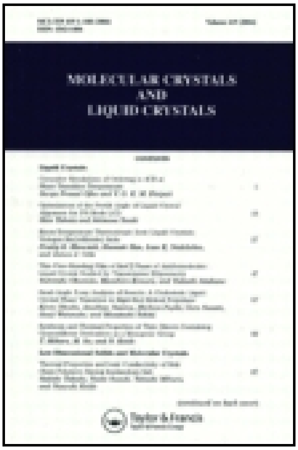

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Two-Dimensional Patterning of Nanoparticles Using Dissipative Structures

Tetsuro Sawadaishi [a b] , Kuniharu Ijiro [a] , Masatsugu Shimomura [a b] , Yukihide Shiraishi [c] , Naoki Toshima [c] , Tetsu Yonezawa [d] & Toyoki Kunitake [b]

[a] Research Institute for Electronic Science, Hokkaido University, Sapporo, 060-0812, Japan

[b] Frontier Research System, The Institute of Physical and Chemical Research (RIKEN), Wako, 351-0198, Japan

[c] Faculty of Science and Engineering, Science University of Tokyo, Yamaguchi

[d] Graduate School of Engineering, Kyushu University

Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2001, Vol. 371, pp. 123-126

Two-Dimensional Patterning of Nanoparticles Using Dissipative Structures

TETSURO SAWADAISHI[1,2], KUNIHARU IJIRO[1], MASATSUGU SHIMOMURA[1,2]*, YUKIHIDE SHIRAISHI[3], NAOKI TOSHIMA[3], TETSU YONEZAWA[4] and TOYOKI KUNITAKE[2]

[1]*Research Institute for Electronic Science, Hokkaido University, Sapporo 060-0812 Japan,* [2]*Frontier Research System, The Institute of Physical and Chemical Research (RIKEN), Wako 351-0198 Japan,* [3]*Faculty of Science and Engineering, Science University of Tokyo in Yamaguchi and* [4]*Graduate School of Engineering, Kyushu University*

Two-dimensional regular patterns of nanoparticles were formed on solid substrate by casting colloidal dispersion. Periodic stripes were formed on mica surface parallel to the receding direction of casting solution. The thickness of each stripe was estimated to be comparable to that of monolayer of particles. From atomic force microscopy (AFM) and scanning electron microscopy (SEM), it was cleared that the monolayer of silica particles were hexagonally packed.

Keywords: colloidal particles; cast film; 2-dimensional patterns; capillary force; metallic nanoparticles; dissipative structures

INTRODUCTION

Two- or three-dimensional arrangement of colloidal nanoparticles is important for the application of photonics materials [1], high-density magnetic data storage devices [2] and biosensors [3]. We have already reported that submicron-sized regular stripe patterns are formed in polymer cast films by freezing of dissipative structures [4]. In our previous research, regular stripe patterns were prepared from linear macromolecules. In this paper, we report the pattern formation of fine particles onto solid surfaces by simple casting in order to extend the generality of pattern formation mechanism.

EXPERIMENTAL

Palladium/platinum bimetallic nanoparticles were prepared by alcohol reduction in the presence of poly (N-vinyl-2-pyrrolidone) [5]. Cationic gold nanoparticles were prepared by the reduction of $AuCl_4^-$ with borohydride in the presence of the disulfide stabilizer [6]. Pt/Pd bimetallic nanoparticles, cationic gold nanoparticles, and silica particles (diameter: 12-450 nm) (NISSAN CHEMICAL INDUSTRIES, LTD.) were dispersed into purified water (Milli-Q SP TOC Reagent Water System), respectively. Ten microliter of colloidal dispersion was dropped onto freshly cleaved mica. Casting solvent was evaporated at 20-150 °C on a hot plate. The cast films prepared were observed by fluorescence microscopy with BHT biological microscope system (OLYMPUS Optical Co., Ltd., Japan). SEM was performed with S-900 (HITACHI). The AC mode AFM was performed with the NV2500 AFM system (OLYMPUS Optical Co., Ltd., Japan).

RESULTS AND DISCUSSION

Dendrite structures were observed in cast films of Pt/Pd bimetallic nanoparticles and cationic gold nanoparticles, when samples were prepared at the room temperature (20 °C). By *in situ* optical microscopy, these structures were located randomly on substrates after solvent was evaporated. It was considered that the structures were colloidal crystal formed by diffusion limited aggregation. On the other hand, at higher temperature, regularly arranged stripe patterns were formed parallel to the receding direction of casting solution. For example, submicrometer-scaled stripe patterns of Pt/Pd bimetallic nanoparticles were obtained by casing colloidal dispersion onto mica substrates at 90 °C (Fig. 1a). Similar

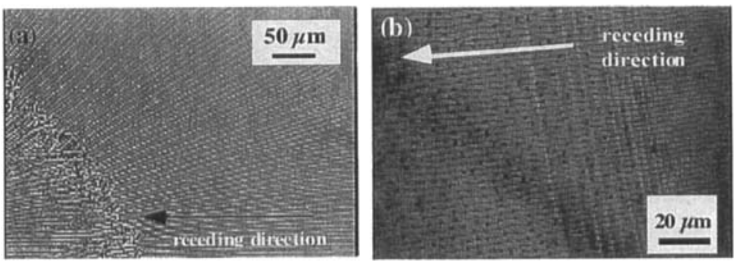

FIGURE 1 Optical micrograph of patterned (a) bimetallic nanoparticles and (b) cationic gold nanoparticles.

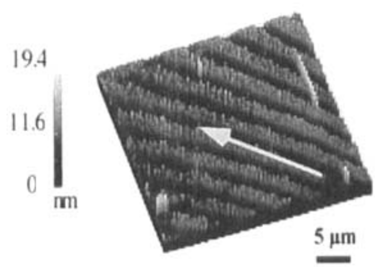

FIGURE 2 AFM image of cationic gold nanoparticles

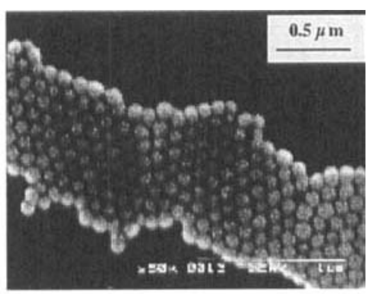

FIGURE 3 SEM image of patterned patterned silica particles (diameter: 100 nm)

regular patterns were observed from cationic gold nanopartilces (Fig. 1b). In this case, by AFM measurement, the thickness of lines was estimated about 5-10 nm comparable to those of single or double layer of the gold nanoparticles (Fig. 2). From *in situ* optical microscopy, it was considered that this phenomenon arose from dissipative structures in which the convections of solution and fractuation of concentration of particles were occurred. During evaporation of solvent, concentrated particles at three-phase line were left on solid surface to form regular stripe patterns. In formation process of submicrometer-scaled patterns, one- or two-dimensional arrangement of colloidal particles is expected, because the particles are densely packed in microcavity on three-phase line. Regular stripe patterns consisting of silica particles (diameter: 25, 100, 450 nm) were also formed parallel to the receding direction. It was suggested from AFM and SEM measurements that silica particles in monolayer were hexagonally packed in the patterns (Fig. 3). Hierarchic structuring of colloidal nanoparticles from nanometer (hexagonal particles packing) to micrometer (regular arranged stripes) can provide novel optical properties of photonic band gap crystals.

References

[1] S. Lin, E. Chow, V. Hietala, P. Villeneuve, J. Joannopoulos, *Science*, **282**, 274 (1998)
[2] C. Haginoya, M. Ishibashi, K. Koike, *Appl. Phys. Lett.*, **71**, 2934 (1997)
[3] O. Velev, E. Kaoer, *Langmuir*, **15**, 3693 (1999)
[4] O. Karthaus, K. Ijiro, M. Shimomura., *Chem. Lett.*, 821 (1996)
[5] N. Toshima, *Macromol. Symp.*, **105**, 111 (1996)
[6] T. Yonezawa, S. Onoue, T. Kunitake, *Chem. Lett.*, 1061 (1999)