Conversion of the Surface Property of Oleic Acid Stabilized Silver Nanoparticles from Hydrophobic to Hydrophilic Based on Host–Guest Binding Interaction

Ming Chen, WenHua Ding, Yang Kong, and GuoWang Diao*

College of Chemistry and Chemical Engineering, Yangzhou University, Yangzhou 225002, Peoples Republic of China

Received August 24, 2007

This paper describes a general method to change the surface property of the oleic acid stabilized silver nanoparticles and successful transferring of the silver nanoparticles from the organic phase into the aqueous phase. By vigorous shaking of a biphasic mixture of the silver organosol protected with oleic acid and p-sulfonated calix[4]arene (pSC4) aqueous solution, it is believed that an inclusion complex is formed between oleic acid molecules and pSC4, and the protective layer of the silver nanoparticles shifts from hydrophobic to hydrophilic in nature, which drives the transfer of silver nanoparticles from the organic phase into the aqueous phase. The efficiency of the phase transfer to the aqueous solution depends on the initial pSC4 concentration. The pSC4–oleic acid inclusion complex stabilized nanoparticles can be stable for long periods of time in aqueous phase under ambient atmospheric conditions. The procedure of phase transfer has been independently verified by UV–vis, transmission electron microscopy, Fourier transform infrared, and 1H nuclear magnetic resonance techniques.

Introduction

Metal nanoparticles have already exhibited their diversity and potential in applications in the field of modern material sciences, especially in microelectronics, optical materials, and biological sensors.1–3 Recently, highly monodisperse nanoparticles have been prepared in organic solutions. In almost all of these colloidal systems, a layer of surfactant molecules is essential to prevent the nanoparticles from aggregation. The long hydrocarbon chains of the surfactants are responsible for the hydrophobicity. These long aliphatic chains also cause the nanoparticles to be immiscible in the aqueous solution, and the biological applications of these nanoparticles are greatly restricted because of their poor solubility in aqueous solution. Development of protocols for achieving high nanoparticle concentration in water, particularly that of gold, would be extremely useful for biological applications of these nanoparticles in the reverse direction are less. The organic–water medium phase transfer of nanoparticles is generally achieved by modification of the surface-bound surfactant layers of the nanoparticles. Previous research on the phase transfer of nanoparticles from organic to aqueous solutions by Rotello and co-workers4 involved a place exchange mechanism to functionalize alkanethiol-capped organic-soluble gold nanoparticles with carboxylic acid groups. Recently, Gittins and Caruso5,6 have reported a facile and rapid one step method for the direct and complete transfer of gold and palladium nanoparticles synthesized in toluene and stabilized by tetraalkylammonium salts across the phase boundary (organic to aqueous). They have used ligand exchange with shorter chain stabilizing agents (4-(dimethylamino)pyridine (DMAP)) to increase the dispersity of nanoparticles in water. In a different approach, Sastry and co-workers7 have used a new technique based on surface-bound interdigitated bilayers

Furthermore, the phase transfer may be used to generate ultrathin nanocrystalline films of metals, chalcogenides, and oxides at the liquid–liquid interface.23–24 Compared to the number of methods of conversion of the surface property from hydrophobic to hydrophilic,9–22 reports on the conversion of the surface property of nanoparticles in the reverse direction are less. The organic–water medium phase transfer of nanoparticles is generally achieved by modification of the surface-bound surfactant layers of the nanoparticles. Previous research on the phase transfer of nanoparticles from organic to aqueous solutions by Rotello and co-workers involved a place exchange mechanism to functionalize alkanethiol-capped organic-soluble gold nanoparticles with carboxylic acid groups. Recently, Gittins and Caruso5,6 have reported a facile and rapid one step method for the direct and complete transfer of gold and palladium nanoparticles synthesized in toluene and stabilized by tetraalkylammonium salts across the phase boundary (organic to aqueous). They have used ligand exchange with shorter chain stabilizing agents (4-(dimethylamino)pyridine (DMAP)) to increase the dispersity of nanoparticles in water. In a different approach, Sastry and co-workers have used a new technique based on surface-bound interdigitated bilayers

to achieve the phase transfer from organic to aqueous solutions. More interestingly, Rao and co-workers have reported a new method of phase transfer using fluorour chemistry, which is shown to be effective in solubilizing gold and CdSe nanoparticles in a fluoruous medium, through phase transfer from an aqueous or a hydrocarbon medium.

Recently, host–guest chemistry and inclusion complexes used in phase transfer have been reported. Yang and cowokers have presented a new surface modification method that is based on the formation of a host–guest complex between α-cyclodextrin and oleic acid, and succeeded in transferring silver nanoparticles from hexane to water. Here, we use the hydrophilic calixarene as host molecule to effectively increase the dispersity of the nanoparticles in aqueous phase. Newly, calixarenes with hydrophobic cavities have received much attention as a fascinating class of receptors that have the ability to interact through apolar–apolar interaction, van der Waals interaction, hydrogen bonding, and C–H⋯π and N–H⋯π complexes with a great variety of guests ranging from apolar compounds such as fullerens to charged molecules such as metallic cations and anions. This versatility makes the calixarene family the third major class of macrocyclic binding agents following the crown ethers and the cyclodextrins. In this paper, silver nanoparticles synthesized in N,N-dimethylformamide (DMF) were capped with oleic acid molecules, which have been proved to be an effective protective agent in the nonaqueous synthesis of nanoparticles of several classes of materials. It is difficult to change the surface structural property of these particles because the exposed groups of oleic acids are aliphatic. To increase the hydrophilic properties of the silver nanoparticles, we used p-sulfonated calix[n]arene (pSC4) sodium as the host molecule to generate inclusion complexes with surface-bound oleic acid molecules. After the formation of the inclusion complex between oleic acid molecules and pSC4, these pSC4–oleic acid complexes could effectively change the surface hydrophilic properties and facilitate the phase transfer of nanoparticles into aqueous solutions. UV–vis spectroscopy, transmission electron microscopy (TEM), FTIR, and 1H NMR techniques proved the method to be a simple and effective way to increase the dispersity of oleic acid–pSC4 stabilized nanoparticles in aqueous solution.

### Experimental Section

Silver nitrate (AgNO₃), sodium borohydride (NaBH₄), oleic acid, and hexane were purchased from Shanghai Chemical Reagents Company. All the chemicals were used as received. p-Sulfonated calix[n]arene (pSC4) sodium was synthesized according to the literature. 1H NMR (CDCl₃, 600 MHz) δ 7.44 (s, 5H, ArH) and 3.85 (s, 8H, ArCH₂) results were similar to those reported by Shinkai. Elemental analysis data for C₃₉H₆₀O₈Na₄: C, 39.15%; H, 2.6%. These values are very close to the theoretical values of 40.38% and 2.40%. Highly pure water (having a measured resistivity of 18.2 MΩ·cm) was obtained from a Millipore Milli-Q UV system.

### Synthesis of Oleic Acid Stabilized Silver Nanoparticles

All glassware used in the following procedures was cleaned in a bath of freshly prepared 3:1 hydrochloric acid/nitric acid and rinsed thoroughly in highly pure water before experiments. Silver nanoparticles were prepared by the reduction of AgNO₃ in N,N-dimethylformamide (DMF). In a typical experiment, silver nitrate (0.1 g) and sodium borohydride (0.1 g) were dissolved separately in 15 mL each of DMF. Then, the silver nitrate solution was added dropwise into sodium borohydride solution in DMF. The color of the solution changed from yellow to brown. At the end, a black precipitate was formed, which was centrifuged at 8000 rpm and purified by washing with absolute ethanol. This process was repeated three times in order to remove the excess DMF. The black precipitate was vaporized in a vacuum oven at 50 °C.

The black powder (50 mg) was dispersed in 5 mL of oleic acid, which was vigorously stirred for at least 24 h at room temperature. The silver nanoparticles capped with oleic acid were centrifuged at 8000 rpm and purified by washing with absolute ethanol. This process repeated three times in order to remove the excess oleic acid. Further removal of ethanol by vaporizing and drying in a vacuum oven at 50 °C gave a bright-black, dry powder of surface-modified silver nanoparticles. The silver nanoparticles protected with oleic acid were redispersed in hexane. The concentration of silver nanoparticles in hexane was estimated to be 0.25 mg/mL. It is found that the silver nanoparticles capped with oleic acid in hexane are stable for many weeks.

### Phase Transfer from Hexane to pSC4 Aqueous Solution

The phase transfer was conducted by vigorously stirring amixture of the silver organosol protected with oleic acid and equal volume of pSC4 aqueous solution at room temperature. The typical concentration of the nanoparticles in hexane was 0.25 mg of the particles/mL. The concentration of pSC4 aqueous solution was 1 mM unless indicated otherwise. Silver organosol (10 mL) capped with oleic acid in hexane was sampled and put into a bottle. Then, 10 mL of pSC4 (1 mM) aqueous solution and 0.1 mL of NaOH (0.1M) were carefully added into the bottle along the wall. Two layers with a clean boundary in the bottle were observed. A yellow organosol layer which contained silver nanoparticles capped with oleic acid was on the top of the colorless aqueous phase. However, the bottom layer became yellow while the upper layer became colorless after vigorously stirring, evidently due to the transfer of silver nanoparticles from the organic phase to the aqueous phase. The direct evidence for the transfer of silver nanoparticles between organic phase and aqueous phase was checked by UV–vis spectroscopy.

The aqueous solution of the silver nanoparticles is extremely stable, and the salt cannot induce precipitation of the silver nanoparticles. In order to separate the nanoparticles from pSC4 aqueous solution, the solution was centrifuged three times at 10000 rpm for 20 min. There were still a few silver nanoparticles in the aqueous solution. Further removal of water by vaporizing and subsequent drying in a vacuum oven at 50 °C gave a brown, dry powder of silver nanoparticles. The Ag precipitated from pSC4 aqueous solution and the powder of the silver nanoparticles protected with oleic acid were further characterized by FTIR spectra and H NMR spectra.

The X-ray powder diffraction (XRD) was taken using a Bruker D8 ADVANCE X-ray diffractometer operated at a voltage of 40 kV and a current of 40 mA with Cu Kα radiation (λ = 0.154056 nm). Contact angle of water on the product was measured by using a Dataphysics OCA40 contact angle analyzer. On a flat surface of the glass flask, the contact angle can be measured by the sessile drop technique. The powder samples were first pressed into a thin pellet.
under 10MPa pressure and then were measured by the sessile drop method. The optical properties of the silver organosol and hydroxols were monitored on a UV-2550 (Shimazu, Japan) double-beam spectrophotometer equipped with a stopped quartz cell with 1.0 cm optical path length. The morphology and size of the silver organosol and hydroxols were investigated on a Philips TECNAI-12 TEM instrument operated at an accelerating voltage of 120 kV. Samples of silver nanoparticles from hexane and pSC4 aqueous solution for TEM studies were prepared by placing drops of the solutions on carbon-coated copper grids. FTIR spectra for the different samples were recorded on a Bruker TENSOR 27 FTIR spectrometer operated at a resolution of 4 cm⁻¹. ¹H NMR spectra were recorded on a Bruker AV 600 MHz instrument. Elemental analysis for pSC4 was carried out using a SERIES II2400 (Perkin-Elmer) elemental analyzer.

### Results and Discussion

As previously described, the phase transfer occurred by vigorously stirring the mixture of silver organosol protected with oleic acid and pSC4 aqueous solution. Actually, the mechanism for the phase transfer of silver nanoparticles from organic phase into aqueous phase is based on the formation of a host–guest complex between pSC4 and oleic acid. Gutsche and co-workers³¹ have testified that p-tert-butylcalix[4]arene and its derivative show a striking ability to form complexes with a variety of small molecules, such as chloroform, benzene, and toluene with great tenacity. It is strongly indicated by the X-ray crystallographic determination that the occluded molecules are inside the calix. Calixarene can also interact with various short-chain carboxylic acid molecules. Therefore, it is evident that between pSC4 and oleic acid an inclusion complex could be formed, which might dissolve in aqueous phase. By vigorous shaking of a biphasic mixture of the oleic acid-stabilized silver organosol and pSC4 aqueous solution, oleic acid, as a guest molecule, would like to be imbibed into the pellet. The contact angle of water on the silver nanoparticles powder sample capped with oleic acid is 97.3°, which shows that the surface of the silver nanoparticles capped with oleic acid is hydrophobic and very difficult to be wetted by water. Such a high water contact angle indicates that the surface polarity is weaker and the surface energy is lower, consequently. It is due to a large number of oleic acid molecules on the surface of nanoparticles, predominantly with alkyl chains exposed to the air–water interface. After the phase transfer, the thin pellet was prepared from the precipitated silver from pSC4 aqueous solution by centrifuging three times at 10 000 rpm for 20 min. The water contact angle, as shown in Figure 2b, decreased to 13.1°, and the wettability increased, obviously, which confirms a change of the silver nanoparticles surface from hydrophobic to hydrophilic. The change in the water contact angle indicates that the surface polarity has increased by the formation of the inclusion complex between oleic acid and pSC4, which facilitates the silver nanoparticles entrance into pSC4 aqueous solution.

The phase transfer of silver nanoparticles from hexane to pSC4 aqueous solution can be confirmed by UV–vis spectrum shown in Figure 3. It is valuable to note that the position of absorption peak of silver nanoparticles in pSC4 aqueous solution is broadened and shifted marginally to the red, which has a red shift of 9 nm compared with that of the organosol (Figure 3A, curves a and b). The aqueous solution of the silver nanoparticles is extremely stable. It is found that there is no precipitation when the aqueous phase containing silver nanoparticles is kept static for several months. In contrast, no plasmon resonance is recorded in the organic phase after phase transfer (Figure 3A, curve c), which confirmed the transfer of silver nanoparticles from organic phase into aqueous phase. To examine the effect of pSC4 concentration on the phase transfer of the silver nanoparticles in aqueous solution, we mixed the silver nanoparticles suspension in hexane (~0.25 mg Ag nanoparticles/mL hexane) with equal volumes of pSC4 aqueous solutions at concentrations of 0.2, 0.5, 0.8, and 1 mM (Figure 3B). As the pSC4 concentration was increased to 1 mM, stable aqueous silver suspensions were obtained. This concentration dependent effect further suggests that the inclusion complex between oleic acid and pSC4 is essential for the phase transfer of silver nanoparticles to aqueous phase. At low concentrations of pSC4, only small portions of surface-bound oleic acid molecules on the surfaces of silver nanoparticles formed

---


complexes with the pSC4, which is not sufficiently hydrophilic for the stabilization of nanoparticles in aqueous phase. However, at relatively high pSC4 concentrations, substantial amounts of oleic acid molecules could form host–guest complexes with pSC4, which lead to the increase of the stability of silver nanoparticles in the hydrophilic media. Figure 3B summarizes the UV–vis curves of the silver particles in pSC4 aqueous solutions at the various pSC4 concentrations. The absorbance peaks of silver nanoparticles shifted from 407 nm in hexane to 415–417 nm after the phase transfer to pSC4 aqueous solutions. Further studies are necessary to elucidate this concentration-dependent effect. As a control experiment, silver nanoparticles in hexane were mixed with equal volume of water containing 0.1 mL of 0.1 mM NaOH and without pSC4, and the mixture was stirred vigorously for 24 h. No color change was observed in either hexane or aqueous phase, and no UV–vis absorption peak was found for aqueous samples. The control experiment confirmed that NaOH without pSC4 cannot make silver nanoparticles transfer into aqueous solution effectively. The function of NaOH in the phase transfer was to decrease the surface tension of aqueous solution, mix the two phases adequately, and increase the collision probability between pSC4 and oleic acid. An indepth study is needed to understand the exact role of NaOH in phase transfer.

The stability of the silver nanoparticles in pSC4 solution after phase transfer was tested by ionic strength. It is well-known that the electrolyte may induce precipitation of the colloidal nanoparticles in aqueous phase in literature. Strouse et al. have shown that the colloidal gold nanoparticles can be precipitated by the addition of electrolyte and, furthermore, that under certain conditions they can be redispersed in water. The stability of silver nanoparticles in pSC4 aqueous solution after phase transfer was checked as a function of electrolyte (NaCl) concentration. The UV–vis spectra showed that the intensity and position of absorption peak of silver nanoparticles in the pSC4 aqueous solution were independent of ionic strengths. The UV–vis spectra after addition of different amounts of NaCl are almost identical indicating that even the large concentration of salt does not

\[ \text{(38) Cumberiand, S. L.; Strouse, G. F. Langmuir 2002, 18, 269.} \]
destabilize the colloidal solution. The exceptional stability of the oleic acid-pSC4-capped silver colloidal solution as a function of ionic strength is a salient feature of this work.

The morphology and size of silver nanoparticles are characterized by transmission electron microscopy (TEM). Figure 4a shows the TEM micrograph obtained from the silver nanoparticles capped with oleic acid in hexane before phase transfer. It is clear that owing to the protection of oleic acid the silver nanoparticles are monodispersible and homogeneous and form two-dimensional self-assembled monolayers. The size distributions of the particles are measured from enlarged photographs of the TEM images. The average diameter of the silver particles is 11.6 nm with a standard deviation, $\sigma$, of 3.0 nm. The histogram of the size distribution was derived from 300 particles and is shown in Figure 4b. The TEM images of oleic acid capped silver nanoparticles film clearly shows the short-range ordering of silver nanoparticles. According to the formula $L(nm) = 0.25 + 0.127n$ ($n$, the number of carbon atoms in the alkyl chain), the length of oleic acid should be 2.5 nm. However, the average value of the interparticle spacing is about 1.7 nm. The interparticle spacing parameter was determined by the single distance measurements (providing the values of the shortest interparticle distances) selectively for regions of the film with the regular packing of the silver nanoparticles. Therefore, the result from the TEM images is contradictory to the calculated values. Because of overlap of hydrocarbon chains of neighboring particles, the chains are partially interdigitated in agreement with the observation of others on self-assembled films of Ag nanoparticles. After phase transfer, the morphology and size of the silver nanoparticles had no change (see Figure 5a). The average diameter of the silver particles after phase transfer is 11.3 nm with a standard deviation 2.9 nm. The particle size distribution was fairly narrow, as shown by the histograms Figure 5b. However, the average value of the interparticle spacing has


FTIR measurements and 1H NMR analyses of pSC4, pure oleic acid nanoparticles from hexane into pSC4 aqueous solution, cannot form two dimension self-assembled monolayers in the aqueous solution any more. The strong electrostatic repulsive interactions among negatively charged silver particles make the average value of the interparticle spacing increase greatly, and the nanoparticles cannot form two dimension self-assembled monolayers in the aqueous solution any more.

To further confirm the mechanism of phase transfer of the silver nanoparticles from hexane into pSC4 aqueous solution, FTIR measurements and 1H NMR analyses of pSC4, pure oleic acid, silver nanoparticles capped with oleic acid, and the precipitated silver from pSC4 aqueous solution were carried out. The results are shown in Figure 6 and Figure 7. Figure 6a is the FTIR spectrum of pure pSC4, which is consistent with the results of Shinkai. For pure oleic acid, the characteristic vibration peaks of OH at 3442 cm⁻¹, CH₂ at 2920, 2850, and 1467 cm⁻¹, CH₃ at 2956 and 1383 cm⁻¹, C=O at 1711 cm⁻¹ are clearly observed in Figure 6b. In Figure 6, curves c and d are the FTIR spectra for the silver nanoparticles capped with oleic acid and the silver nanoparticles obtained from pSC4 aqueous solution after phase transfer, respectively. When the silver nanoparticles were capped with oleic acid, the O atom in the COOH group of oleic acid offers an isolated electron to the silver atom and coordinates with the silver atom, which leads to lowering of the OH peak to 3424 cm⁻¹ and the C=O peak shift to 1709 cm⁻¹. Comparing curves c with d, it is evident that both curves are much different. All characteristic peaks of oleic acid and pSC4 shown in curves a and b, respectively, can also be observed in curve d after phase transfer, which clearly indicates that the inclusion complexes between oleic acid and pSC4 were formed by shaking the biphasic mixture. The bending vibration peak of CH₂ of the oleic acid was decreased to 1457 cm⁻¹, and the intensity of the peak was much larger than that in curve c, which implied that the inclusion complexes of oleic acid and pSC4 were formed. Therefore, the FT-IR spectra show that the silver nanoparticles in aqueous solution are capped with the inclusion complexes of oleic acid and pSC4.

Direct evidence of the microenvironment change of protons can be obtained from 1H NMR experiments, which can provide information about the formation, stability, and structure of inclusion complexes. Figure 7 shows the 1H NMR of pSC4 in D₂O (curve a), pure oleic acid in CDCl₃ (curve b), silver nanoparticles capped with oleic acid in CDCl₃ (curve c), and silver nanoparticles obtained from aqueous solution of pSC4 in D₂O (curve d). The values of the chemical shifts of pSC4 were shown in Experimental Section. In Figure 7b, the chemical shifts at 1.268 and 0.895 ppm correspond to methylene protons attached to CH₃ and methyl protons in the pure oleic acid molecule, respectively. From curve c, all peaks of the oleic acid shown in curve b can be observed and a slight upfield shift occurred for oleic acid, which is due to the O atom of the COOH group of oleic acid donating an isolated electron to silver atom and forming a coordination with the silver atom. The feeble movement of chemistry shift of the oleic acid shows that the silver nanoparticles were capped by oleic acid. However, after phase transfer, all peaks of pSC4 and oleic acid shown in curves a and b can be observed, which means that the silver nanoparticles were capped by the inclusion complex of oleic acid and pSC4 rather than monomeric oleic acid or pSC4, which agrees with the results of FTIR. Furthermore, the significant changes of chemistry shifts for oleic acid and pSC4 strongly confirmed that the silver nanoparticles were modified by the inclusion complex. From Figure 7d, a great upfield shift occurs for oleic acid. The peaks of the methylene protons attached to CH₃ and the methyl protons were shifted to 1.136 and 0.722 ppm, respectively. The chemical shift of other protons of oleic acid also occurred with great changes. The changes of chemical shifts of oleic acid suggest that the oleic acid monomer has completely entered into the hydrophobic cavity of pSC4 and the phenyl ring engendered shielding effect for oleic acid protons, which led the decrease of the chemical shift of the protons of oleic acid. On the other hand, due to the hydrocarbon chain of oleic acid entering into

Figure 6. FTIR spectrum of (a) pSC4, (b) pure oleic acid, (c) the silver nanoparticles capped with oleic acid before phase transfer, and (d) the powder of the silver nanoparticles from pSC4 aqueous solution after phase transfer.

the hydrophobic cavity of pSC4, the signal of pSC4 protons is shifted upfield. The peak of methylene protons of pSC4 becomes broadened and shifts to 3.875 ppm. The values of chemical shifts of aromatic protons decrease to 7.381 ppm. Therefore, the surprising changes of chemistry shifts for oleic acid and pSC4 strongly prove that the Ag nanoparticles are capped by the inclusion complex again, which lead to the protecting layer of silver nanoparticles being shifted from hydrophobic to hydrophilic. Overall, the NMR spectra further prove the mechanism for the phase transfer of silver nanoparticles from organic phase into aqueous phase as illustrated in Scheme 1. The whole procedure of phase transfer is divided into two steps. First, the molecules of oleic acid are absorbed on the surface of silver nanoparticles. Because of the hydrophobic hydrocarbon chains of oleic acid, the silver nanoparticles are soluble only in organic solvents, such as CHCl₃ and hexane (shown in Scheme 1a). It
is found that the silver nanoparticles capped with oleic acid in organic solvent possess fine stability. Second, by vigorous shaking of a biphasic mixture of the oleic acid-stabilized silver organosol and pSC4 solution, oleic acid, as a guest molecule, would like to enter into the hydrophobic cavities of pSC4 to form oleic acid–pSC4 inclusion complex (shown in Scheme 1b). As a consequence, silver nanoparticles are threaded by inclusion complexes between oleic acid and pSC4, and the surface property changes from hydrophobic to hydrophilic. The protecting layer of silver nanoparticles shifts from hydrophobic to hydrophilic, which drives the phase transfer of silver nanoparticles from hexanes into pSC4 solution. We believe this approach can be an effective method for changing the surface property of nanoparticles from hydrophobic to hydrophilic and for the formation of stable nanoparticles in aqueous solutions, which can be extended to other metals and metal oxides nanoparticles, such as gold, platinum, and Fe₂O₃. Furthermore, the formation of the inclusion complexes is reversible. Therefore, the reversible phase transfer may actually be through the host–guest binding interaction. Further studies on the reversible phase transfer are in progress.

**Conclusion**

The protecting layer of silver nanoparticles shifts from hydrophobic to hydrophilic based on host–guest binding interaction. Silver nanoparticles capped by oleic acid in hexane have been successfully transferred to pSC4 aqueous solution. By stirring of a biphasic mixture of the oleic acid-stabilized silver organosol (guest molecule) and pSC4 aqueous solution, hydrophobic alkyl chains of oleic acid enter into the hydrophobic cavities of the host molecule pSC4 to form oleic acid–pSC4 inclusion complex. As a consequence, the silver particles are threaded by inclusion complexes between oleic acid and pSC4 and the surface property changes from hydrophobic to hydrophilic, which drive the phase transfer of silver nanoparticles from hexane into aqueous solution. The authors believe that this approach can be an effective method for the stabilization of oleic acid molecular capped nanoparticles in aqueous solutions, which is an important aspect for the exploration of possible biological, catalytic, and sensoric applications in various physicochemical environments.

**Acknowledgment.** The authors acknowledge the financial support from the National Natural Science Foundation of China (Grant No. 20373060, 20673094, 20773107), the Natural Science Key Foundation of Educational Committee of Jiangsu Province of China (Grant No. 07KJA15015), the Foundation of Jiangsu Provincial Key Program of Physical Chemistry in Yangzhou University, and the Foundation of the Educational Committee of Jiangsu Provincial Universities Excellence Science and Technology Invention Team in Yangzhou University. The authors also acknowledge the Foundation of the Educational Committee of Jiangsu Provincial General Universities Graduate Student Scientific Research Invention Plan and the Testing Center of Yangzhou University for TEM, XRD, and NMR experiments.