Device Fabrication for Optical Lever Measurement of Torsional Motion

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In physics, there is a growing question: is gravity quantum? One proposed experiment requires the precise measurement of angular motion of a torsional oscillator[1]. To this end, we were tasked with fabricating a thin silicon-nitride bridge with a silicon weight – or pillbox - in its center, as shown in Fig.1.

The fabrication of suspended nitride structures is not new, and there is more than one successful method to complete such a fabrication[2]. Common procedures include a straight-forward series of steps involving lithography and a combination of wet and dry etching to undercut and release the structure[2-3].

Despite the existence of established methods, the fabrication of our bridge remains challenging. One component of this challenge occurs because our final bridge is >100 mm rather than only hundreds of microns long, as is the norm. Another feature of our bridge is a 200~300 µm tall, silicon pillbox located in the center of the bridge. This pillbox limits our ability to follow standard nitride bridge fabrication practices because we must avoid undercutting the pillbox during any step in the process.

We have successfully created a process in which a series of aligned lithography, RIE, and DRIE steps outline the bridge and pillbox, as seen in Fig. 2. The general processing steps are shown in Fig. 3. However, the last step of releasing the bridge completely from silicon in a wet etch (Fig. 3 (h)) has been relatively unsuccessful with our current efforts. We propose to attach a carrier wafer to the bridge to mitigate additional stresses from moving in the liquid. The carrier wafer will be attached with a material that will sublimate so that detaching the carrier wafer will also not cause any stress on the bridge.

[1]Al Balushi A, Cong W, Mann RB. Optomechanical Quantum Cavendish Experiment. Physical Review A 98, 2018.
[2]Subhani KN, Khandare S, Biradar RC, Bhat KN. Novel fabrication of fixed suspended silicon nitride structure for MEMS devices with Dry Etching. IOP Conference Series: Materials Science and Engineering 872: 012157, 2020.
[3]Beyder A, Sachs F. Microfabricated torsion levers optimized for low force and high-frequency operation in fluids. Ultramicroscopy 106: 838–846, 2006.

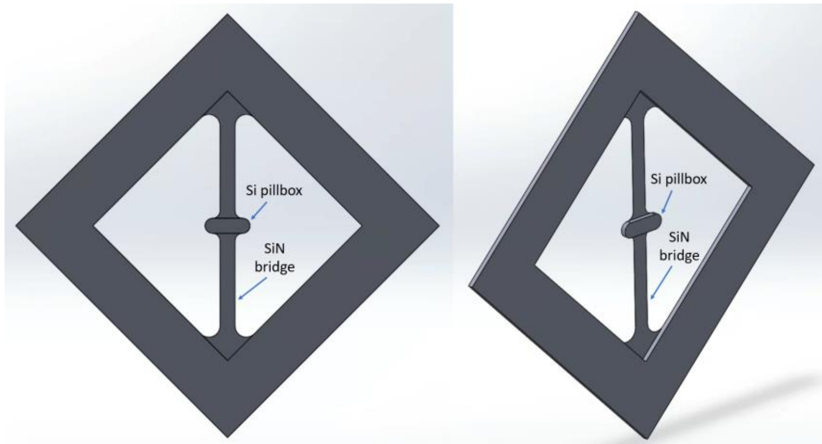

Fig. 1: Silicon nitride bridge with silicon pillbox design.

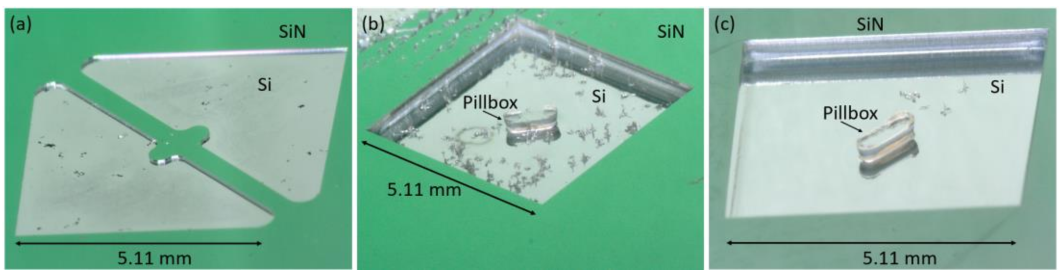

Fig. 2: (a) Top of SiN bridge after DRIE on both sides, right before wet etch step; (b) bottom portion of bridge with Si pillbox, after DRIE on both sides, right before wet etch step; (c) cleaner fabrication of bottom portion of bridge with Si pillbox, after DRIE on both sides, right before wet etch step.

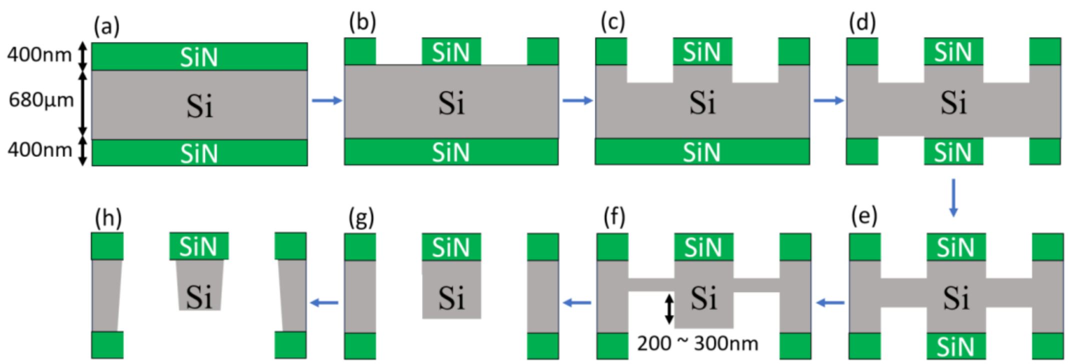

Fig. 3: Process flow for SiN bridges with a silicon pillbox: (a) Substrate dimensions; (b) topside lithography then reactive ion etch (RIE) outlining bridge and pillbox; (c) deep reactive ion etch (DRIE) of topside; (d) aligned lithography and RIE, outlining pillbox, of bottom side; (e) DRIE of bottom side, where the pillbox outline is not etched; (f) continued DRIE of bottom side, including pillbox; (g) DRIE continued until all silicon not on the bridge or pillbox is gone; (h) wet etch of the remaining silicon covering the bridge (but not etching through the pillbox).