姓名：于卿　　学号：21026096　　指导老师：彭新生 教授

Micro/Nano-structure membranes based on colloidal nanoparticles and filtration technique

Qing Yu and Xinsheng Peng*

State Key Laboratory of Silicon Materials, Department of Materials Science and Engineering, Zhejiang University, Hang Zhou, 310027, China

Introduction

Functional nanoparticles in the form of thin films have attracted plenty of attention.[1] Ordered macroporous solids/films have been studied a lot in the application fields of sensors, catalysts and optoelectronic devices.[2-4]They are often prepared by colloidal crystal templating method, including polystyrene (PS), poly (methyl methacrylate) (PMMA) and silica spheres.[5–22] This templating method allows precise control of the pore size and the macroporous structures.

In this work, we demonstrated our previous work on micro/nano-structure membranes conducted from PS and gold colloidal particles by filtration technique with a sacrifice layer of $Cu(OH)_2$ nanostrands. Surface Enhanced Raman Spectrum properties of gold nanoparticle films were also detected.

Experiments

Self-assembly of ordered nanoparticle films and ordered macroporous films

- Filtration of nanostrands as the sacrificing layer
- Filtration of A nanoparticles on the nanostrands
- Filtration of B nanoparticles which are falled into the interstitial voids of the preformed sphere arrays of A
- Removal of nanostrands
- Removal of A nanoparticles

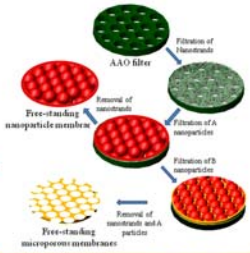

Fig. 1 The synthesis procedure of the ordered nanoparticle films and macroporous films

Results and Discussion

1. Number control of layers of thus prepared nanoparticle films

- There is a leaner relationship between the filtration volume of PS colloidal particles and the number of layers which can be seen in Fig. 2.
- This leaner relationship can be extended to other kinds of colloidal particles.
- So the layers of nanoparticle films can be controlled by using this filtration technique.

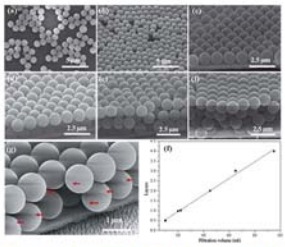

Fig. 2 SEMimages of the PS layers prepared by filtering (a) 10 mL, (b) 20 mL, (c) 22 mL, (d) 45 mL, (e) 65 mL, and (f) 95 mL of 0.001 wt% 1.09 mmPS colloids on CHN layer, respectively. (g) The enlargement of (d). (f) The relationship between the filtration volume and the stacking layer numbers of the PS colloids.[23]

2. Morphologies of ordered gold nanoparticle films and macroporous films

- ✓ Nanostrands with a diameter of 2.5-5nm were synthesized and deposited uniformly on AAO substrate through filtration.
- ✓ PS latex templates with a hexagonal structure have been naturally formed on the nanostrands layer by filtration.
- ✓ The film was readily to peel off and became free-standing after removing the nanostrand sacrificing layer.

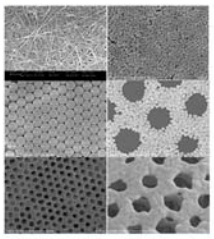

Fig. 3 SEM images of (a)[24] nanostrands layers formed on AAO surface (b)[24] the film prepared from 5 ml 40 nm gold nanoparticle, (c)[23] bilayer of 1.09 mm PS templates, (d)[23] 10 mL 100 nm gold nanoparticles filling the PS monolayer templates, (e)[23] and (f)[23] macroporous gold films after removing PS templates and CHN layers.

3. SERS of gold nanoparticle films

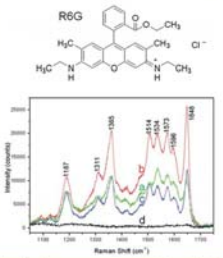

Fig. 4 Raman spectra (a)–(c) of R6G molecules on the gold nanoparticle films prepared from 10 ml, 20 nm, 10 ml 40 nm, and 20 ml 150 nm gold nanoparticles, respectively; (d) is recorded from 1×10^{-4} M R6G solution.

Table 1 Raman Enhancement factors and relative intensities of the vibrations of R6G molecules recorded from 20 nm, 40 nm and 150 nm gold nanoparticle films. Laser excitation was 514.5 nm.

Raman mode/cm⁻¹	20 nm EF (×10⁶) (rel. int. to 1648 cm⁻¹ mode)	40 nm	150 nm
1189	1.62 (0.8)	2.21 (0.42)	1.58 (0.64)
1311	1.55 (0.66)	2.81 (0.47)	1.63 (0.56)
1361	2.97 (1.12)	5.45 (0.81)	2.89 (0.91)
1506	3.07 (0.97)	6.45 (0.79)	2.95 (0.78)
1534	**4.16 (1.29)**	6.15 (0.78)	3.25 (0.76)
1573	2.63 (1.19)	4.67 (0.80)	2.45 (0.73)
1594	2.44 (1.02)	4.12 (0.66)	1.81 (0.58)
1648	2.75 (1)	**6.59 (1)**	**3.77 (1)**

The nanosize of the interspaces between the gold nanoparticles may have confinement effect of the trapped R6G molecules and result in the abnormal enhancements and relative stronger intensities at frequencies at 1534 and 1596 cm^{-1}.

Conclusion

- ■ Free-standing ultrathin gold nanoparticle films were prepared through simple filtration and peeling off techniques using unique metal hydroxide nanostrands.
- ■ These films are free-standing and robust enough to transfer onto certain substrate for further applications.

Primary References

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