

# Nanopatterning via selective dissolution of one photoisomer

P. Cantu,<sup>1</sup> T. L. Andrew,<sup>2</sup> and R. Menon<sup>1\*</sup>

<sup>1</sup>*Department of Electrical and Computer Engineering, University of Utah,  
Salt Lake City, UT 84112*

<sup>2</sup>*Department of Chemistry, University of Wisconsin-Madison,  
Madison, WI 53706*

\**rmenon@eng.utah.edu*

The resolution of conventional photolithography is generally restricted to about half the wavelength of illuminating light due to the far-field diffraction limit.<sup>1</sup> To address this limit we have developed an alternative optical lithographic technique that exploits unique combinations of spectrally selective reversible and irreversible photochemical transitions to achieve deep sub-wavelength resolution with potential extension to 3-dimensions. This approach, which we refer to as Patterning via Optical Saturable Transitions (POST), has the potential for massive parallelism, enabling the creation of nanostructures and devices at a speed surpassing what is currently possible with scanning e-beam lithography.

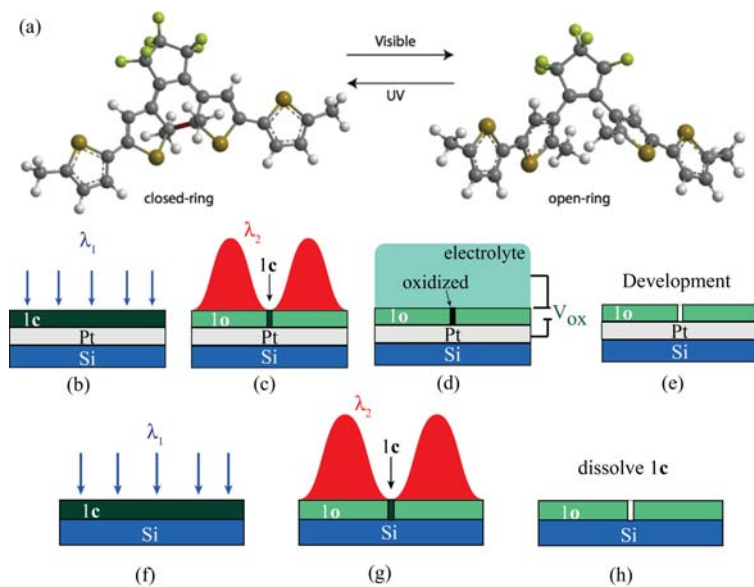
In the POST process, a thin film, of a novel photochromic diarylethene derivative, Fig. 1(a), namely, 1,2-bis(5,5'-dimethyl-2,2'-bithiophen-yl) perfluorocyclopent-1-ene is thermally evaporated onto a substrate (i.e. silicon wafer). Upon uniform irradiation with short-wavelength UV,  $\lambda_1$ , the open-ring isomer, **1o**, converts to the closed-ring form, **1c**. A subsequent illumination with a node,  $\lambda_2$ , at 633nm converts the molecules back to the open-ring form, **1o**, except in the near-vicinity of the node. By optically saturating this transition, the molecules in the closed-form, **1c**, remain in a region that is far smaller than the far-field diffraction limit. It is at this stage that a *locking* mechanism is applied to fix the sub-wavelength region, and isolate it from further optical processing. Previously, the *locking* mechanism of POST was performed via electrochemical oxidation, Fig. 1(b)-(e).<sup>2,3</sup> Here, we report an electrode-free technique as a highly selective *locking* mechanism that bypasses electrochemical oxidation by exploiting difference in solubility between the two thermally stable photoisomer states of the molecule, Fig. 1(f)-(h), by developing the sample in a polar solvent (100 wt(%) ethylene glycol).<sup>4</sup> This highly selective solubility *locking* step opens the door to an inexpensive, scalable nanopatterning technique.

An experimental demonstration of POST technique using the solubility difference *locking* is shown in Fig. 2.

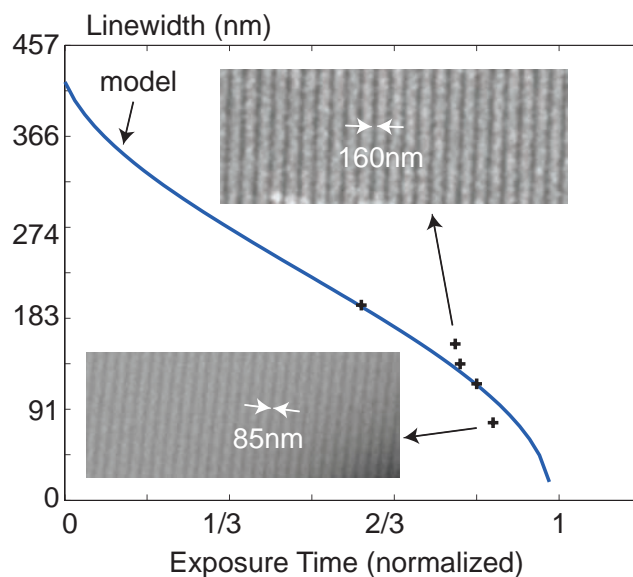
In this presentation, we will describe our experiments to improve the robustness of the process as well as present preliminary patterning of complex 3-D geometries with POST.

▪

- [1] E. Abbé, Arch. Mikrosk. Anat. Entwicklungsmech. 9, 413 (1873).
- [2] N. Brimhall, et al, *Breaking the Far-Field Diffraction Limit in Optical Nanopatterning via Repeated Photochemical and Electrochemical Transitions in Photochromic Molecules*, Physical Review Letters. 107, 205501 (2011).
- [3] P. Cantu, et al, *Subwavelength nanopatterning of photochromic diarylethene films*, Applied Physics Letters. 100, 183103 (2012).
- [4] P. Catu, et al, *Nanopatterning of diarylethene films via selective dissolution of one photoisomer*, Applied Physics Letters. 103, 173112 (2013).



**Figure 1:** (a) Photochromic molecule (compound 1) used as recording medium in POST. Compound 1 exists as an open-ring isomer  $I_o$  and a closed-ring isomer  $I_c$ . (b)-(e) Sequence of steps for conventional POST. (f)-(h) Sequence of steps for dissolution-based method.



**Figure 2:** Linewidth vs exposure time for single exposure and development. The simulated curve is shown as a solid blue line, while the experimental data is shown using crosses. A sinusoidal illumination with period of 457nm was assumed. Inset: SEM images