Towards photonics-enabled quantum memory: integrating high-reflectivity mirrors and Ta_2O_5 waveguides

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High-reflectivity dielectric mirrors are promising for quantum applications, including computing and communication. Mirrors fabricated with alternating Ta_2O_5/SiO_2 layers have demonstrated reflectivity exceeding 99.999%.[1,2] Additionally, Ta_2O_5 waveguides on SiO_2 cladding have demonstrated low-loss capabilities, reported down to 3 dB/m.[3] To realize devices for quantum applications, particularly quantum memory, individual components must be integrated into a scalable fabrication platform.

We report ongoing efforts to develop cavities that integrate high-reflectivity mirror coatings and Ta_2O_5 rib waveguides. We fabricate mirrors consisting of 33 alternating quarter-wavelength (at 1550 nm) Ta_2O_5 and SiO_2 layers on both flat optical substrates and those with 0.5 m radius of curvature. Combining these mirrors to make a Fabry-Perot cavity, we demonstrate >99.996% reflectivity (>90,000 finesse).

To develop integrated photonic circuits, we developed a process to deposit a 3-wavelength SiO_2 clad and 1-wavelength Ta_2O_5 layer on the mirror, pattern waveguides and grating couplers with electron-beam lithography (Fig 1), and transfer the pattern 400 nm into Ta_2O_5 via dry etching (Fig 2). We discuss optimization efforts, through which we achieve 0.9 dB/cm waveguide losses.

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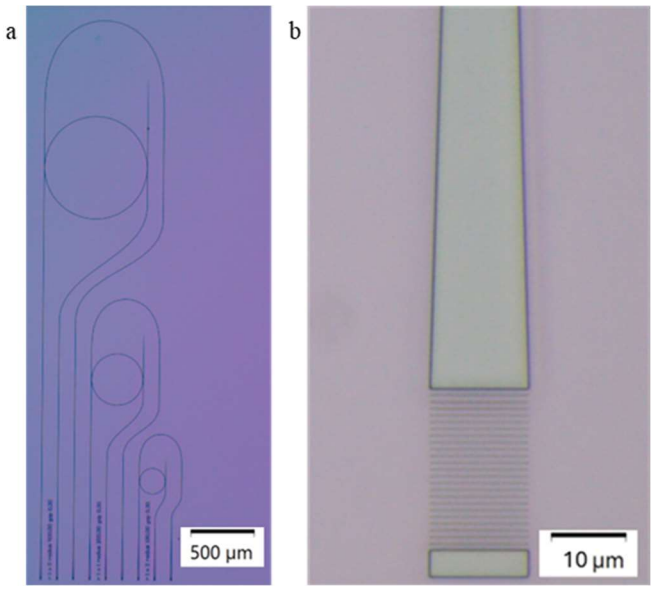

Figure 1: Optical images of waveguides (a) and grating couplers (b) patterned with electron-beam lithography.

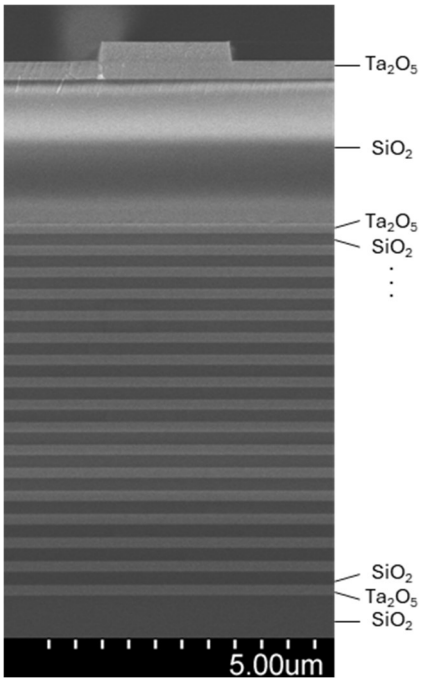

Figure 2: Cross-section scanning electron microscope image of Ta_2O_5 waveguide fabricated on SiO_2 clad and 33-layer dielectric stack of alternating Ta_2O_5 and SiO_2.