Three-dimensional networks derived from hyperuniform point patterns and their optical properties

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Abstract

Amorphous photonic materials derived from hyperuniform point patterns [1] (strictly or in approximation) have drawn a lot of attention recently. It has been claimed, both theoretically and experimentally [2-4], that if reproduced in a dielectic material with a sufficiently large refractive index contrast substantial photonic bandgap (PBG) emerges both in two and three dimensions [5-6]. However, for the case of three dimensional materials evidence for the existence of a full photonic gap is still scarce. Moreover, the robustness of such a gap in the presence of imperfections or deviations from the desired geometry is largely unknown. The latter will be crucial however for any possible experimental realization of this new type of materials.

In the present work we numerically analyze light transport through hyperuniform dielectric networks with a high refractive index n>2.5 in air. We show how the transmission spectrum is affected by structural parameters of the network including the filling fraction of the dielectric phase, the shape and aspect ratio of dielectric rods. From our Finite Difference Time Domain (FDTD) computer simulations we extract parameters describing light transport inside our material, such as light scattering attenuation length and study how they are influenced by the geometrical parameters of the network. Furthermore, we compare these results with FTIR measurements of such structures, which we have manufactured by means of the two-photon laser nanolithography combined with ZnO and TiO_2 infiltration followed by a silicon double inversion process.

References

[1] Florescu, M., Torquato, S., Steinhardt, P. J., PNAS, **Vol. 106** (2009) 20658–20663
[2] Haberko, J. and Scheffold, F., Opt. Ex. **21** (2013) 1057–1065
[3] Haberko, J., Muller, N., and Scheffold, F., Phys. Rev. A, **88** (2013) 043822
[4] Muller, N., Haberko, J., Marichy, C., and Scheffold, F., Adv. Opt. Mat, **2** (2014) 115–119
[5] Froufe-Pérez, L. S., Engel, M., Damasceno, P. F., Muller, N., Haberko, J., Glotzer, S.C. and Scheffold, F., submitted, http://arxiv.org/abs/1602.01002
[6] Liew, S. F., Yang, J. K., Noh, H., Schreck, C. F., Dufresne, E. R., O'Hern, C. S. and Cao, H. Phys. Rev. A **84** (2011) 063818

Figures

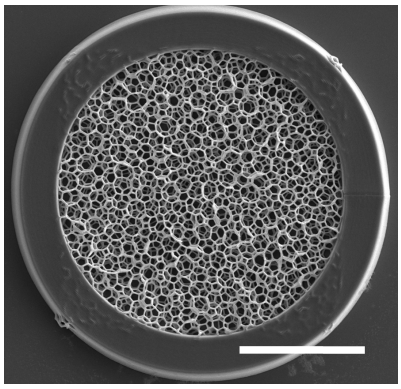

Fig. 1: An SEM micrograph of a 3D hyperuniform all-dielectric network. Scale bar is 30 μm

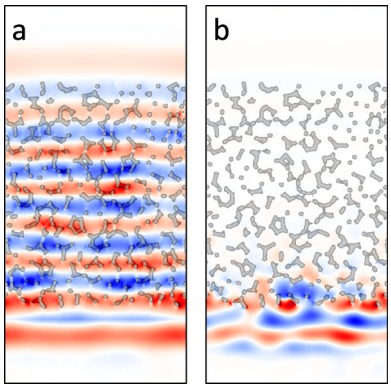

Fig. 2: Light transport through a 3D hyperuniform dielectric network (cross-section). Electric field intensity map for a wavelength outside (a) and inside (b) the PBG.