The effect of SDBS-Ag^+ ligand structure on the preparation of flake-like silver particles

Y.H. Song[1, 2], G.Y. Liang[1], Y. Yang[2], W.W. Gao[2]
1Department of Materials Physics, Science School, Non-equilibrium Condensed Matter and Quantum Engineering Laboratory, Xi'an Jiaotong University, Xi'an, 710049, Shaanxi, P.R.China
2Research Center of Metallurgical Engineering & Technology of Shaanxi Province, Xi'an University of Architecture and technology, Xi'an, 710055, Shaanxi, P.R.China

Introduction

The novel properties and broad application of nano-size silver particles in the fields of electrics, optics, catalyze and biosensors have attracted great interest[1]. Particularly, the flake-like silver particles display more excellent properties, because of its large specific surface area, low oxidation trend and good conductivity[2].

Sodium dodecyl benzene sulfonate (SDBS) has a sulfonic group (SO_3), a phenyl and linear dodecyl. Any of the oxygen atoms in the culfonic group (—SO_3) may form coordinate bond with silver ion. As surfactant, it plays an important role in silver particles preparation, i.e. template. It may form porous flexible organic-inorganic sandwich structure with silver ions [3]. Therefore, silver particles with special shape can be prepared by reducing the silver ions.

Water-soluble high molecular polymer polyvinyl pyrrolidone (PVP) contains a large molecular chain. It can adsorb SDBS to form bound-micelles. Besides, both nitrogen and oxygen atoms in PVP have non-bonding lone electrons, which are easy to form dipolar bond. Therefore, PVP can be used as a second ligand in the SDBS–PVP complex solution system to produce the silver sulfonate compound with a special structure[4].

In this paper, the flake-like silver particles were prepared, and the effect of the ligand structure on the shape of silver particles was discussed.

Experimental

Analytically pure reagents, that is polyvinyl pyrrolidone (PVP), sodium dodecyl benzene sulfonate (SDBS), silver nitrate($AgNO_3$), hydrazine hydrate ($N_2H_4\cdot H_2O$) and absolute alcohol, were used in the experiment.

For the preparation of silver particles, 25mL $AgNO_3$ solution was first added into 75mL SDBS + 1.5%PVP complex solution, and then reduced by $N_2H_4\cdot H_2O$. After reaction, as-prepared particles were centrifugally separated in the TTGL-16G freezing centrifugal machine, and washed by alcohol.

The structure of silver powders was characterized by X-ray diffraction (XRD) (using Cu k_α radiation). The observation of silver particles was carried out on the JSM-6360LV-type scanning electron microscopy (SEM).

Result and discussion

Fig.1. shows the XRD pattern of the prepared particles. Four diffraction peaks of Ag appear in the pattern, which confirms that the prepared particles are silver.

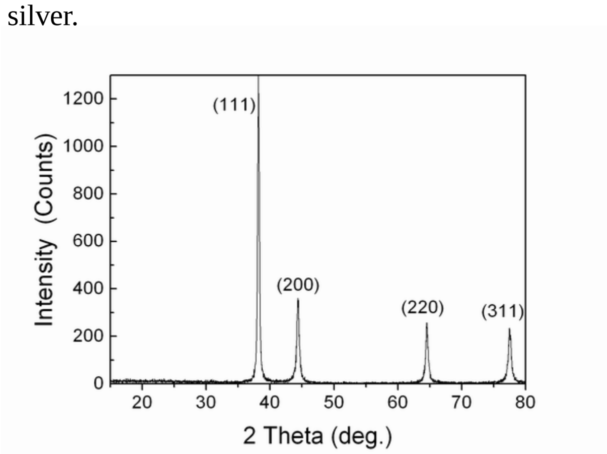

Fig.1 XRD pattern of the prepared particles

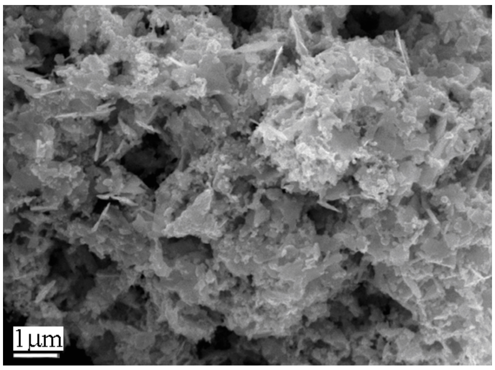

Fig.2 SEM images of silver particles

Fig.2 shows the SEM image of silver particles. It is seen that the silver particles are flake-like with very large specific surface area.

SDBS play an important role in the shape control of silver particles. Fig.3 shows the organic/inorganic sandwich structure of SDBS-Ag^+ ligand. The organic layer consists of alkyl chains, and the inorganic layer consists of SO_3-M-O_3S. Two S atoms, four O atoms and two Ag^+ form an eight-element ring. Every two eight-element rings share three atoms with each other. These eight-element rings connect to construct a network structure, which is the inorganic layer. The formation of this planar sandwich structure is the result of the electrostatic effect of phenyls and the stack of π-π bond.

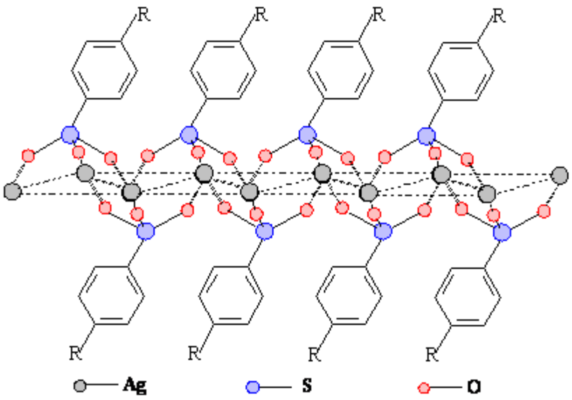

Fig.3 The ligand structure of SDBS with Ag^+

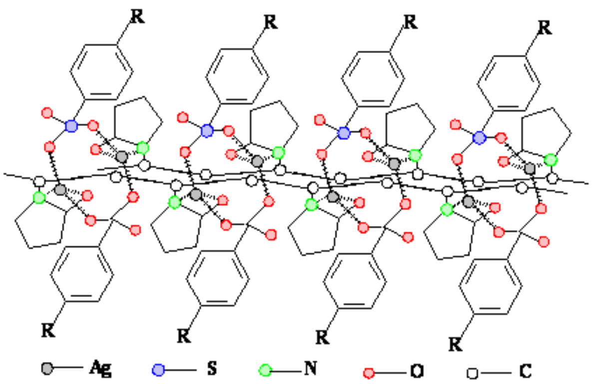

Fig.4 The ligand structure of PVP+SDBS with Ag^+

With water-soluble PVP molecule, SDBS can form bound-micelle on the PVP molecule chains. Besides, the non-bonding lone electrons of nitrogen and oxygen atoms in PVP are easy to interact with S=O bond in SDBS, and the dipolar bond produced by N and O may also bond with Sp3 hybrid orbital of silver outer-shell electron. These make PVP like a belt tying the planar eight-element ring network together, as shown in Fig.4. Large molecule (PVP) can constrain SDBS micelle and make the sandwich structure more stable. This sandwich structure limits the Ag^+ in one plane, which will restrict the vertical growth of silver particles and make them flake-like.

In the silver particles preparation, Ag^+ is previously added into the SDBS+PVP complex solution. The Ag^+ can very uniformly disperse. This makes a very well organic/inorganic sandwich structure form. Hence, flake-like silver particles with very large specific surface area form after adding $N_2H_4 \cdot H_2O$ into the complex solution.

Conclusion

1. SDBS and Ag^+ can construct the organic/ inorganic sandwich structure, which plays a role of template during the growth of silver particles.
2. PVP acts as a belt tying the eight-element rings together, making the organic/ inorganic sandwich structure more stable.
3. The organic/ inorganic sandwich structure restricts the vertical growth of silver, leading to the formation of flake-like silver particles during reduction.

Reference

[1] B. Wiley, Y. Sun, B. Mayers and Y. Xia, Shape-Controlled Synthesis of Metal Nanostructures: The Case of Silver, Chem. Eur. J., 11(2005) 454~463.

[2] J. Yang, Q.B. Zhang, J. Y. Lee, H.P. Too, Dissolution–recrystallization mechanism for the conversion of silver nanospheres to triangular nanoplates, J. Colloid. Interf. Sci., 308(2007) 157–161.

[3] B.J. Gunderman, P.J. Squattrito, Structural Variations in Layered Alkali Metal Naphthalenesulfonates, Inorg. Chem., 34(1995) 2399-2406.

[4] S.K. Makinen, N.J. Melcer, M. Parvez, et al., Highly Selective Guest Uptake in a Silver Sulfonate Network Imparted by a Tetragonal to Triclinic Shift in the Solid State, Chem. Eur. J., (2001) 5176-5182.