Integrating Structural Colors With Micro-Optics

Joel K.W. Yang[1,2]

1. Engineering Product Development, Singapore University of Technology and Design, Singapore 487372
2. Institute of Materials Research and Engineering, A*STAR (Agency for Science, Technology and Research), Singapore
E-mail: joel_yang@sutd.edu.sg

Structural colors are generated from nanoscale structures of various materials due either to interference or optical resonance effects. The ability to achieve a wide range of colors by simply tuning geometric properties opens up fascinating opportunities to the nanoengineer or nanoscientist to design colors using material properties, sizes and shapes as input parameters. This physical approach contrasts with the chemical approach for synthesizing pigments and dyes. Using semiconductor fabrication methods, 2D structures based on metals and high index dielectrics have been realized, e.g. nanodisks, ellipses, etc. defined with electron-beam lithography and vacuum deposition methods.

Recently, we have extended the generation of structural colors from 3D nanostructures created using two-photon polymerization lithography (TPL). The use of TPL, an additive manufacturing process with sub-micron print resolutions, to produce structures for optical effect is a relatively new endeavor [1]. We have previously shown the fabrication of nanopillars, gratings, mesh-like, and wood-pile photonic crystal structures that appear colorful under white-light illumination.

We now demonstrate the integration of these structural colors with other micro-optical elements, such as microlenses and spiral phase plates. Equipped with TPL as a nanoscale 3D printer, structural color geometries are conveniently integrated in a single print run with other user-defined optics. Doing so enables one to produce structured light from incoherent light sources, holographic color prints, and control of the light-field for 3D representation. We will discuss the use of structural colors combined with micro-optics for enhanced information content and optical security [2].

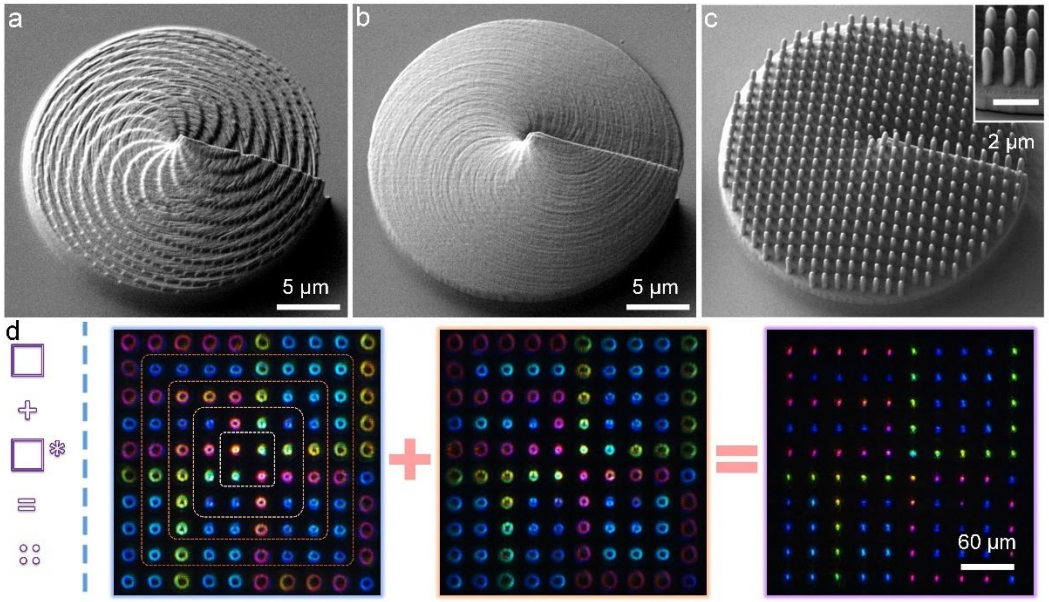

Fig. 1 (a-c) Tilted view SEM of different stages of 3D printing an optical element consisting of a focusing spiral phase plate and with nanopillar structural colors. (d) Optical micrograph demonstrating arrays of these elements in generating colored beams carrying orbital angular momentum, with their characteristic donut beams at the focal plane. Aligning two of such arrays on separate substrates result in focused spots instead of donut intensities. Adapted from Ref. [2].

References

[1] Hao Wang, et al., "Two-Photon Polymerization Lithography for Optics and Photonics: Fundamentals, Materials, Technologies, and Applications", in press *(2023)*

[2] Hongtao Wang, Hao Wang, Qifeng Ruan, John You En Chan, Wang Zhang, Hailong Liu, Soroosh Daqiqeh Rezaei, Jonathan Trisno, Cheng-Wei Qiu, Min Gu, Joel KW Yang, "Coloured vortex beams with incoherent white light illumination", Nature Nanotechnology *(2023)*.