Fabrication of Pixellated Inverse Opal Films by Selective Photo-polymerization

이승곤, 이기라*, 문준혁**, 양승만
한국과학기술원 광자유체 집적소자 연구단, *LG화학 기술연구원, **University of Pennsylvania
smyang@kaist.ac.kr

One of the remaining issues in self-assembled colloidal crystals is to create the defective or patterned structures for photonic-crystals-based microdisplay devices, integrated photonic chips, as well as micro-cavities for extracting or adding the light of specific frequency. (1) Here, we describe a simple and facile method for the two-dimensional array of pixellated colored cells by selective photon-induced polymerization in colloidal crystal films.

For tuning the reflective colors of colloidal photonic crystals, we should find a way to control refractive index mismatch, lattice constant, symmetry (or orientation), magnetic permeability, andprecisely positioned defects. Among them, one of the simple and feasible factors in colloidal photonic crystals is to control the refractive index contrast between matrix and colloidal particles. In addition to the manipulation of refractive indices, it is still needed to pattern colloidal photonic crystals in micrometer scales for practical applications in photonics devices and micro-displays. To do this, we used the selective reaction of a photo-curable prepolymer inside opaline colloidal crystal structures. (2)

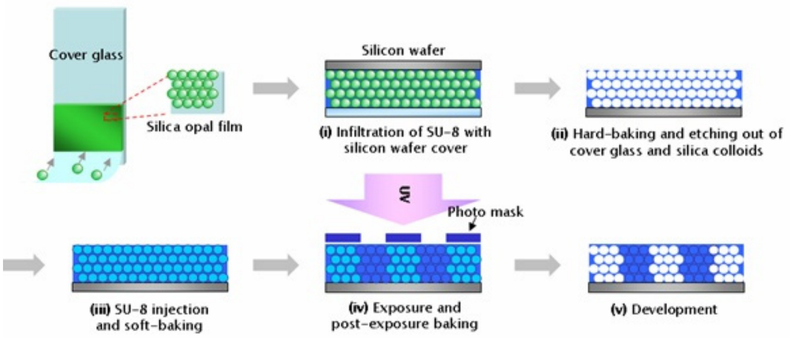

Figure 1. Schematic of patterned inverse opal film

As shown in the experimental scheme of figure 1, we have explored photolithography to patternize the inverse opals. Before all experiments on patterning of photonic crystals, high quality silica opal films were deposited on glass substrates by a vertical dip-coating method. To obtain a polymeric inverse opal film as a scaffold structure, a prepolymer of negative photoresist (SU-8) was infiltrated into the silica opal film and hard-baked. The silica colloids were dissolved out with HF solution leaving behind well-ordered macropores in face centered cubic (fcc) lattice (step ii). (Caution: HF solution is extremely corrosive and toxic; it should be handled with care.) Then, the silica opal film was taken away from the glass substrate and placed upside down onto a wafer so that the smooth and plane surface was facing out. This was an important procedure for the subsequent patterning process. The same negative photoresist was backfilled the macropores (step iii) and the capillary force drove the photoresist to infiltrate into the macropores. At the soft-baking step, the film remainedtransparent, which implied that the refractive indices of the inverse opal scaffold and injected photoresist (SU-8) were almost matched. In our previous work, we reported that the refractive indices of hard-baked and soft-baked negative photoresists of SU-8 were 1.5929 and 1.5925, respectively. [(4)] This small difference in refractive indices did not cause the scattering of UV beam which otherwise could entail corona around the patterns. Finally, UV light was irradiated onto the prepared composite film through a mask film with designed patterns (step iv). At the exposed spots, the soft-baked photoresist was completely cross-linked by cation-polymerization during the post exposure baking and these spotsremained transparent after development. Since the soft-baked photoresist was still soluble in developing solution, the unexposed parts returned back to the original inverse opal scaffold after developing process (step v). The prepared inverse opal film exhibited patterned reflection colors. In addition, a square pattern of three different colors could be produced by selective double exposure, as illustrated in the figure 2.

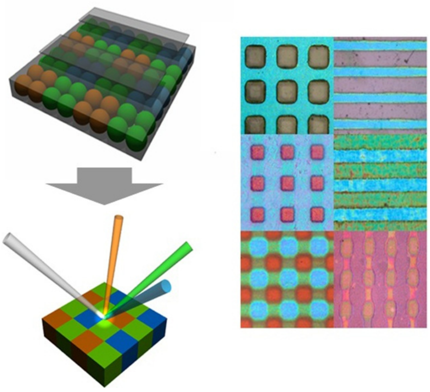

Figure 2. Gallery of patterned inverse opal structures by selective photopolymerization

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