Sputtered Oxide Integrated Photonics

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Principal Investigator(s): Amy Foster

User(s): Neil MacFarlane, David Irvine, Aaron Schreyer-Miller

Affiliation(s): Electrical and Computer Engineering Department, Johns Hopkins University
Primary Source(s) of Research Funding: Viavi Solutions, Inc.
Contact: amy.foster@jhu.edu, nmacfar2@jhu.edu, dirvine4@jhu.edu, aschrey1@jh.edu
Primary CNF Tools Used: Oxford 100 Etcher, Oxford PECVD, PT770 Etcher, Zeiss SEM, JEOL 6300

Abstract:

Niobium tantalum dioxide (NbTaOx) is a material developed by collaborator Viavi Solutions. NbTaOx films are deposited using low temperature pulsed DC magnetron sputtering. We have been investigating NbTaOx as a new platform for both linear and nonlinear integrated photonics. We have fabricated ring resonators with quality factors as high as 858,000 corresponding to propagation losses as low as 0.47 dB/cm. Using these high-quality ring resonators, we have also investigated the nonlinear capabilities of the NbTaOx platform and demonstrated optical parametric oscillation.

Summary of Research:

NbTaOx is a high linear refractive index material, with a linear refractive index that is about 10% higher than that of silicon nitride at a wavelength of 1550 nm. This high refractive index results in a high index contrast with respect to the typical silicon dioxide (SiO_2) cladding material. The higher contrast produces highly confined waveguide modes, allows for tighter waveguide bending radii, and enhanced nonlinear interactions.

Our waveguides were dispersion engineered for broadband nonlinear interactions, which require anomalous dispersion. Through design and simulation, it was found that the required film thickness for anomalous waveguide dispersion at C-band wavelengths was about 800 nm. Because these films are deposited using a sputtering deposition technique, depositing 800 nm thick films does not come with the same challenges associated with depositing thick Si_3N_4 films like stress induced film cracking. The waveguide devices were patterned using electron-beam lithography. We used a chromium etch mask was dry etched using the CNF PT770 etcher. The NbTaOx film was then etched using the CNF Oxford 100 etcher. The devices were clad with SiO_2 and diced into individual chips. SEM images of waveguide cross section and side wall are shown in Figure 1.

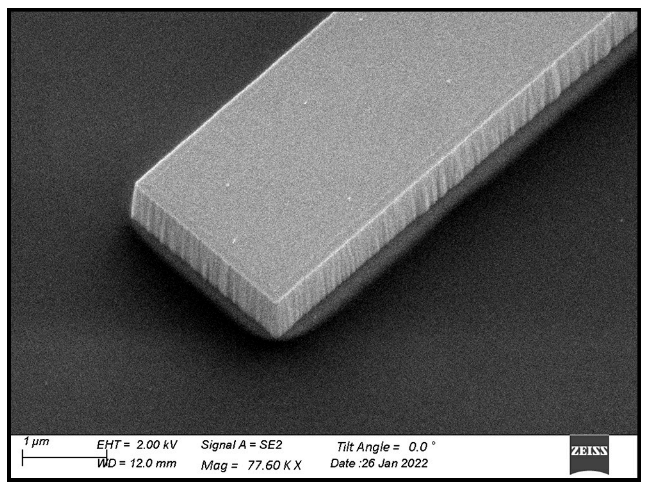

Figure 1: SEM image of NbTaOx waveguide sidewall.

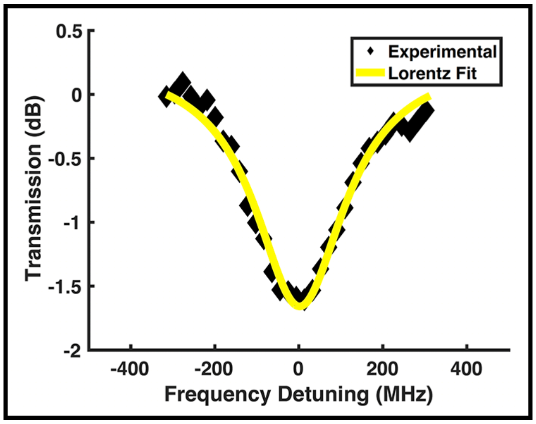

Figure 2: Individual resonance fit to a Lorentzian function.

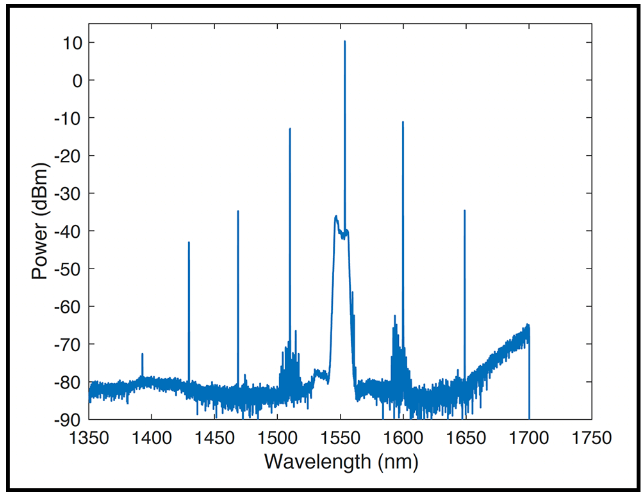

Figure 3: a) Spectrum of optical parametric oscillator generated in NbTaOx ring resonator.

The linear transmission of the waveguides was measured as a function of propagation length ranging from 0.6 cm to 2.8 cm. The losses varied from 0.56 dB/cm to 0.99 dB/cm for waveguide widths of 3.5, 2.5, and 1.5 µm.

We also extracted propagation losses by measuring the spectrum of high-quality ring resonators. The resonator spectrum for the 2.5 µm waveguide width are shown in Figure 2. The highest quality factor resonance was found to be 858,000, which corresponds to linear propagation losses of 0.47 dB/cm.

Using the high-quality ring resonator, we investigated the nonlinear capabilities of the NbTaOx films by generating optical parametric oscillation. The spectrum of the frequency comb is shown in Figure 3. We couple a high-power pump on-chip and slowly tune its wavelength to one of the resonance wavelengths of the device. Once the round-trip optical parametric gain via four-wave mixing within the ring exceeds the round-trip losses, the four-wave mixing process spontaneously generates single and idler sidebands of an optical parametric oscillator shown in Figure 3.

Conclusions and Future Work:

Our initial investigation into the NbTaOx films indicated that they are a high-quality platform for both linear and nonlinear integrated photonics. These results are the first demonstration of frequency comb generation in this material platform. Some of our immediate future work is to lower the oscillation threshold and to fill in more comb lines of the Kerr frequency comb. This will be done through a combination of fabrication optimization as well as decreasing the size of the ring resonators. In addition to this, we plan to investigate the minimum bending radius capabilities of this platform and use this information to demonstrate dense and complex linear integrated photonic circuits.