Fabrication protocol for functionalized quartz cylinders

Our lab developed functionalized quartz cylinders (with its extraordinary axis perpendicular to its cylinder axis) that can specifically be attached to biomolecules for direct single-molecule torque measurements on the angular optical trap (Deufel et. al, Nature Methods, 2007). The birefringence of quartz enables torque application once the cylinder's extraordinary axis deviates from the incident beam polarization. The cylindrical shape helps orient the cylinder axis along with the beam propagation direction, facilitating independent control of force and torque application. These cylinders were made out of a quartz wafer via a top-down nanofabrication process at Cornell Nanoscale Facility (CNF).

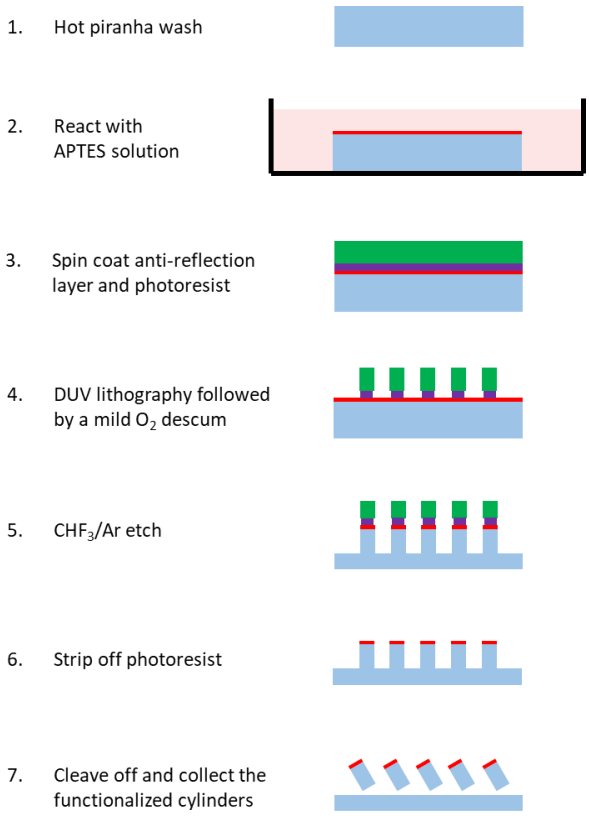

Figure 1. Fabrication process flow for functionalized quartz cylinders.

Detailed quartz cylinder fabrication protocol:

1. Wash the 4-inch X-cut seedless quartz wafer (Precision Micro-Optics, PSQB-131332) with hot piranha.
2. Functionalize the surface of the quartz wafer with 1% (3-aminopropyl)triethoxysilane (APTES, Sigma 440141) in 95% ethanol solution (95% ethanol, 5% water, pH to 5.0 using acetic acid). This step modifies the surface with amine groups to be compatible with protein coupling.
3. Spin coat anti-reflection layer DS-K101, then soft bake at 185 °C for 90 s.
   Spin coat photoresist UV1400-1.4, then soft bake at 135 °C for 90 s.
4. Pattern pillars via deep ultraviolet (DUV) lithography with ASML PAS 5500/300C DUV wafer stepper, followed by post-exposure bake at 115 °C for 90 s.
   Develop in AZ 726 MIF developer for 60 s, then hard bake at 115 °C for 90 s.
   Perform a mild O_2 plasma to descum the surface residue with Oxford PlasmaLab 80+ RIE system.
5. Dry etch with chemistry (45 sccm CHF3, 15 sccm Ar, 50 mTorr, 200 W) for ~ 50 min with Oxford PlasmaLab 80+ RIE system.
6. Strip off the remaining photoresist with Microposit Remover 1165 along with sonication until the photoresist is completely removed (can be checked from scanning microscope image).
7. Cleave off the quartz cylinders with a razor blade.
   Note: always use a fresh blade to cleave the cylinders.

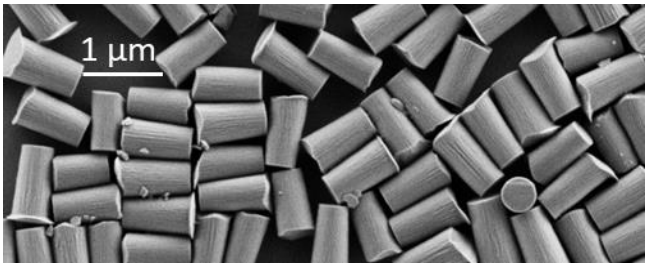

Figure 2. A scanning microscope image of cleaved quartz cylinders.