A Single Grain of OBDG in a Semi-dilute Solution - Photonic Crystal

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Many researches and inventions of non-linear optical material have been stimulated for these decades by the publications on the optical properties of three-dimensionally arrayed dielectric materials by Yablonovitch and John in 1987. The optical materials allow us to control the flow of light, providing a new technology for optical devices, such as low-energy consumption laser resonators, high-speed computers, light storage, and so on.

We have succeeded in the fabrication of a photonic crystal (PhC) by self-assembly of block copolymers (BCP) that generally form one-, two-, and three-dimensional periodic nanostructures, i.e., lamellar, cylindrical, spherical, gyroids microdomains, etc. Lattice spacings of the microdomain structures depend on the molecular sizes of BCPs. To obtain a large spacing on the order of the wavelength of visible light, we should utilize BCPs with ultra-high-molecular weight (UHMW), such as 10^6 g/mol. They, however, are highly entangled and, hence, too viscous in bulk to attain structural equilibrium. Even in a semi-dilute solution at several percent, we have found that solvent selectivity strongly induces microphase separation (Fig. 1) [1,2]. BCPs can easily form equilibrated structures with high order at such low concentrations because of their high mobility. Large grains on the order of centimeters (Fig. 2) were obtained in the vicinity of the boundary of the lyotropic order-disorder transition. These phenomena were well analyzed by computer simulation using “SUSHI” [3,4].

We have successfully applied these structures in a THF/water mixture to a laser resonator. The specimen utilized here was a ultra-high-molecular-weight polystyrene-*b*-polymethylmethacrylate diblock copolymer, forming ordered-bicontinuous double gyroid with a tris octahedron structure. They successfully inhibit the spontaneous emission of dyes, and laser emission was generated in twenty four directions as seen in Fig. 3. The laser threshold was 0.1 μJ/pulse and is dependent on the refractive index difference between the phases, i.e., the reflectivity, and the number of the stacked lattice planes. In this paper, we will discuss the resonator efficiency as a function of reflectivity and grain size, and also a new possible pathway to realize metamaterials.

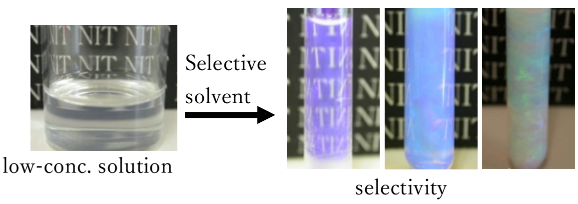

Figure 1 Microphase separation induced by selective solvent

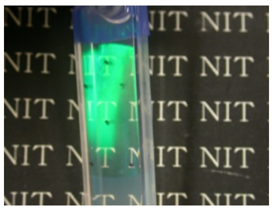

Figure 2 a giant grain in a BCP solution.

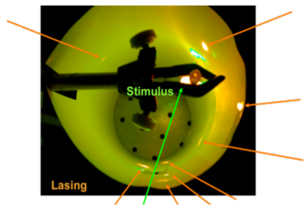

Figure 2 Laser emission from microdomain sturctures

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[1] K. Tsuchiya, S. Okamoto et al., *OPTICS EXPRESS,2008*, **16 (8)**, 5362-5371 (2008)

[2] K Ando, T Yamanaka, S Okamoto, T Inoue, N Sakamoto, D. Yamaguchi, S Koizumi, H Hasegawa and N Koshikawa, *IOP Conf. Series: Mater. Sci. and Eng.*, **14**, 012012(1) (2010)

[3] K Ando, T Yamanaka, S Okamoto, N Sakamoto, D Yamaguchi,S Koizumi, H Hasegawa and N Koshikawa, *J. Phys.: Conf. Ser.*, **247**, 012040(1) (2010)

[4] developed by the group of Professor Doi (http://www.octa.jp/OCTA/sushi_jp.html)