FABRICATION OF MONO-DISPERSED SPHERICAL ASSEMBLIES AND THESE STRUCTURAL COLORS BY USING MICROFLOW DEVICE

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ABSTRACT

Structural colors are caused by the interaction of visible light with micro structures of the substances, on a length scale comparable to optical wavelength. We pay marked attention to the structural colored materials because of these less fading and low environment burden compared with the colored materials using dyes. This report shows that we fabricated mono-dispersed spherical assembly (MDSA) composed of submicron silica particles as a structural color material by using a micro flow focusing device (MFFD). Moreover, we will introduce the improvement for the coloration of the spherical assembly by magnetic particles.

KEYWORDS: structural color, micro flow focusing device (MFFD), mono-dispersed spherical assembly (MDSA), magnetic particle

INTRODUCTION

We unconsciously have had a damaging effect on environment with producing a variety of materials for the development and prosperity of humankind. As a result we had serious environmental problems caused by pollutions. Pigments and dyes that are useful for fulfilling life are no exceptions. Considering the rise of an environmental awareness and the minimal impact of environment in future, we need to produce environmentally friendly color materials. Structural colored materials must be the strong candidates because a variety of colored materials can be prepared just by changing the microstructures of the materials [1]. Here, we describe the preparation of new structural colored materials by mixing white particles such as mono-dispersed submicron silica particles and black particles like magnetite particles using a micro flow focusing device (MFFD).

Structural colors are caused by interference of light, scattering, and diffraction effects; the color tints are influenced by refractive indices and structural form of substances [2]. One of the most widely anticipated structural colored materials are a colloidal crystal with a periodic optical nanostructure, composed of mono-dispersed submicron silica particles. Structural colored pigments can be obtained from the smashed powders of colloidal crystal. As, however, the powders obtained exhibit different colors because the structural color from such a periodic dielectric structure is caused by Bragg diffraction [3]. In comparison, spherical assemblies (SAs) of the mono-dispersed submicron silica particles are particular interest because of the possibilities for the controlled unicolor materials. In addition, such color materials can have the application potential for biomolecular screenings or color displays [4, 5]. To use SAs for such applications, we need to apply a micro flow focusing device (MFFD) for preparing the mono-dispersed SAs (MDSAs) of mono-dispersed submicron silica particles (Figure 1).

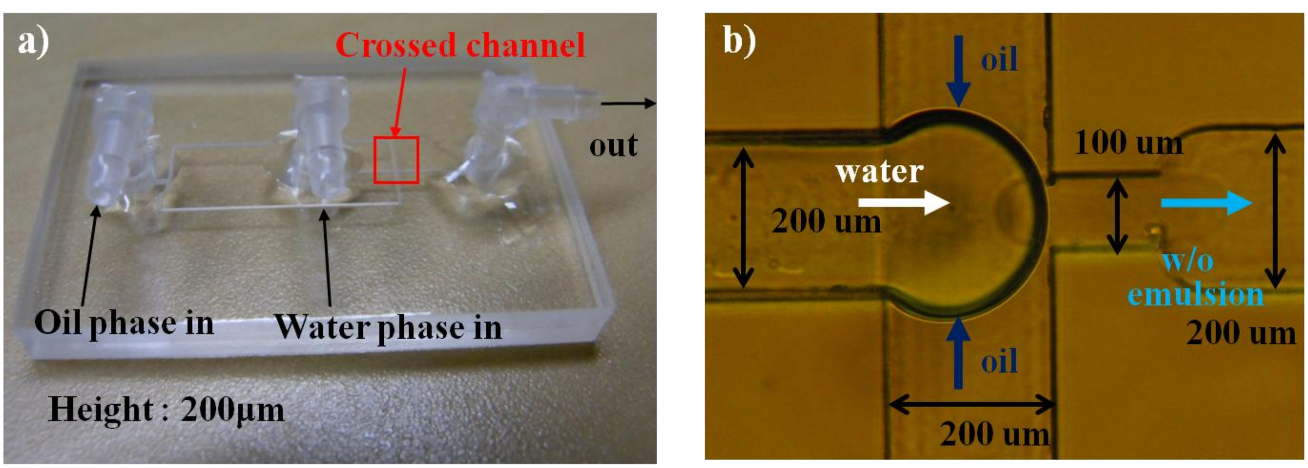

Figure 1 Photographs of our micro flow focusing device (MFFD): a) Overall view, b) The crossed channel of MFFD. The device has the channel of 200 µm diameter. Oil phase: 0.2 wt% of Span80 is dissolved in hexadecane. Water phase: Silica particles are suspended in aqueous solutions with or without Fe_3O_4.

EXPERIMENTAL

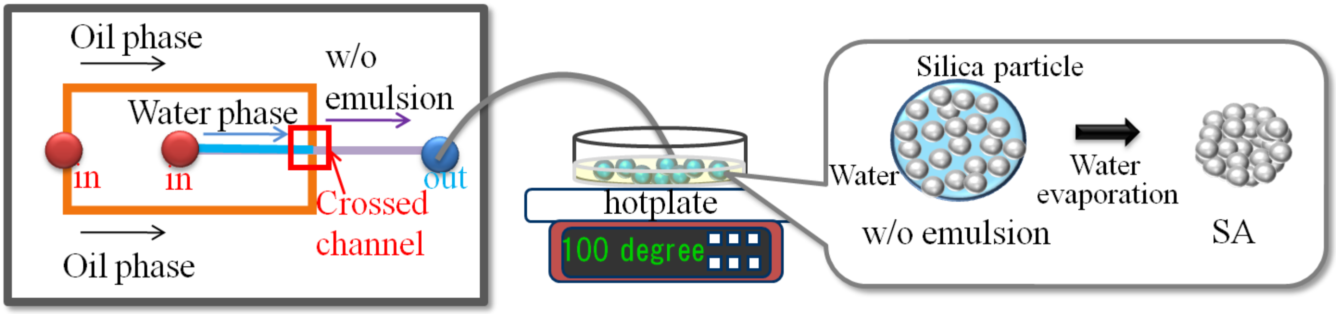

Figure 2 Outline of MDSAs fabrication process.

We prepared the MFFD made of poly(methyl methacrylate), which has a flow focusing geometry integrated into a planar flow channel of 100 and 200 μm diameters to form aqueous drops containing mono-dispersed submicron silica particles in a continuous and immiscible oil phase. The MFFD has also an oil phase inlet, a water phase inlet, a crossed channel, and an outlet (Figure 1a). A water-in-oil (w/o) emulsion can be prepared at the crossed channel using this MFFD (Figure 1b). We used an oil phase of a hexadecane solution including 0.2wt% of Span80 and an water phase suspending mono-dispersed submicron silica particles with or without Fe_3O_4. The oil and the water phases are inserted to the flow channels by syringe pumps, and the w/o emulsion is produced at the crossed channel (Figure 2). The moment that a mono-dispersed aqueous droplet was fabricated is shown in Figure 3a. The emulsion comes out of the exit, and then flows into a dish filled with oil on a hotplate (Figure 3b). As a result, mono-dispersed aqueous droplets containing mono-dispersed submicron silica particles can be obtained by the MFFD (Figure 3c). The mono-dispersed aqueous droplets are dried in oil phase in the dish at 100 °C for 6 hours. In this drying process we used a hydrophobic dish made of poly tetrafluoroethylene because spherical SAs cannot be obtained when we use a hydrophilic dish such as a glass dish due to the adsorption of the aqueous droplets to the surface of the dish; the aqueous droplets interact with the surface of the hydrophilic dish and cannot keep these spherical shapes. In the drying process, water in the aqueous droplets is evaporated by the application of heat and the silica particles in the aqueous droplets are flocculated. After drying the aqueous droplets in the oil phase, MDSAs of the silica particles are fabricated: the MDSAs exhibit brilliant colors because of the crystal structure. The size of the MDSAs can be controlled by changing the concentration of the silica particles in the aqueous solutions (Table 1). The diameters of the fabricated MDSAs were from 53.8 μm to 77.8 μm according to the concentration of the silica particles. The coefficients of variance of the MDSAs were under 10%; we could prepare MDSAs with various sizes just by changing the concentration of the silica particles in the aqueous suspension by using the MFFD. Moreover, we tried to improve the coloration of the MDSAs by the addition of magnetic particles. Figure 4a is a picture of the MDSAs made of just mono-dispersed submicron silica particles with 200 nm in diameter. These MDSAs exhibit glossy pearl-like structural color. However, the coloration of the MDSAs can be dramatically changed by the addition of small amount of magnetic particles (Figure 4b). These MDSAs with magnetic particles reveal dazzling blue structural color. By adding the magnetic particles, we can also expect the magnetic responsivity of the MDSAs.

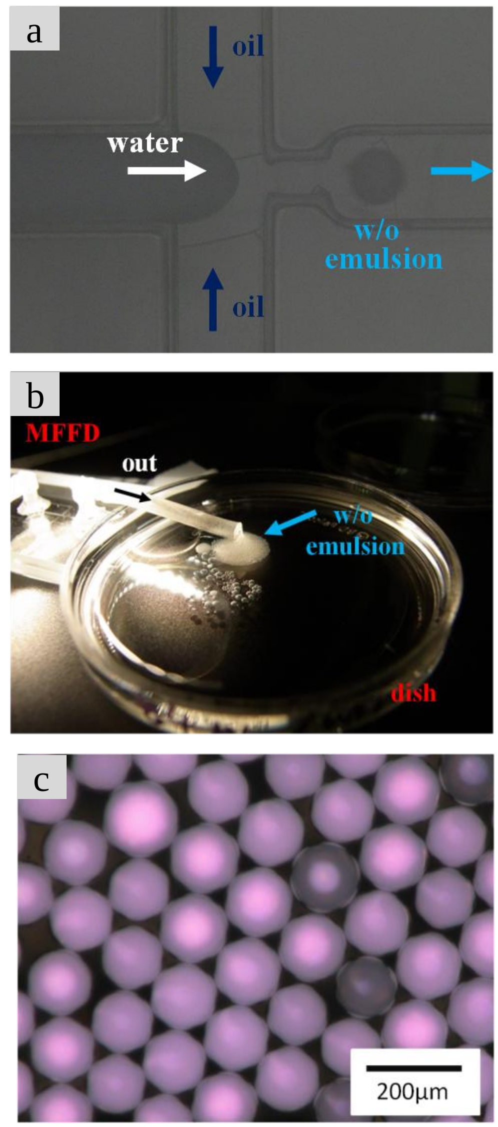

Figure 3 The pictures of MDSAs fabrication process.
a) Picture of crossed channel
b) W/o emulsion which was output on dish
c) Picture of w/o emulsion

Table 1 The sizes of SAs depending on the initial concentration of mono-dispersed submicron silica particles.

Concentration of silica particles (wt%)	10	20	30	40
Average diameter (μm)	53.8	63.0	73.3	77.8
Value of CV (%)	6.3	4.6	4.7	3.7

CONCLUSION

We could fabricate mono-dispersed spherical assemblies by using MFFD that have a crossed channel. The diameter of MDSAs could be varied by changing the concentration of silica particles in the water phase. Furthermore we could change color saturation by adding magnetic particles. These results indicate that the MDSAs will become new and environmentally friendly color materials.

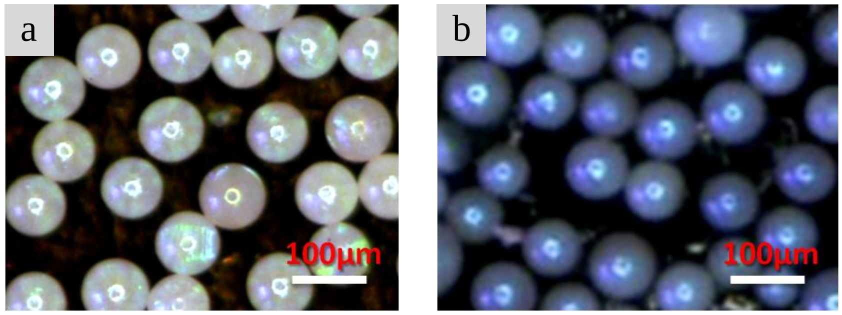

Figure 4 Photographs of MD SAs
a) MDSAs composed of only mono-dispersed submicron silica particles. b) MDSAs composed of mono-dispersed submicron silica particles and magnetic particles.

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