Application of 3D laser nanolithography to the fabrication of photonic crystals

J. Haberko[a,b], F. Scheffold[a], J-F Dechezelles[a]

[a]University of Fribourg, Chemin du Musée 3, 1700 Fribourg, Switzerland
[b]AGH University of Science and Technology, al. Mickiewicza 30, 30-059 Krakow, Poland
jakub.haberko@unifr.ch

3D laser nanolithography is a versatile technique that allows fabricating arbitrary 3D structures with a resolution better than 1 µm. In this method ultrashort (≤100 fs) laser pulses are utilized to induce crosslinking in a polymer photoresist via a two-photon absorption process. The laser light is focused through a high numerical aperture objective. Due to the fact that the probability of the two-photon absorption process is proportional to light intensity squared, the crosslinking only takes place in a small volume of the photoresist around the focal point, where the laser power is the highest. By precisely manipulating the substrate using a 3d piezoelectric stage, one can selectively write a desired pattern into the polymer material and, after dissolving the non-crosslinked photoresist, obtain a free-standing structure.

In this work we utilize the technique to manufacture 3D photonic crystals. In order to enhance the refractive index contrast some of the structures were infiltrated with inorganic material by means of atomic layer deposition or chemical vapor deposition. We mainly focus on the so-called woodpile structure, which consists of a series of dielectric rods arranged in layers. For a sufficiently large refractive index of the dielectric material this structure possesses an omnidirectional photonic bandgap [1-3]. Optical characterization of the structures was carried out by means of the FTIR spectroscopy, both in transmission and in reflection mode.

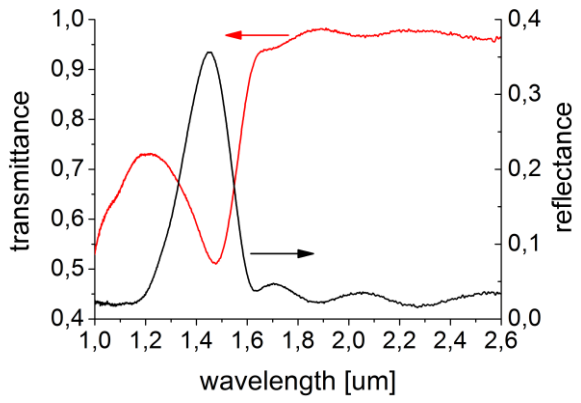
As the optical properties of a photonic crystal scale with its size, the position of the bandgap can be tuned by rescaling the structure. Optical spectra of a series of woodpile structures differing in pitch will be presented here. Furthermore, we will present two types of dual photonic crystals with a double bangap. One of them is a sandwich consisting of two different woodpile structures integrated into one photonic crystal. The other one is a hybrid photonic crystal containing of a woodpile structure and a colloidal crystal. The latter was manufactured by sedimentation of PMMA particles from a suspension. Moreover, a possibility to template the substrate to promote crystallization of the molecular crystal in such a hybrid device will be presented.

References

[1] J.D.Joannopoulos et al., Molding the Flow of Light, 2nd ed., Princeton Univ. Press, 2009
[2] M. Deubel, G. von freymann,M. Wegener, S. Pereira, K. Busch, C. M. Soukoulis, Nature Materials, **3** (2004) 444
[3] I. Staude, M. Thiel, S. Essig, C. Wolff, K. Busch, G. von Freymann, M. Wegener, Optics Letters, **35** (2010) 1094

Figures

a)



b)

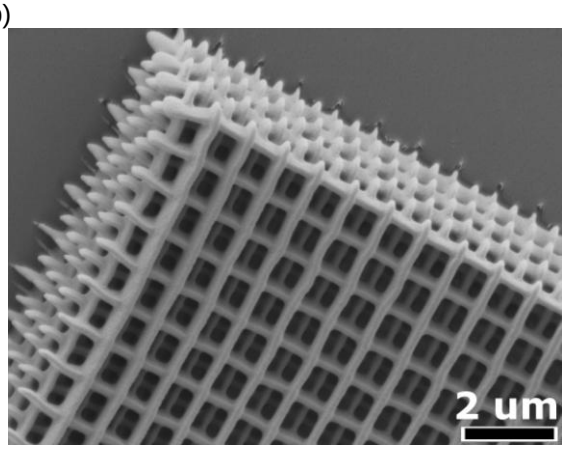


Fig. 1: a) Optical spectra of a woodpile photonic crystal manufactured by 3D laser nanolithography. b) Scanning electron micrograph of the structure.