Geometry-driven Structural Color Control In Silicon-rich Nitride (SRN) Metasurfaces.

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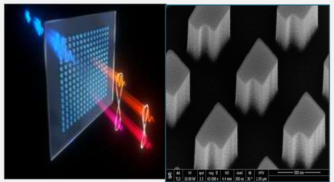
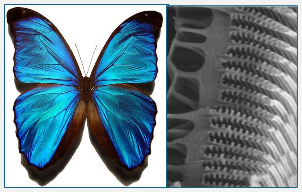
Metasurfaces



1

A metasurface is an ultra-thin, engineered material that uses nano-scale patterns to precisely manipulate light, enabling applications from creating flat lenses to producing vivid structural colors for advanced anti-counterfeiting.

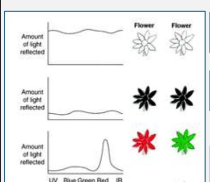
Structural Colors



Structural colors, unlike pigment-based hues, are produced by nanoscale structures whose geometry—not chemistry—creates colors, offering superior durability, tunability, and fade resistance, and are employed in applications ranging from anti-counterfeiting on banknotes to optical sensors.

We used silicon-rich nitride (SRN) as the dielectric material for our metasurfaces because, unlike conventional dielectrics, SRN enables continuous tuning of both refractive index and extinction coefficient simply by adjusting the SiH_4:N_2 ratio during PECVD, providing unparalleled design flexibility for metasurface applications.

How do we see colors?



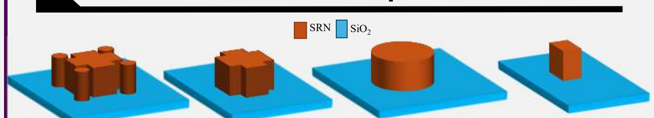
2

White→High reflection across the visible spectrum

Black→Low reflection (high absorption) across the visible spectrum

Colored Object (e.g.,Red)→High reflection of specific wavelengths .

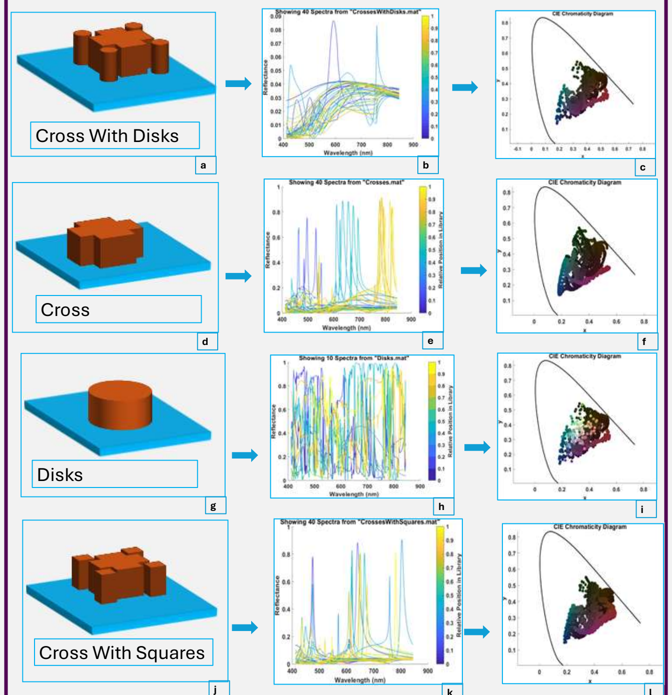
Some Geometries Explored



Simulating Nanophotonic Structures

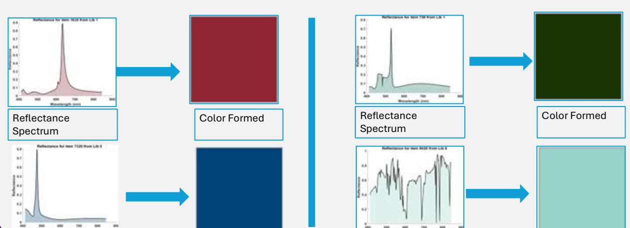
Tool: Rigorous Coupled-Wave Analysis(RCWA), is a computational method used to determine how electromagnetic waves—like light—interact with periodic structures.

Computation Results



We simulated periodic arrays of four distinct nanostructure geometries using Rigorous Coupled-Wave Analysis (RCWA) (Fig. a, d, g, j). The resulting reflectance spectra were used to generate a comprehensive spectral library (Fig. b, e, h, k). To visualize the range of achievable colors, each spectrum from the library was then plotted as a point on a CIE chromaticity diagram (Fig. c, f, i, l). As shown, modifying the nanostructure geometry provides direct control over the achievable color gamut.

Structural colors in the library

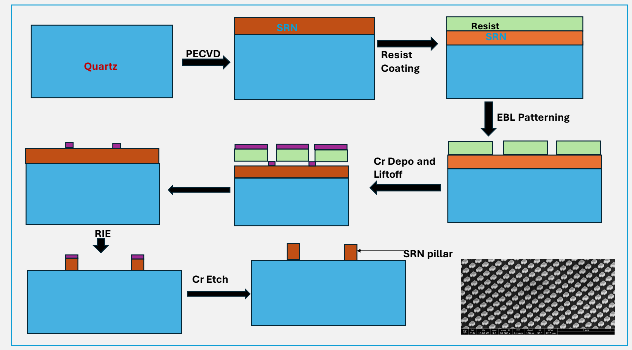


Device Concept

RGB Values were extracted from the image for all pixels.

Each extracted RGB value was mapped against the closest RGB gotten from the Library.

Device Fabrication Workflow



Future Direction

Our next step is to fabricate the device featuring the VINSE logo (3). We will achieve a broader color palette by exploring new nanostructure geometries and optimizing SRN deposition recipes for enhanced optical properties.

References & Acknowledgements

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1. *Tomás Santiago-Cruz et al., Science(2022)*
2. *Glover, B. J. and Whitney, H. M., Annals of Botany, Structural color and iridescence in plants: the poorly studied relations of pigment color, 105, 4, 505-511 (2010)*