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DC electrical conductivity of Au nanoparticle/chloroform and toluene suspensions

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Au nanoparticles are remarkable materials and have been widely used due to low electrical and high corrosion resistance. Alkylthiol stabilized gold nanoparticles have attracted particular interest [1] since the high affinity of the sulfur group to the gold core allows one to modify some functionalities of the alkylthiol and hence allows one to tailor the surface properties of the nanoparticles [2, 3]. Although the electrical conductivity in bulk samples constructed by nanoparticles has been investigated [4–7], such study of the suspensions of nanoparticles/solvent is lacking. It would be interesting to study the electrical properties of nanoparticles stabilized by organic molecular outside and the effect on the electrical properties of dispersing nanoparticles into different solvents.

The present work aims at an examination of the electrically conductive behavior of Au nanoparticles in chloroform and toluene solvents. Moreover, our results are able to serve as a reference for future testing with nanoparticle/solvent suspension such as medical testing and chemical testing afterwards.

Gold nanoparticles were prepared by chemical method and detailed procedure can be found in [8]. The concentrations in the aqueous phase were 2×10^{-3} mol/L in $HAuCl_4$, 2×10^{-3} mol/L in sodium oleate and 1×10^{-2} mol/L in $NaBH_4$. Colloidal gold nanoparticles were prepared by mixing above aqueous phases under thorough stirring for 30 min at room temperature (*RT*). Dodecanethiol and hexadecanethiol/chloroform and toluene solvents (5×10^{-4} mol/L) were used to extract Au nanoparticles, respectively. Homogeneous Au nanoparticles/chloroform and toluene solvent suspensions were obtained thereafter. Scanning electron microscopy (SEM) observation of the gold nanoparticles synthesized was performed on LEO 55VP SUPRA.

The resistance of gold nanoparticles/chloroform and toluene solvent suspensions was measured by a parallel Pt electrode (DJS-1) with dimension of 6×5 cm^2. An Agilent (Model 4156C) electrometer was used in the V/I mode, with which DC conductivity of the sample was calculated.

Fig. 1 shows the SEM image of Au nanoparticles transferred from the water surface dropped on a silicon substrate. It can be seen that the shape of the gold particles is mostly sphere like with 10 nm in diameter.

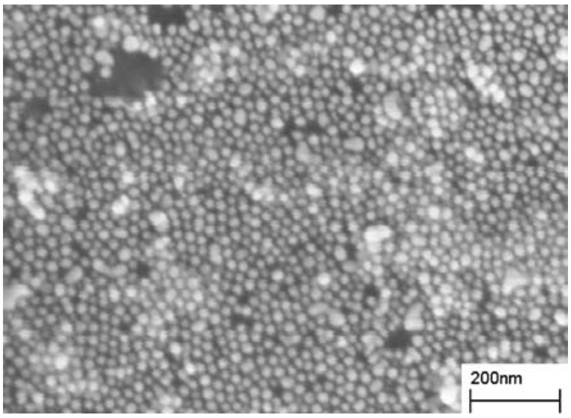

Figure 1 SEM image of Au nanoparticles with 10 nm in diameter.

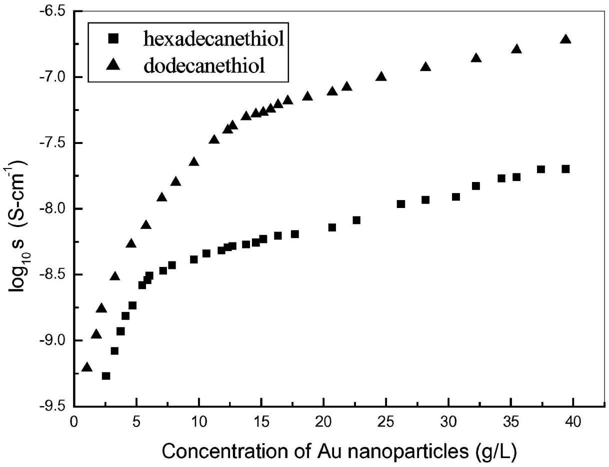

Figure 2 Electrical conductivity of C16Au and C12Au/chloroform suspensions vs. concentration of Au nanoparticles.

The room temperature dc conductivity (σ_{dc}) of gold nanoparticles capped by hexadecanethiol (C16Au) and dodecanethiol (C12Au) in chloroform solvent are plotted as a function of Au concentration in Fig. 2. We can see that there are two distinct regions in the graph, the first region indicating a rapid increase of conductivity with the concentration up to a moderate value, and the second region indicating a slow increase beyond this concentration. The electrical conductivity for pure chloroform solvent with no Au nanoparticle is about 2.67×10^{-10} S·cm^{-1} and the conductivity of

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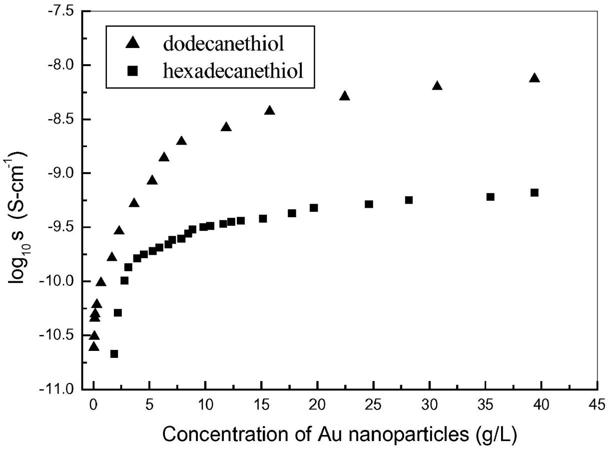

Figure 3 Electrical conductivity of C16Au and C12Au/toluene suspensions vs. concentration of Au nanoparticles.

Au nanoparticle/chloroform suspension increases evidently with the addition of Au nanoparticles. The conductivity increases to about 2.05×10^{-7} S·cm^{-1} when the concentration of the C12Au/chloroform suspension is about 40 g/L. The moderate concentration in C12Au/chloroform suspension is about 11.22 g/L which is smaller than that for C16Au/chloroform suspension, 5.47 g/L. It can be concluded that the shorter the alkylthiol chain outside the Au nanoparticle, the larger the conductivity in such suspension.

Fig. 3 shows the room temperature dc conductivity (σ_{dc}) of C12Au and C16Au in toluene solvent as a function of Au concentration. The moderate concentration for C12Au/toluene suspension is about 7.88 g/L which is obviously larger than that for C16Au/toluene suspension, 2.77 g/L.

As shown in Figs 2 and 3, the introduction of Au nanoparticles does increase the conductivity of both chloroform and toluene solvent suspensions by up to three orders of magnitude. From the low concentration to moderate concentration, a rapid increase in the electric conductivity can be observed. This indicates that for concentration of Au nanoparticles below such moderate concentration, the nanoparticles are almost isolated and the electrical conductivity is governed mainly by the electrical characteristics of the solvent. In this situation, the average distance between Au nanoparticles is not small enough for the electrons to tunnel through the solvent or for other physical contacts between nanodots to be formed. Also the conductive networks have not been constructed in the suspensions. As the fraction of Au nanoparticles increases further, the nanodots start to contact with one another through aggregation of particles and the distance between Au nanoparticles decreases which contributes to form some conductive connection. As aggregation is a basic feature of a colloidal system [9], this aggregation accounts for the construction of conductive networks which facilitates the conductivity of the samples. When the concentration is higher than the moderate value, the electrostatic stabilization of Au nanoparticles arising from the solvent is not enough to keep the primary particles suspended in the solvent as the case at lower concentration. A new dynamic equilibrium will be established according to the interaction between the agglomerates of gold nanoparticles and solvent, but the conductive networks have to be less efficient, resulting in lower increasing rate of the electrical conductivity in the system [10].

The room temperature dc conductivity (σ_{dc}) of C16Au is smaller than that of C12Au when the Au nanoparticle concentrations are same. It is because that the hexadecanethiol molecular chain (about 1.75 nm) is larger than that of the dodecanethiol molecular (about 1.45 nm), which makes the distance between C16Au nearby is larger than those C12Au. Therefore, longer distance between Au nanoparticles makes the electron more difficult to tunnel even though the gold nanoparticle concentration is above the moderate value.

In summary, the dc conductivity of hexadecanethiol and dodecanethiol capped gold nanoparticles in chloroform and toluene solvent suspensions is conspicuously Au nanoparticle concentration dependent, it increases as the concentration increases and attains to a somewhat steady value after the concentration reaches to a moderate value. The moderate concentration is 5.47 g/L and 11.22 g/L for C16Au and C12Au/chloroform suspensions, respectively. The moderate concentration is about 7.88 g/L and 2.77 g/L for C12Au and C16Au/toluene suspensions, respectively. The shorter the molecular chain outside of the Au nanoparticle in this article, the larger the electrical conductivity for the Au nanoparticle/chloroform and toluene solvent suspensions.

Acknowledgments

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