Multiple higher-order bandgaps in infrared polymer photonic crystals

M. Straub, M. Ventura, M. Gu

Centre for Micro-Photonics, School of Biophysical Sciences and Electrical Engineering, Mail 31,
Swinburne University of Technology, PO Box 218, Hawthorn, Victoria 3122, Australia

Photonic crystals with sizeable bandgaps between higher photonic bands allow for the fabrication of technologically relevant optical microdevices at much larger structural dimensions. We present a new type of polymer photonic crystals which feature a multitude of higher-order bandgaps in the mid and near infrared spectral region. The crystals are void channel microstructures which are generated by laser scanning of a femtosecond pulsed visible beam at sufficiently high power to locally melt the material in the focus and leave a void trace of about 1 μm in diameter behind (fig. 1(a), [1]). A woodpile structure arrangement of void channels (fig. 1(b)) results in photonic crystals with a unit cell geometry, which is very flexible and allows for tuning the number and size of higher-order bandgaps. Figure 2 shows an example with two fully developed higher-order gaps and a third one on the verge of appearance. The fundamental bandgap as well as the higher-order bandgaps obey the Bragg condition. Photonic band structure calculations are carried out using an iterative eigensolver program (fig. 2(a)). Their results are consistent with the Fourier transform infrared spectra measured in transmission and reflection (fig. 2(b)) and allow for the determination of structural parameters such as the channel cross section and the effective refractive index of the polymer material after fabrication. With increasing ratio of the layer spacing to the in-plane channel spacing the number of higher-order bandgaps rises, and transitions from mere resonant angle Bragg reflections (peak No. 4 in fig 2(b), right) to bandgap total reflection are observed. We emphasize the enormous potential for applications of these highly correlated infrared polymer photonic crystals.

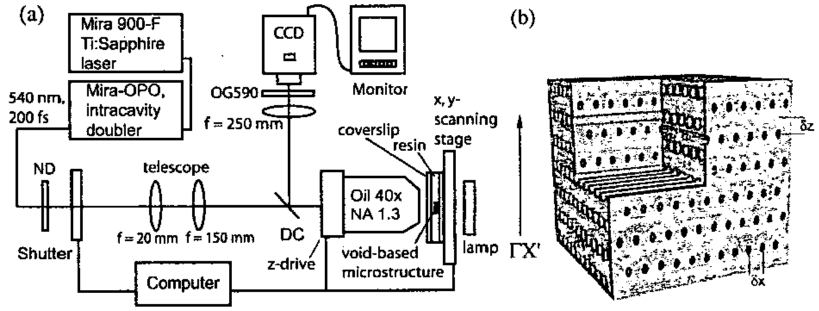

Fig. 1. (a) Experimental setup for void microstructure fabrication, and (b) sketch of a microchannel woodpile structure. Void channels are generated by translating the sample in the focus of high-repetition ultrashort pulsed light. Shutter and piezoelectric stages are computer controlled. A CCD camera monitors the fabrication.

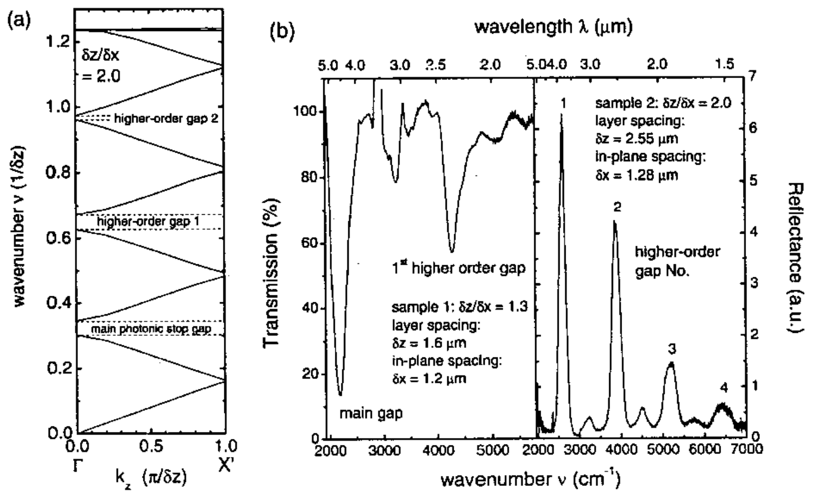

Fig. 2. (a) Dependent on the ratio δz/δx between the layer spacing and the in-plane channel spacing large photonic stop gaps and many higher-order gap exist in the stacking direction ΓX'. (b) Main gap and first higher-order gap in transmission (left) for a sample with δz/δx = 1.3. For δz/δx = 2.0 three higher-order gaps are observed in reflection (right). They are at integer multiples of the main gap wavenumber. The fourth peak is due to Bragg backscattering. The small satellites between the peaks are also attributed to forbidden modes of light propagation.

[1] M. J. Ventura, M. Straub, and M. Gu, Appl. Phys. Lett. **82**, 1649-1651 (2003)

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