

Photopolymer Photonic Crystals: Lattice Fidelity, Refractive-Index Contrast, Defects and Spectral Response

Qualification of periodic printed photonic structures from lattice geometry to measured band and structural-colour response

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3Dresyns by Resyner Technologies S.L.

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Abstract

Photopolymer photonic crystals translate three-dimensional lattice geometry and refractive-index contrast into stop bands, structural colour and defect-mediated optical states. This review treats lattice fidelity, defect population, refractive state and spectral response as coupled manufacturing measurands. Recent reviews describe additive routes to photonic-crystal architectures and place two-photon and vat-photopolymer techniques within the broader optical-fabrication landscape. The central qualification problem is to distinguish spectral shifts caused by lattice constant or fill fraction from those caused by refractive-index change, disorder or intended defects. A practical framework is proposed using dimensional mapping over the printed volume, refractive-index/dispersion measurement, defect inspection and angle-resolved or transmission/reflection spectroscopy. Structural colour or a single stop-band image is not treated as sufficient evidence because different combinations of geometry and material state can produce similar spectral signatures.

Keywords: photonic crystal; photopolymer; two-photon polymerisation; lattice fidelity; refractive index contrast; structural colour; defects; spectrum

1. Significance and scope

Photonic-crystal function is collective. A lattice can appear visually regular yet contain systematic pitch bias, local collapse or refractive-index drift sufficient to move or broaden its spectral features. Qualification therefore requires a volume-aware description of periodicity and defect state together with the optical constants of the finished polymer.

1.1 Corpus boundary

ER-338 owns periodic photonic-crystal structures and defect-controlled spectral response. ER-331 owns refractive micro-optics, ER-332 metasurfaces, ER-339 conventional diffractive phase elements, and ER-428 microresonators/frequency-selective optical components. ER-338 does not absorb those non-periodic or resonator-specific qualification questions.

2. Lattice fidelity is a distribution, not a single pitch

Photonic-crystal response depends on periodicity, filling fraction, feature shape and long-range order. Local shrinkage, missing struts or stitching errors can broaden or split spectral features even when the mean pitch is correct [1-4] [5].

3. Index contrast sets the optical leverage

The same lattice geometry produces different stop bands and efficiencies as the refractive-index contrast changes. Finished-state polymer index, infiltration medium and porosity should therefore accompany structural metrology [1,2].

4. Defects can be functional or parasitic

Intentional cavities and waveguides rely on controlled defects, whereas random vacancies, distortion and roughness create scattering and spectral broadening. Qualification should distinguish designed from stochastic defect populations.

5. Spectral response closes the loop

Reflectance, transmission, angle dependence and polarisation response should be compared with the measured lattice and material state. Structural colour photographs are useful illustrations but not sufficient qualification.

6. Qualification architecture

Qualification should measure lattice constant, feature dimensions, fill fraction and defect placement over a representative volume rather than at one surface. The refractive index and its wavelength dependence are then paired with transmission, reflection or angle-resolved spectral measurements. Comparing measured spectra with models based on measured geometry helps separate dimensional bias from material-index error.

7. Minimum evidence for transfer

Transfer records should include fabrication modality, orientation, support/development history, lattice dimensions and distribution, material state, defect specification and the optical geometry used for spectroscopy. The additive-manufacturing literature spans several photonic-crystal classes [1], so comparison should be made through dimensionless geometry and refractive contrast rather than colour or nominal pitch alone.

7.1 Evidence hierarchy and transfer

A spectral shift that follows measured lattice contraction supports a geometric explanation; broadening without mean shift points more strongly toward disorder, defect variability or spatial index heterogeneity. Angle dependence provides an additional discriminator because some geometry errors and isotropic index changes affect dispersion differently.

7.2 Research priorities

Priority work includes three-dimensional metrology of buried lattice features, uncertainty propagation from pitch and refractive index into band-position prediction, and environmental ageing studies. Defect-engineered crystals also need methods that distinguish intentional states from accidental disorder at scale.

Table 1. Minimum qualification matrix for photopolymer photonic crystals.

Periodic-structure state	Minimum measurement	Qualification purpose
Lattice	pitch, filling fraction and orientation	defines nominal band structure
Material	index contrast and absorption	sets optical strength
Defects	vacancies, distortion and stitching	predicts scatter/broadening
Spectrum	reflection/transmission versus angle	tests photonic response
Repeatability	multi-build spectral and geometry spread	tests manufacturing control

8. Interpretation matrix

Stop-band shift, broadening, reduced contrast and angle-dependent asymmetry are separated in the diagnostic matrix. Each is linked to a measurement of pitch, disorder, index or defect position so that spectral changes can be assigned to a physical state rather than labelled generically as print error.

Table 2. Diagnostic interpretation matrix for photonic-crystal spectral deviations.

Spectral observation	Plausible mechanism	Discriminating control
Band shifts with humidity	index or swelling change	simultaneous geometry/index conditioning
Broad spectrum	disorder or polydispersity	lattice-statistics map
Weak stop band	low contrast or incomplete structure	index/porosity and section imaging
Strong sample-to-sample colour variation	build-scale shrinkage or stitching	spatial pitch mapping

9. Limitations and evidence gaps

Photonic-crystal studies use different lattice types, wavelength ranges and materials, and many report exemplary spectra rather than production distributions. Numerical thresholds therefore remain architecture-specific. This review does not set a universal band-gap or colour tolerance and does not infer bulk refractive index from spectral position without geometric support.

10. Conclusions

Photopolymer photonic crystals should be qualified through the measured relationship between lattice geometry, refractive-index contrast, defect state and spectral response. A visually periodic structure is not enough, and a spectral shift is not automatically a geometric error. ER-338 provides the measurement chain needed to distinguish these mechanisms and to transfer periodic optical structures with evidence rather than appearance.

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Competing interests

The author is Founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L. No comparative product recommendation is made.

Data availability

No new experimental dataset was generated for this review.