above, at least comprising

- ≥ 20 wt% of metal nanoparticles stabilized with at least one dispersing assistant, based on the total amount of the metal nanoparticle dispersion;
- at least one liquid dispersion medium comprising at least 50 wt% of a polar solvent, preferably water; and
- 0-3 wt% of additives,

characterized in that the at least one dispersing assistant has at least one free carboxylic acid group or salt thereof as functional group, and has at least one further ionizable, more particularly protonatable

or deprotonatable, functional group.

In another aspect, there is provided the use of a metal nanoparticle dispersion as defined above for producing conductive printing inks.

In another aspect, there is provided the use of a metal nanoparticle dispersion as defined above for producing conductive coatings or conductive structures.

Having proven particularly advantageous in this context is a method in which, following the production of stabilized nanoscale metal particles in at least one liquid dispersion medium (solvent), flocculation of the metal nanoparticles is deliberately induced, and the metal nanoparticle floc formed is redispersed in at least one liquid dispersion medium (solvent), optionally by addition of a base, and the metal nanoparticle dispersion is set to a desired metal nanoparticle concentration.

A metal nanoparticle sol or metal nanoparticle colloid is also referred to in accordance with the ~~invention~~ disclosure as a metal nanoparticle dispersion.

The present ~~invention~~ disclosure accordingly provides a method for producing a metal nanoparticle dispersion, more particularly a silver nanoparticle dispersion, more particularly having a metal nanoparticle content of ≥ 20 wt%, based on the total amount of the metal nanoparticle dispersion, in which

a) a metal salt, at least one dispersing assistant comprising at least one free carboxylic acid group or salt thereof as functional group, and a reducing agent, optionally in the presence of hydroxide ions, are combined in solution and reacted with one another to form stabilized metal nanoparticles;

b) flocculation of the resultant metal nanoparticles is generated in the reaction mixture obtained in step a);

c) the floc obtained in step b) is separated from at least part of the rest of the reaction mixture;

d) the floc obtained in step c) is redispersed with addition of at least one dispersion medium, optionally with addition of a base;

e) the metal nanoparticle dispersion obtained in step d) is optionally purified; and

f) the desired concentration of stabilized metal nanoparticles for the metal nanoparticle dispersion obtained in step d) or e) is set.

The metal nanoparticle dispersion produced in accordance with the ~~invention~~disclosure, also referred to as a metal nanoparticle sol, has preferably a metal nanoparticle content, more particularly silver particle content (Ag and dispersing assistant), of ≥ 20 wt% to ≤ 60 wt%, as for example ≥ 30 wt% or ≥ 50 wt%, based on the total amount of the metal nanoparticle sol. It is, however, also possible, optionally, for higher metal nanoparticle contents to be attained.

Metal nanoparticles, more particularly silver nanoparticles, are understood in the context of the invention to be those having a d_{50} of less than 300 nm, preferably having a d_{50} of 5 to 200 nm, more preferably of 10 to 150 nm, very preferably of 20 to 140 nm, as for example of 40 to 80 nm, as measured by means of dynamic light scattering. Suitable for the measurement by means of dynamic light scattering is, for example, a Malvern Dynamic Light Scattering Particle Size Analyzer from Malvern Instruments GmbH.

The metal nanoparticles are stabilized by means of at least one dispersing assistant and are dispersed in at least one solvent, also referred to as liquid dispersion medium.

In the method of the invention, the nanoscale and submicroscale metal particles, preferably silver particles, are produced in step a) in the presence of at least one dispersing assistant which has at least one carboxylic acid group (-COOH) or a carboxylate group ($-COO^-$) as ionizable functional group. By this means the metal nanoparticles are coated on their