Low Power Structural Color Tuning in a-Si Dielectric Metasurface via Li-ion Insertion

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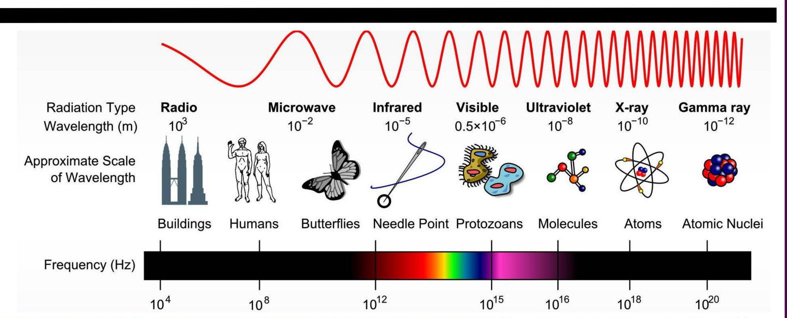
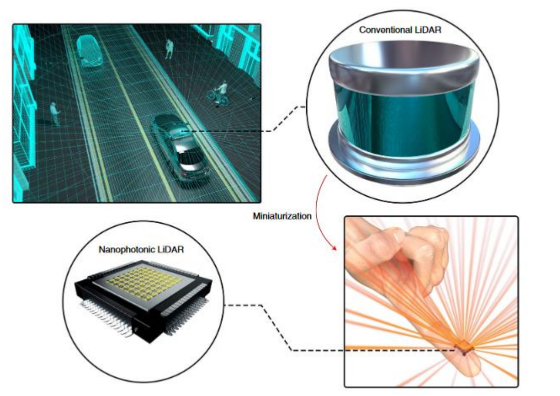
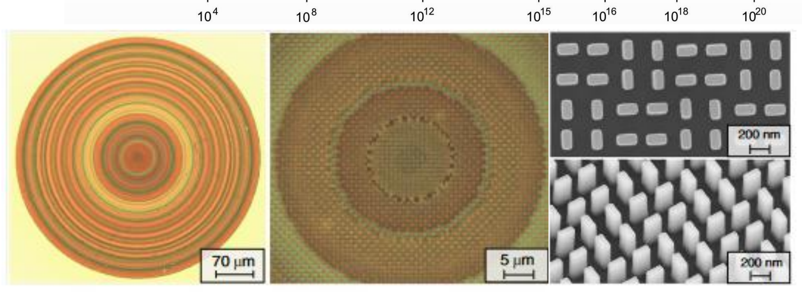
Introduction to Metasurfaces

Metasurfaces use sub-wavelength scatterers that control the phase, polarization, and amplitude of light through arrangement and geometry

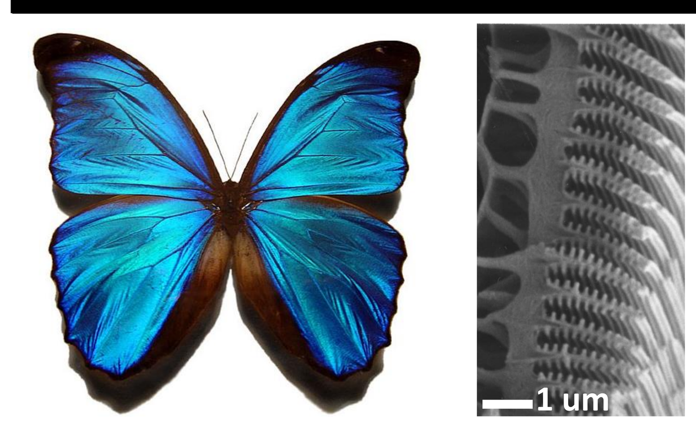






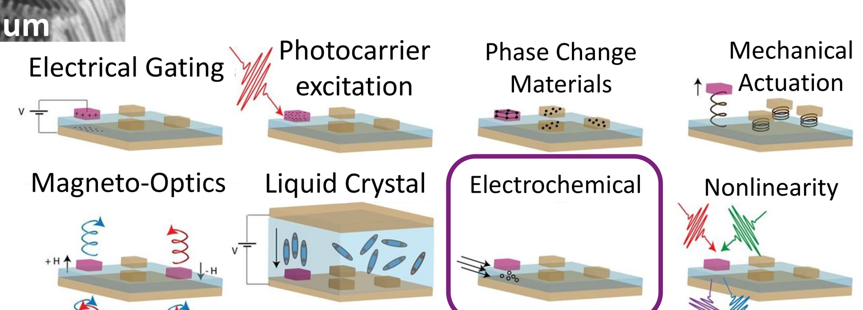
Applications include LIDAR, augmented/virtual reality displays, compact imaging, remote sensing, and more[1,2]

What is Structural Color?



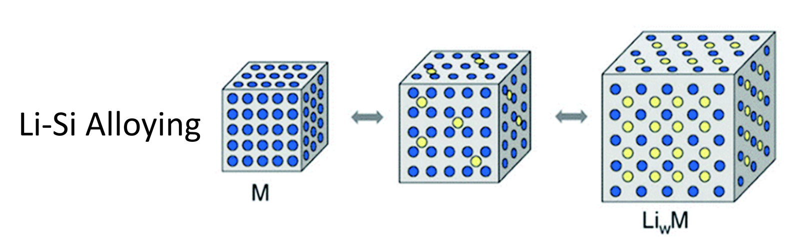
Pigment color is produced by absorption of specific bands of wavelengths of light. Structural color results from the nanoscale geometry of a material. Because of the lack of chemical pigments, structural colors are vibrant and resistant to fade.

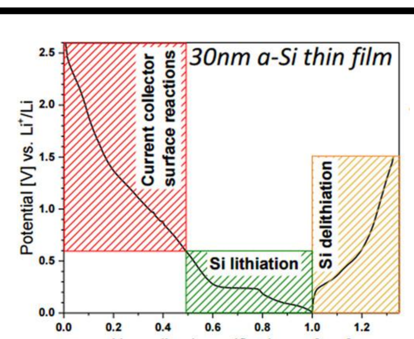
Active materials are incorporated into structural color arrays, changing the refractive index, array geometry, or both with an applied stimulus

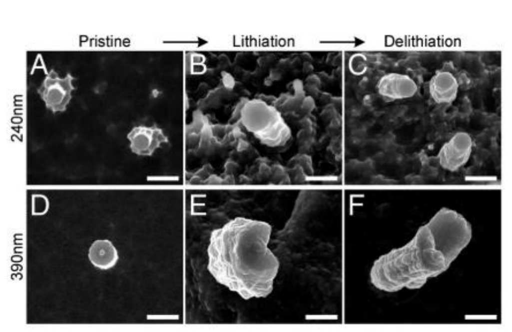


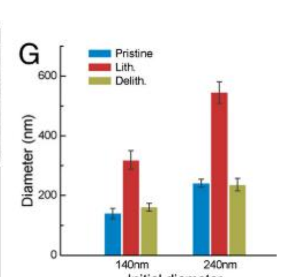
a-Si: a High-Capacity Li Anode Material

Si, often utilized in nanophotonics for its refractive high index, offering high Li capacity at 4800 mAh/g (compared to 360 mAh/g graphite)





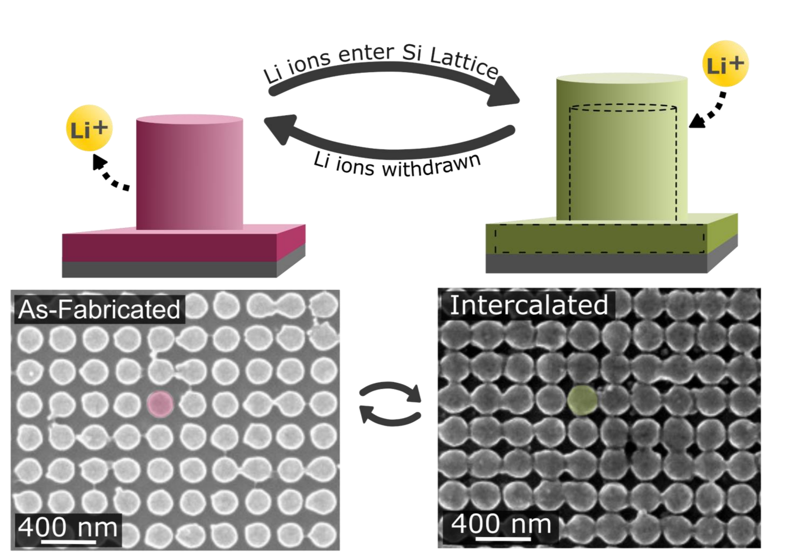




The reaction takes place at a low voltage vs. Li/Li+

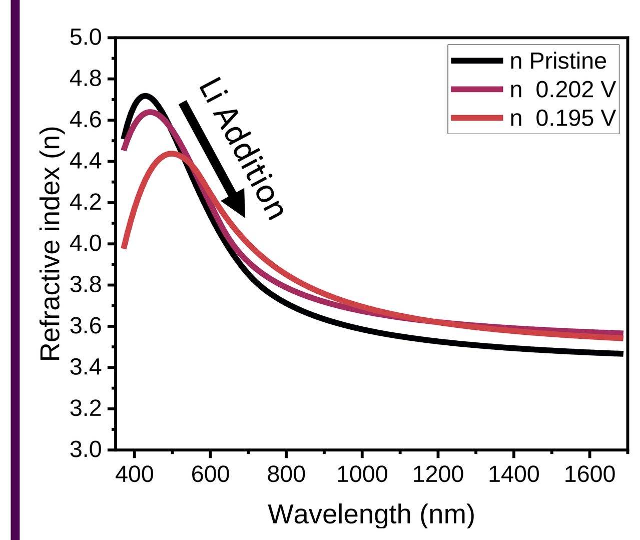
Nanostructured silicon shows resistance to fracturing induced in bulk films

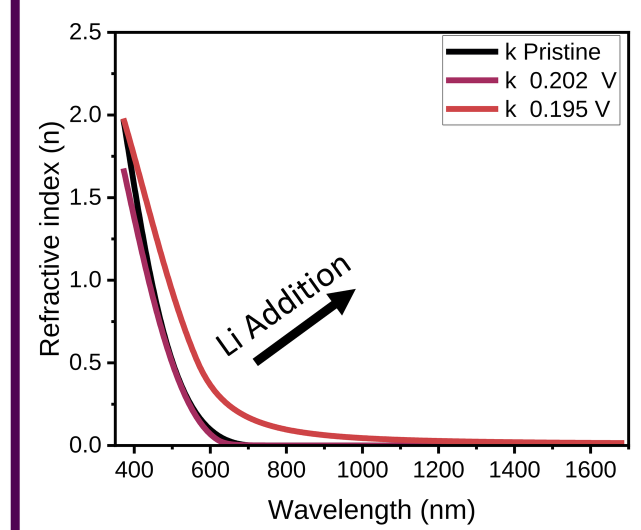
Device Concept

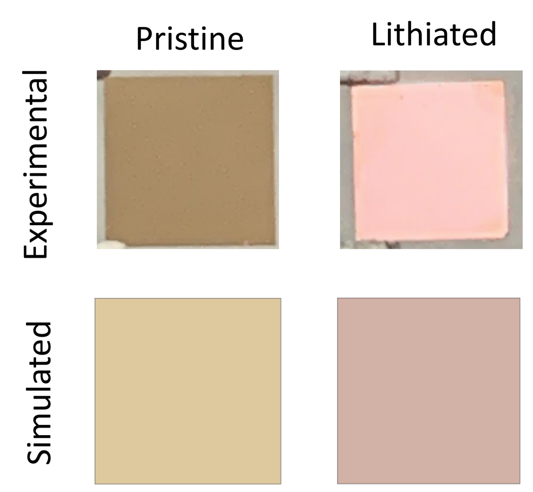


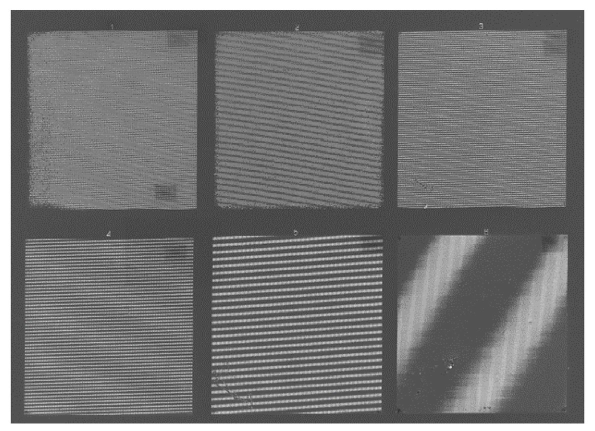
We employ Li-ion insertion into amorphous silicon Fabry-Perot films and metasurfaces, utilizing change in refractive index and accompanying lattice expansion as tuning mechanisms

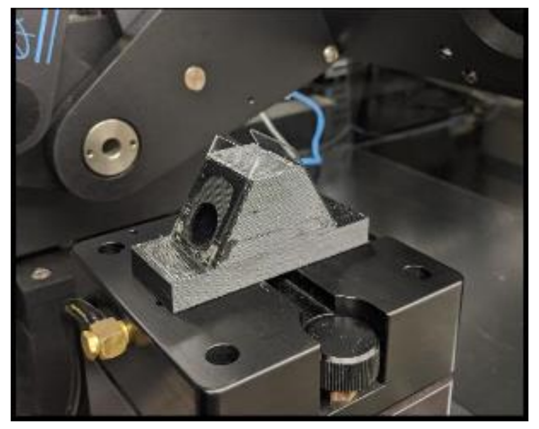
Measuring Refractive index

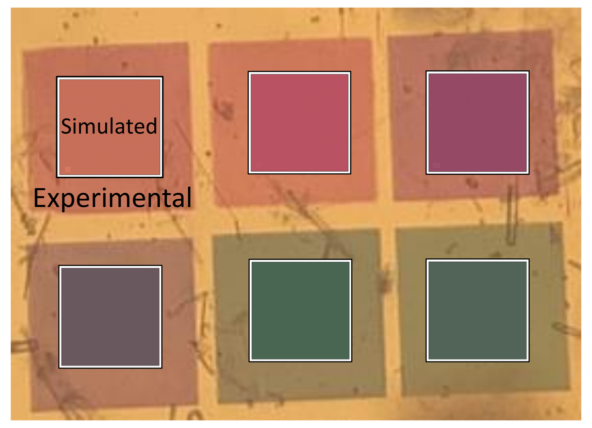






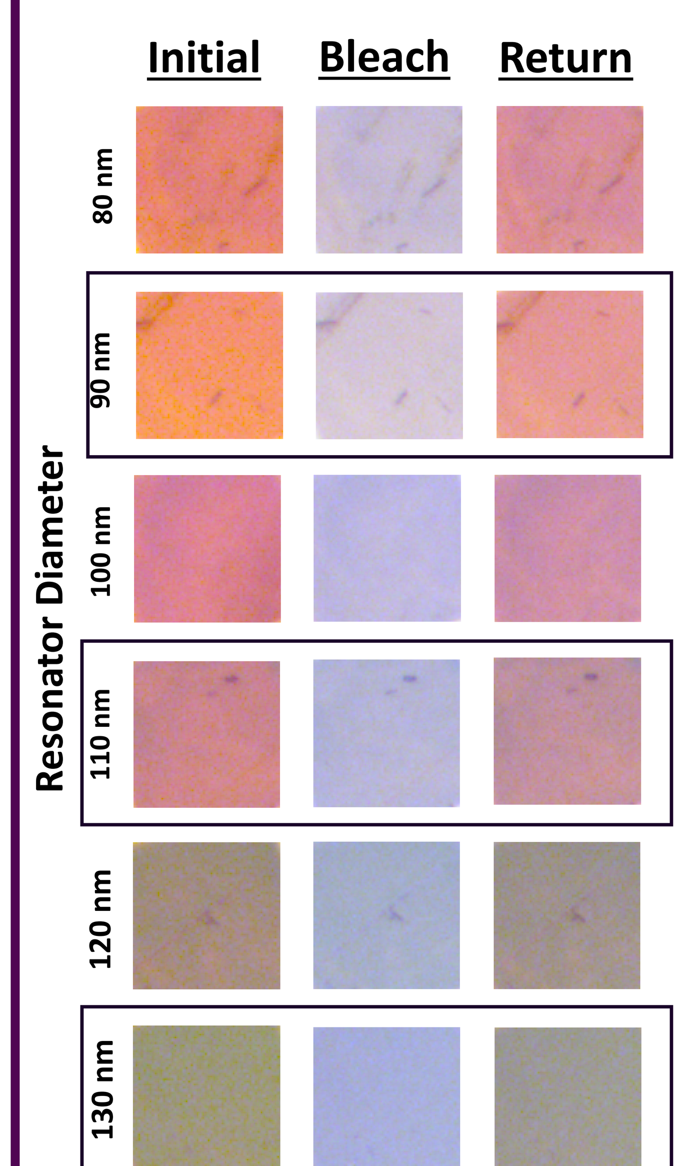


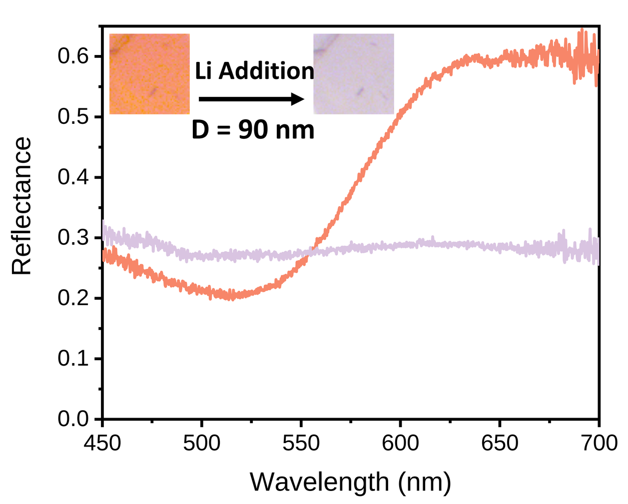


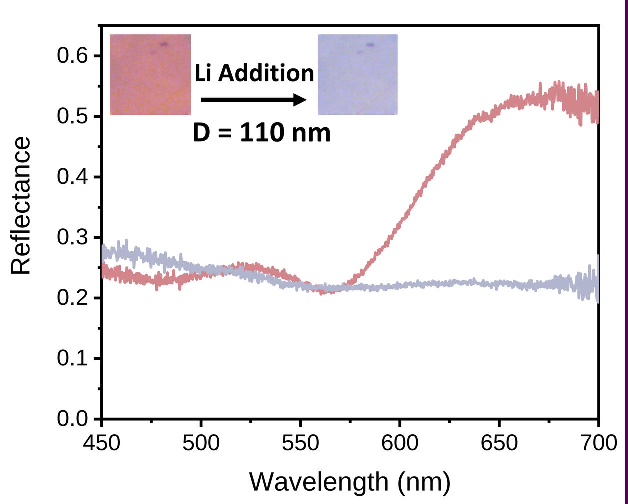


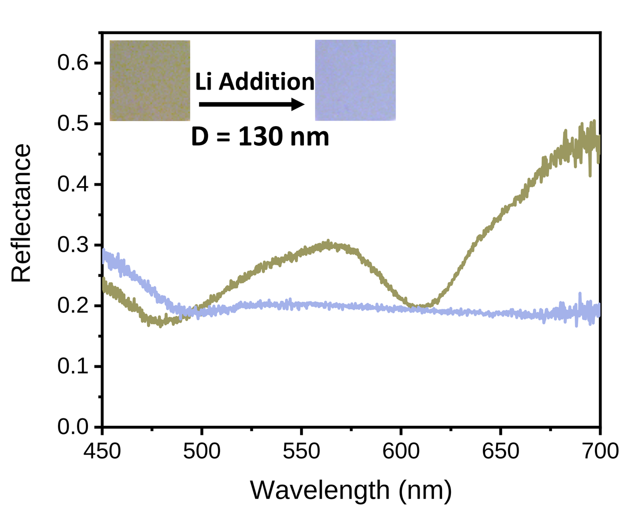
50 nm thin films of a-Si were deposited using PECVD. Films were deposited onto Ti films, utilizing Ti as both a lithium barrier material and electrode. Films were run galvanostatically at c/2 rate vs. Li counter/reference electrode and $LiClO_4$ /PC electrolyte in an argon glovebox. Films were rinsed of separator debris and packaged in an air-free ellipsometry box for measurement. Results show that at the alloying potential of 0.2 V vs. Li/Li+ a color change from gold to pink, indicating both volumetric expansion and refractive index change. The changes are observed on the scale of microvolts

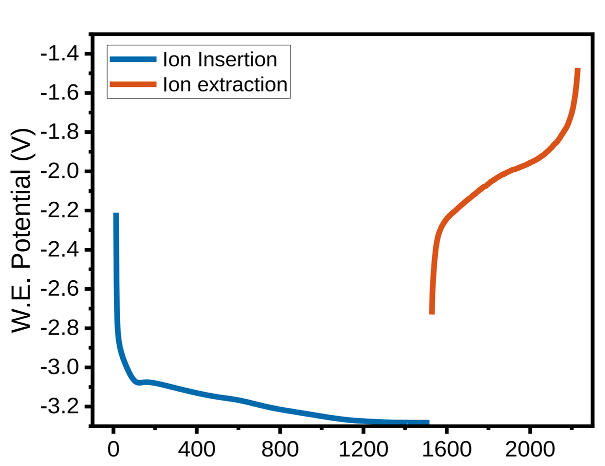
Active Structural Color Metasurface





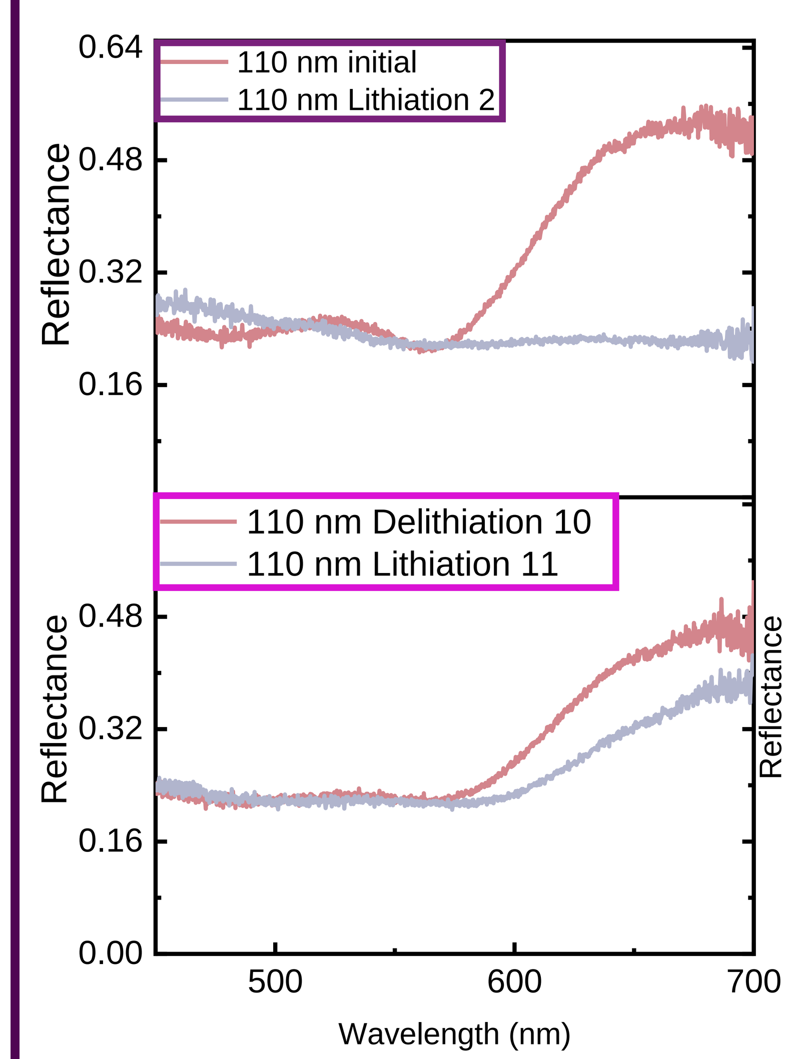


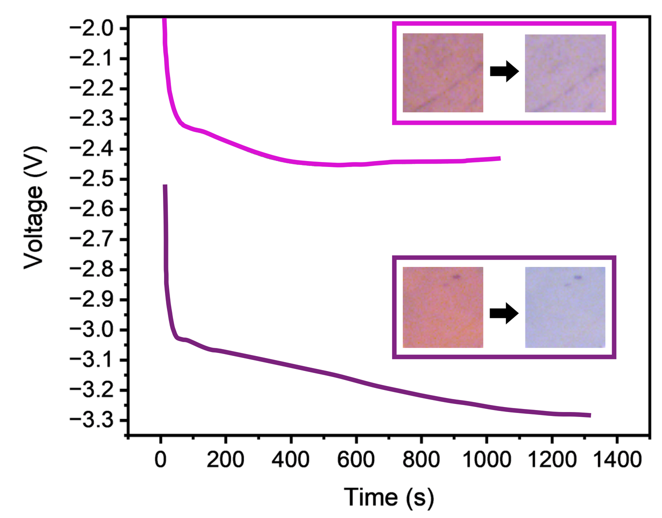


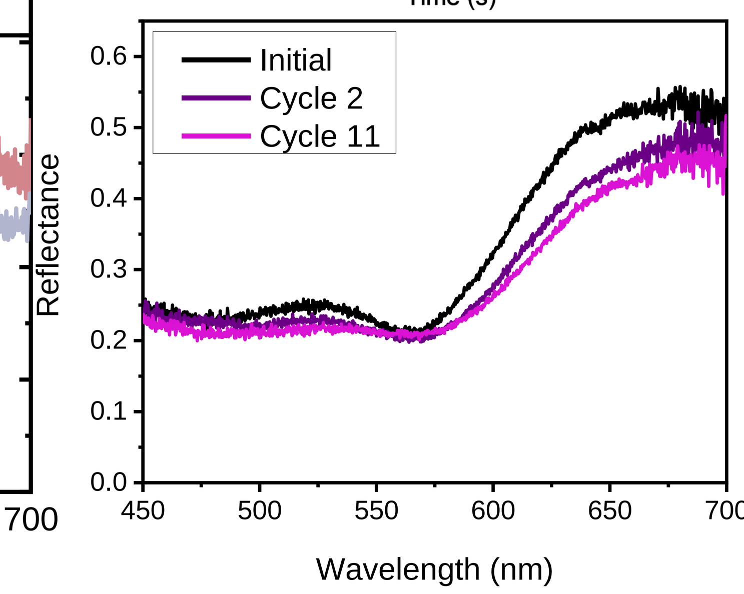


a-Si films were patterned into structural color metasurface arrays, with resonator diameters measuring between 80 and 130 nm in diameter. Arrays were placed in a homemade optical electrochemical cell and cycled using an LFP counter/reference electrode in 1M $LiClO_4$ /PC electrolyte. Samples were cycled galvanostatically while optical measurements and images were collected in-situ. All arrays were observed to show color bleaching to greyscale before returning to their original colors upon reverse bias. Highlighted here are arrays with diameters of 90, 110, and 130 nm with the corresponding galvanostatic curves.

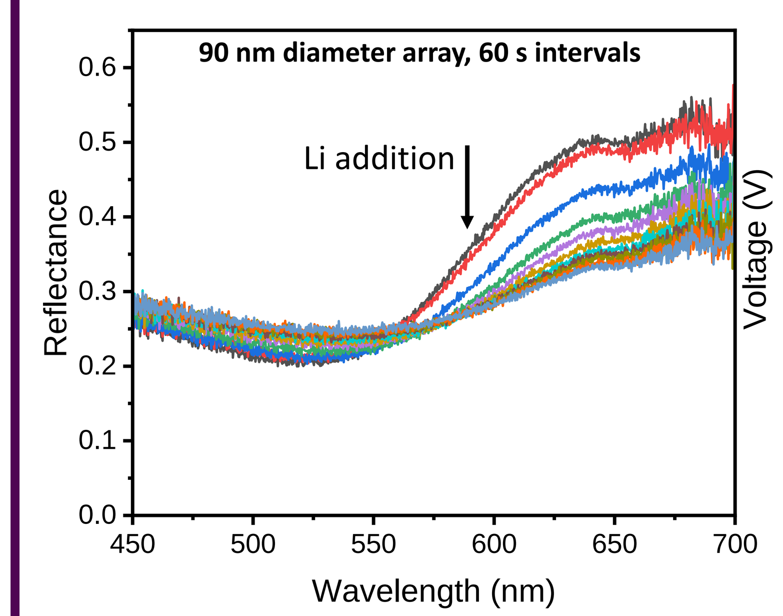
Color Return and Switch Depth

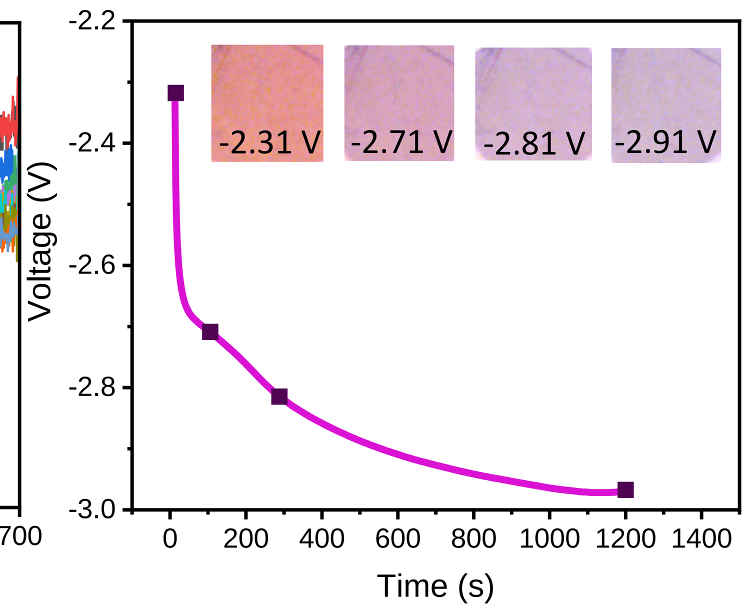


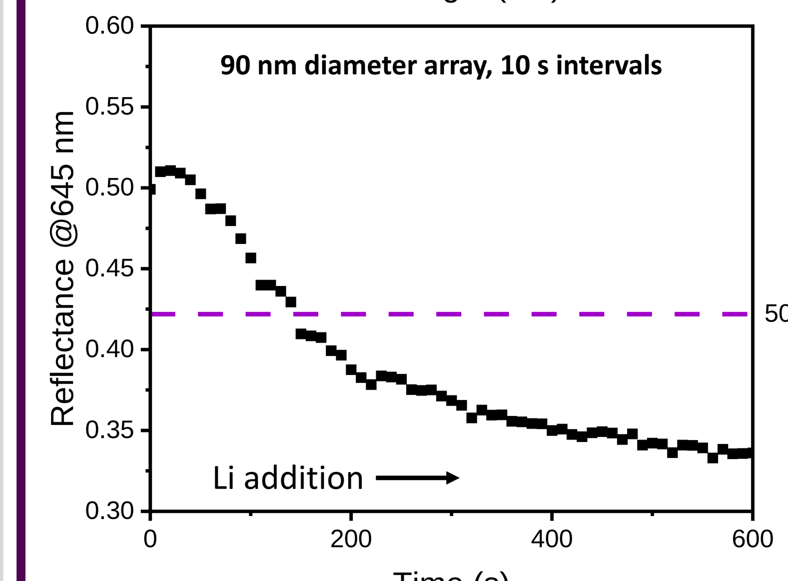




Comparison of switch depth between the first and tenth cycles for the 110 nm diameter array. The first cycle had a switch depth of 0.279 at 645 nm between the delithiated state and lithiated states; this decreased to a depth of 0.099 after the 10th cycle. A decrease of 0.069 occurred between the initial state and the first delithiated (return) state. Between the second and eleventh cycle return the device reached a steady state, decreasing by 0.029 over 10 cycles. Cycle life can be extended by improving pre-cycling conditions.







Color bleaching occurs rapidly with the first minutes of the reaction, reaching 50% switch depth within 2 minutes. Increasing current density would improve bleaching/coloration time

References & Acknowledgements

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