Proximity Field Nanopatterning Lithography for Large Area 3D Photonic Nano-Structures: Forward and Inverse Problem Modeling

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The great complexity of the 3D photonic crystal (PhC) topology and the resulting fabrication difficulties and the implied intricacy of the photonic crystal devices have hindered 3D PhC research. Phase imprint lithography in photopolymer substrates offers a cheap, rapid, simple, and scalable alternative to the standard layered (bottom/up or top/down) approach to fabricating PhC's borrowed from silicon processing. The idea that a phase mask would contain all the information necessary for the creation of a fully integrated optical device in a single exposure makes it particularly attractive. The key element is the Talbot imaging of the interference pattern produced by the phase mask. A necessary requirement is a conformable, elastomeric phase mask with features of relief that have dimensions comparable to the optical wavelength. Placing this type of mask against a photosensitive solid film leads to intimate physical contact driven by van der Waals forces. Relief features with lateral dimensions comparable with the wavelength and with depths sufficient to substantially modulate the phase can produce sub-micrometer periodic 3D distributions of intensity with light that has a suitable level of coherence.

The major impediment to this simplistic approach is the necessary prior knowledge of the phase mask features required for the generation of the appropriate interference pattern. To help guide the fabrication process, modeling using rigorous coupled wave analysis (RCWA) is utilized to determine the two dimensional master pattern structures best suited to generate the final desired 3D structure. The complex propagation vector is calculated and relevant diffraction orders are recalculated based on the Abbe theory of image formation. Although RCWA can help determine the final exposure structure from a given mask pattern, it would be desirable to compute the inverse, that is, start with a structure and determine how the phase mask should be built. As such we implement a multi-path forward optimization-search technique to back track the mask design capable of generating the specified photonic crystal structure. Here we report on our progress on both the experimental and theoretical fronts.