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Hyperuniform disordered photonic bandgap materials, from microwave to infrared wavelength regime.[1]

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Recently, we have introduced a new class of hyperuniform disordered (HUD) photonic bandgap (PBG) materials enabled by a novel constrained optimization method for engineering the material's Fourier transform to be continuous, isotropic and stealthy. Their structure factor $S(k)$ is equal to zero for small k and exhibits a broad ring of maximum values around a characteristic wave-length range. Experimentally, an isotropic complete PBG (at all angles and for all polarizations) in an alumina-based HUD structure and single-polarized PBGs for plastic-based HUD structure have been demonstrated. Using measured and simulated transmission and phase delay information through these HUD structures, we also unfolded their band structures and reconstructed the effective dispersion relations of propagating electromagnetic modes in them. The intrinsic isotropy in these disordered structures is an inherent advantage associated with the lack of crystalline order, offering unprecedented freedom for functional defect design impossible to achieve in photonic crystals. In the microwave regime, we have shown the creation of freeform waveguides, which can channel photons robustly along arbitrarily curved paths and around sharp bends, and be decorated with defects to produce sharply resonant structures useful for filtering and frequency splitting. Recent simulation and experimental results for waveguides and modulators based on submicron-scale planar hyperuniform disordered PBG structures further highlight their ability to serve as highly compact, flexible and energy-efficient platforms for photonic integrated circuits.

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