Towards Sequentially Infiltrated Two-Photon Polymerized 3D Photonic Crystals for Mid-IR Spectroscopic Applications

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Photonic crystals (PhCs) can slow the group velocity of light for enhanced light-matter interaction, enabling applications in mid-infrared (MIR) spectroscopic sensing systems [1]. The photonic bandgap (PBG) is a group of wavelengths that are forbidden to pass through the PhCs. Over planar microfabrication techniques, two-photon polymerization (2PP) allows rapid fabrication of 3D-PhCs. But 2PP materials have a low refractive index, which leads to only partial PBGs. The process of sequential infiltration synthesis (SIS), derived from atomic layer deposition (ALD) [2], allows precursor gases to infiltrate and react deep within the polymer [3], resulting in increased refractive index.

In this work, we present 2PP-fabricated IP-Dip resin-based 3D PhCs, as shown in figure 1(a), and use SIS to achieve broad PBG. The partial PBG was confirmed by Fourier transform infrared spectroscopy (FTIR) analysis in figure 1(b). For infiltration testing, 100 µm cubes were fabricated at a 700 nm hatching distance and ZnO SIS was performed. The ZnO-infiltrated cube was focused ion beam (FIB) half-milled, and energy dispersive spectroscopy (EDS) was performed on the milled structure, showing counts of Zn L-shell shown in figure 1(c), confirming infiltration. SIS is further used on 2PP-fabricated PhCs to achieve increased refractive index, making PhCs suitable for applications in MIR spectroscopic sensing.

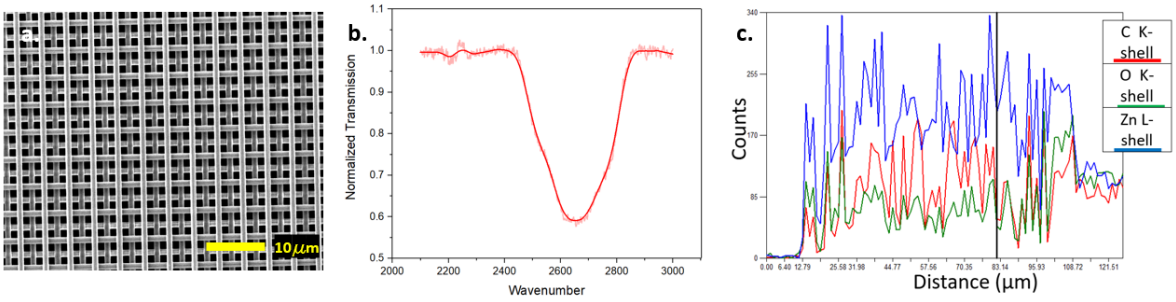

Figure 1(a) Scanning electron microscope (SEM) analysis of 2PP fabricated PhC. (b) FTIR response of 2PP fabricated PhC normalized to silicon background. (c) EDS analysis of milled structure with Zn, O and C shell X-rays respectively.

[1] Singhal, A. et al (2022) IEEE Sensors J. 22-21, 20126-20137
[2] Peng, Q. et al (2011) ACS Nana, 5-6, 4600-4606
[3] Ramanathan, M. et al (2013) J. Mater. Chem. 1-11, 2080-2091

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Supplementary Page

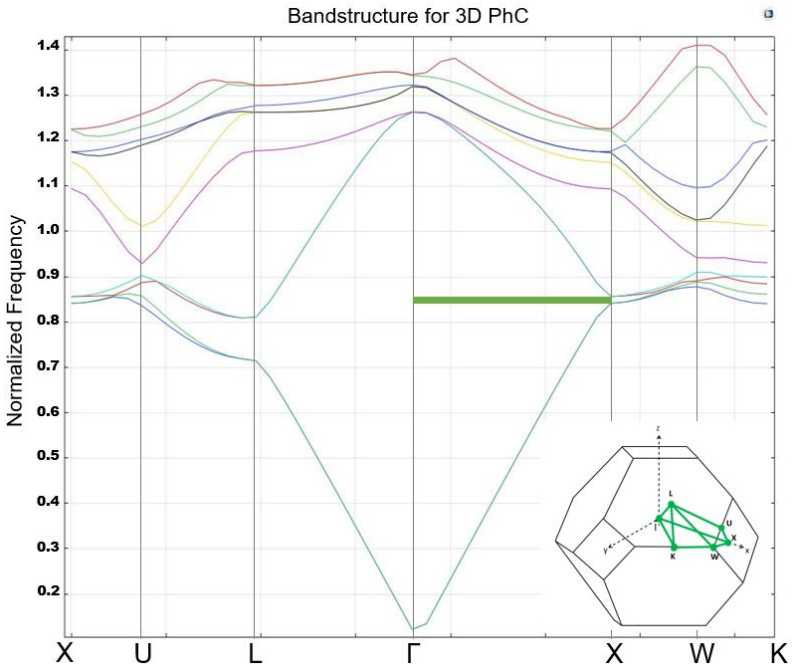

Figure 2: Finite element analysis (FEA) of IP-Dip Resin based 3D PhCs confirming presence of partial PBG. This can be used to tune PhCs to target wavelength by adjusting lattice constant.

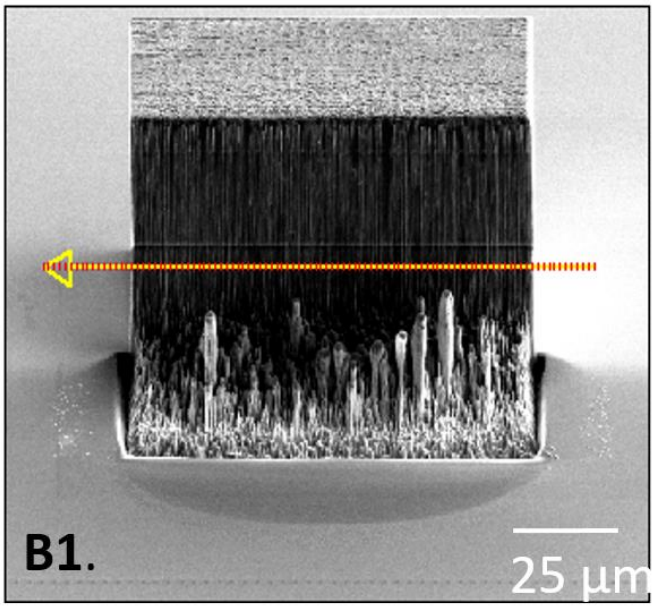

Figure 3: Focused ion beam (FIB) half-milled (milling dose equivalent to dose required for Si depth of 4 µm) ZnO-infiltrated IP-L 780 two-photon polymerized 100 µm cube utilizing 200 nm hatching distance, and electron beam trace shown by the arrow.