Dynamic Color Tuning with Electrochemically Actuated TiO_2 Metasurfaces

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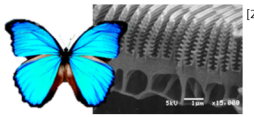
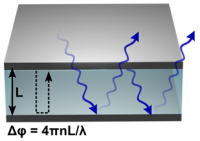
Color by Resonance

Structural color – color dictated by form. Decouples intrinsic material properties from optical response.

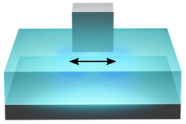

[2]

Examples:

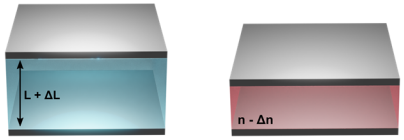
1) Fabry-Perot Cavity – Resonance via constructive interference of reflected waves. [3]



2) Gap Plasmon Metasurface – coupled plasmonic resonances distributed throughout artificial medium with critical dimension less than wavelength of incident light. [4]



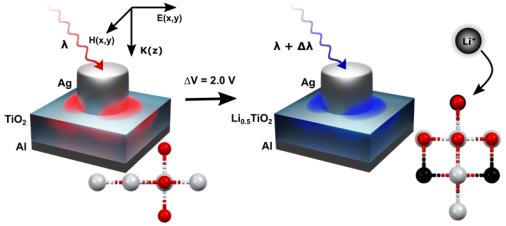
Tuning a Resonance



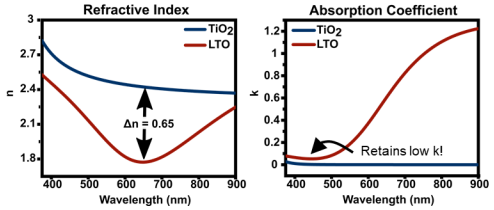
Goal: Low-loss, energy-efficient, dynamic structural color.

Titanium Dioxide ↔ Lithium Titanate

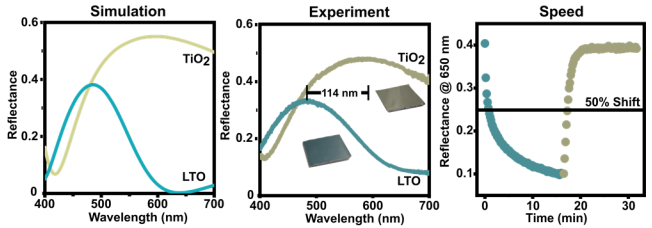
$$TiO_2 + xLi^+ + xe^- \leftrightarrow Li_xTiO_2$$



Electrochemical intercalation of lithium changes optical properties.

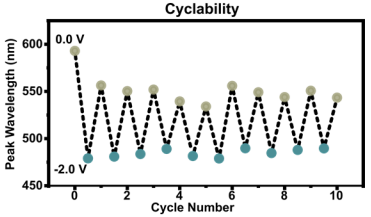


Demo 1. Fabry-Perot Cavities

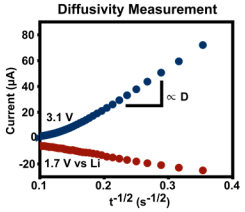


100 nm TiO_2 on Titanium backplane

- Reality matches expectation
- **Low power**: 2 V external bias
- **Good cycle life**: stable after initial formation loss
- **Slow**: 50% shift in 50 s



Rate and the Role of Mass Transport

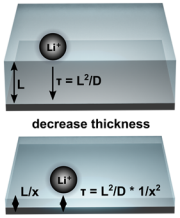


Reaction rate is limited by mass transport of lithium through solid.

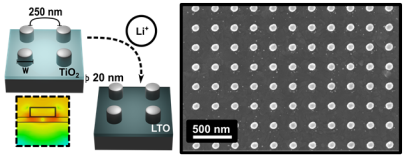
Measured D ≈ 1E-11 cm^2/s

Characteristic diffusion time:

$$\tau = \frac{L^2}{D}$$

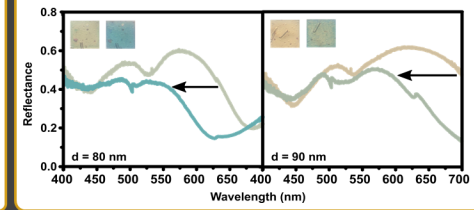


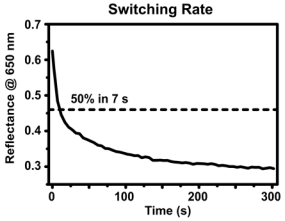
Demo 2. Gap Plasmon Metasurface



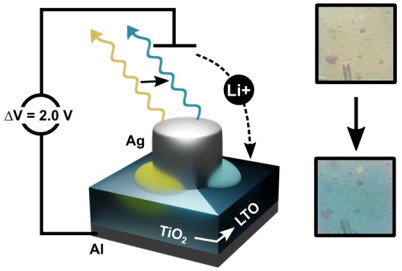
Silver nanopillars on 20 nm TiO_2

- Shrinking active layer reduces interaction volume with light.
- Gap plasmon resonance enhances electric field in TiO_2.
- **Improves switching rate.**





Summary



Contributions:

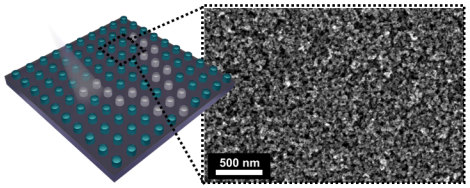
- Measurement of LTO
- Low-k at blue wavelengths
- > 100 nm tuning

Applications:

- Low-power displays
- Active camouflage
- Anti-counterfeiting

Future Work

Embossed nanoparticles enable photodoping of all-dielectric metasurfaces.



Large-area ✓ Lithography-free ✓ Optically-addressed ✓

Acknowledgments

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References

1. Eaves-Rathert, J. et al. Dynamic Color Tuning with Electrochemically Actuated TiO_2 Metasurfaces. *Submitted.*
2. Ruiz-Clavijo, A. et al. Engineering a Full Gamut of Structural Colors in All-Dielectric Mesoporous Network Metamaterials. ACS Photonics 5, 2120–2128 (2018).
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