Maximizing intensity in TiO₂ waveguides for nonlinear optics

Overview
TiO₂ is a widely transparent, highly nonlinear novel photonic material that has potential applications in all-optical switching and other nonlinear processes. In order to best exploit its large nonlinearity, we have optimized our fabrication process and have simulated design parameters that aid in producing and maintaining large pulse intensities within integrated photonic structures.

Waveguides
Once fabricated, TiO₂ photonic waveguides have trapezoidal cross sections (left) and are capable of guiding visible light (right).

Nonlinear properties
A short pulse in a nonlinear waveguide generates new wavelengths. Here, we show spectral broadening at both 800 nm (left), 1550 nm (middle), and green-light from 1550 nm pulses (right).

Dispersion engineering
Nonlinear effects cause ultrafast pulses to broaden, disperse and thus attenuate. By tuning the waveguide geometry, we obtain anomalous group velocity dispersion which directly counters these effects and produces optical solitons.

Fabrication steps
- Begin with silicon wafer with thermal oxide film
- Deposit thin TiO₂ film using reactive sputtering
- Spin on e-beam resist layer
- Immerses resist in developer to remove exposed regions
- Write pattern into resist using electron beam lithography
- Lift-off metal film by dissolving resist
- Etch through TiO₂ film using reactive ion etching
- Remove remaining metal leaving TiO₂ waveguides

Fabrication materials
Smooth features are important to achieve low propagation losses in photonic waveguides. We achieve the most consistent etch by using chromium as an etch mask compared to aluminum oxide (left). We also obtain smoother features by using ZEP as a resist instead of PMMA (right).

Coupling pads
We can optimize for insertion losses by fabricating low index polymer coupling pads (top). Using an adiabatic taper, we can increase our waveguide input coupling efficiency by 30% by implementing a coupling pad (bottom).

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