

## **Nanoscale 3D Printing of Structural Colors and Micro Optics**

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**Time: 1:45pm – 3:00pm**

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**Abstract:** Structural colors are generated from nanoscale features 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 fascinating opportunities to the nanoengineer or nanoscientist to design colors using material properties, and nanostructure geometry as input parameters. This physical approach contrasts with the chemical approach for synthesizing pigments and dyes, where colors arise due to optical absorption. 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 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. 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.



**Biography:** Joel Yang received his Master of Science (2005) and PhD (2009) degrees from the Massachusetts Institute of Technology, Department of Electrical Engineering and Computer Science. He is Full Professor (since Aug 2023) in the Engineering Product Development pillar at the Singapore University of Technology and Design (SUTD). He held a joint appointment as Principal Scientist at the Institute of Materials Research and Engineering (IMRE) of A\*STAR until 2023. He is recognized for pioneering work in plasmonic and structural color printing, achieving record-level printing resolution at 100,000 dpi and credited for the widely-used “salty-developer” to improve the resolution of electron beam lithography. His research interests include Nanoplasmonics, 2D and 3D printed nano optical design elements (NODE), and sub-10-nm resolution lithography. He serves as Associate Editor of Science Advances. He is Fellow of Optica (former OSA The Optical Society), National Research Foundation (NRF) Investigator (class of 2020), and A\*STAR Investigator (2010). His accolades include the Institute of Physics Singapore (IPS) Nanotechnology Medal and Prize, MIT Technology Review TR35 award, and the Singapore Young Scientist Award.

Hosted by Prof. Jayakanth Ravichandran, Prof. Jianhua (Joshua) Yang, Prof. Han Wang, Prof. Chongwu Zhou, Prof. Stephen Cronin, and Prof. Wei Wu.

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