Large Area 3D Helical Photonic Crystals

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Three-dimensional helical photonic crystals are attractive for chiral metamaterial devices. Chiral optical materials mix electrical and magnetic responses such that magnetic dipoles are excited by the electric component of the light field and vice versa. Thus in chiral metamaterials the propagation of light along the helix axis is blocked for circular polarization with the same handedness as the helices, whereas it transmits the other, and therefore is useful as circular polarizer. If the chirality is strong enough, negative refraction may occur for one circularly polarized wave, while for the other circular polarization the refractive index remains positive. This gives rise to interesting phenomena that are inaccessible with conventional negative index materials, such as negative reflection for electromagnetic waves incident onto a mirror embedded in such a medium. A novel interferometric lithography (IL) technique utilizing six separate two-beam exposures for fabricating three-dimensional helical photonic crystals is presented. In contrast to most demonstrations to date[c] which used a two-photon direct-write process, IL is a large-area process readily adaptable to realistic manufacturing constraint. This novel interferometric lithography uses only TE polarized light for maximum contrast and allows for independent dimensional control of each axis of the helix. Both mathematical models and experimentally realized three-dimensional helical photonic crystals (over an mm^2 in area and up to 5 μm tall, with a helix spacing of 890 nm on a hexagonal grid) are presented. The helical photonic crystals are formed as thick photoresist structure that can be subsequently used as a mandrel for a sol-gel or metal electroforming process, enabling a high index contrast chiral metamaterial. Optical FTIR measurements of these helical photonic crystals, with the transmission and reflection curves for various polarizations of incident light will be presented.

Keywords: Photonic Crystal, Interferometric Lithography, Chiral Metamaterials.
Materials: Futurrex NR7, Brewer Science ARC i-CON-7.

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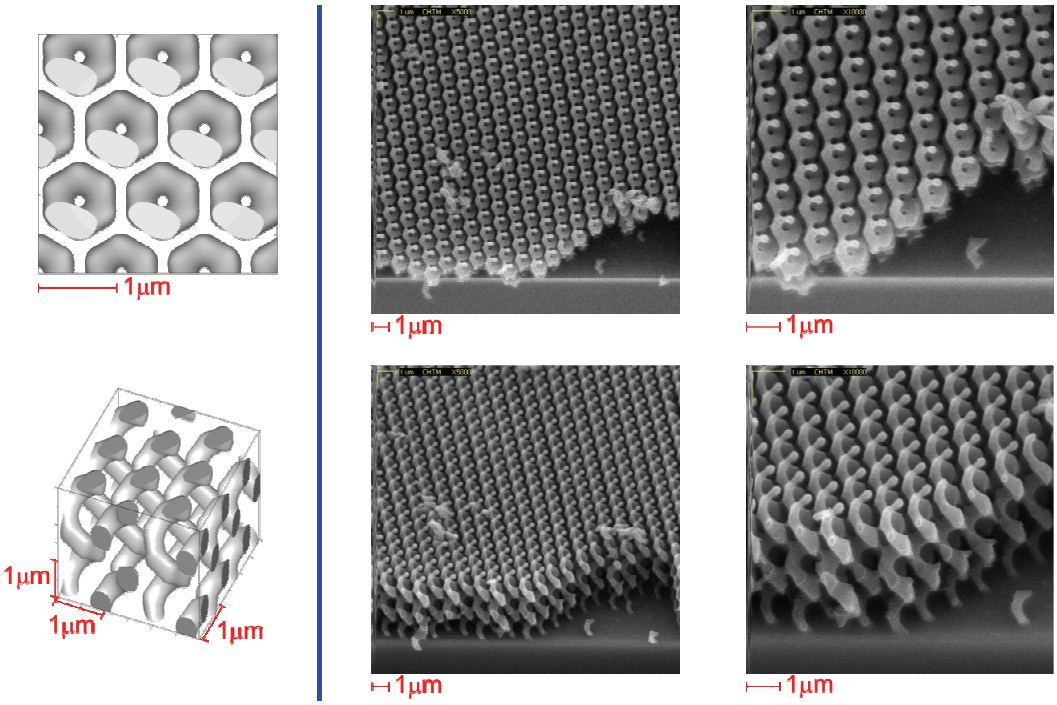
[c] M. Thiel, H. Fischer, G. von Freymann, and M. Wegener, Three-dimensional chiral photonic superlattices, *Optics Letters* **35** (2), p166-168 (2010)



3D helical photonic crystals fabricated using 6 two-beam exposures with 60° rotation (355 nm exposure, NR7 resist – *n* ~ 1.7).

Left Images: Mathematical simulations;
Right Images: SEM images of experimental structures;
Upper images top-down view; lower images 45° cross-section view.

(Model parameters: helix spacing Λ_a = 890 nm, helix period height Λ_z = 1813 nm)