Femtosecond fabrication of three-dimensional photonic crystals in polymers

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Abstract--*We report on the successful femtosecond fabrication of polymer-based micro-void channel photonic crystals with a high degree of perfection. In woodpile-type structures large main bandgaps in the mid infrared wavelength region and numerous higher-order gaps are observed.*

Photonic crystals with bandgaps in the infrared or the visible spectral region are a challenge for micro-fabrication, as they require a highly correlated arrangement of structural elements at a size of only a few hundred nanometers. The most common ways to generate them are the use of semiconductor technology or the self-organization of colloidal particles. Recently, we have fabricated a polymer-based photonic crystal that operates in the near infrared wavelength region using a high repetition-rate femtosecond laser and high-resolution optics [1].

In this paper, we report on the generation of continuous-void polymer microstructures and void channel based infrared photonic crystals [2]. We demonstrate that void channel microstructures can be fabricated inside a commercially available pre-cured photopolymer resin, which makes up a transparent bulk solid. High repetition rate, femtosecond pulsed laser light at a wavelength of 540 nm induced micro-explosions dispersing material from the focus and leaving voids in its centre. Translation of the polymer through the focus resulted in micro-void channels featuring elliptical cross sections perpendicular to the channel axis with smooth, well-defined boundaries. A photonic crystal with a high degree of perfection was created by stacking layers of such void channels in a 20 layer woodpile structure which allows suppression of mid-infrared light transmission to as much as 85% (see Fig. 1).

A 710 nm femtosecond pulsed beam from a 5 W pumped mode-locked Ti:Sapphire laser (Mira 900-F; Coherent, Santa Clara, CA, U.S.A.) passed through an optical parametric oscillator (Mira-OPO, Coherent; 1065-1265/545-625 nm) with an intra-cavity optical frequency doubler. The resulting beam of wavelength 540 nm had a repetition rate of 76 MHz and a pulse width of 200 fs. The polymerizable material used was Norland NOA 63 resin, which is a polyurethane oligomer having C=C unsaturation and is crosslinked by a mercapto-ester oligomer. The photonic bandgap was measured in the infrared transmission and reflection regime in a Fourier transform infrared micro-spectroscopy system (Nicolet Nexus/Continuum). Fig. 1(a) is the electron microscope image of the void channels while Fig. 1(b) is the schematic diagram of the woodpile photonic crystal. The corresponding transmission and reflection spectra are shown in Fig. 1(c).

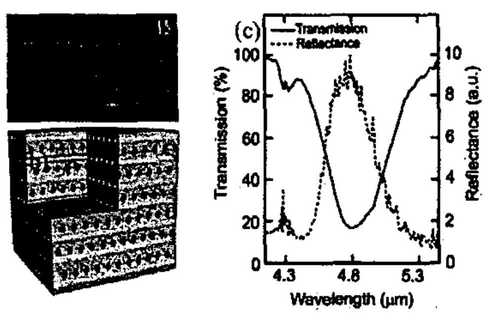

Fig. 1 Image, structure and spectrum of polymer based photonic crystals.

References

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