# Atomic Layer deposited nano-mechanical resonators for Silicon photonics

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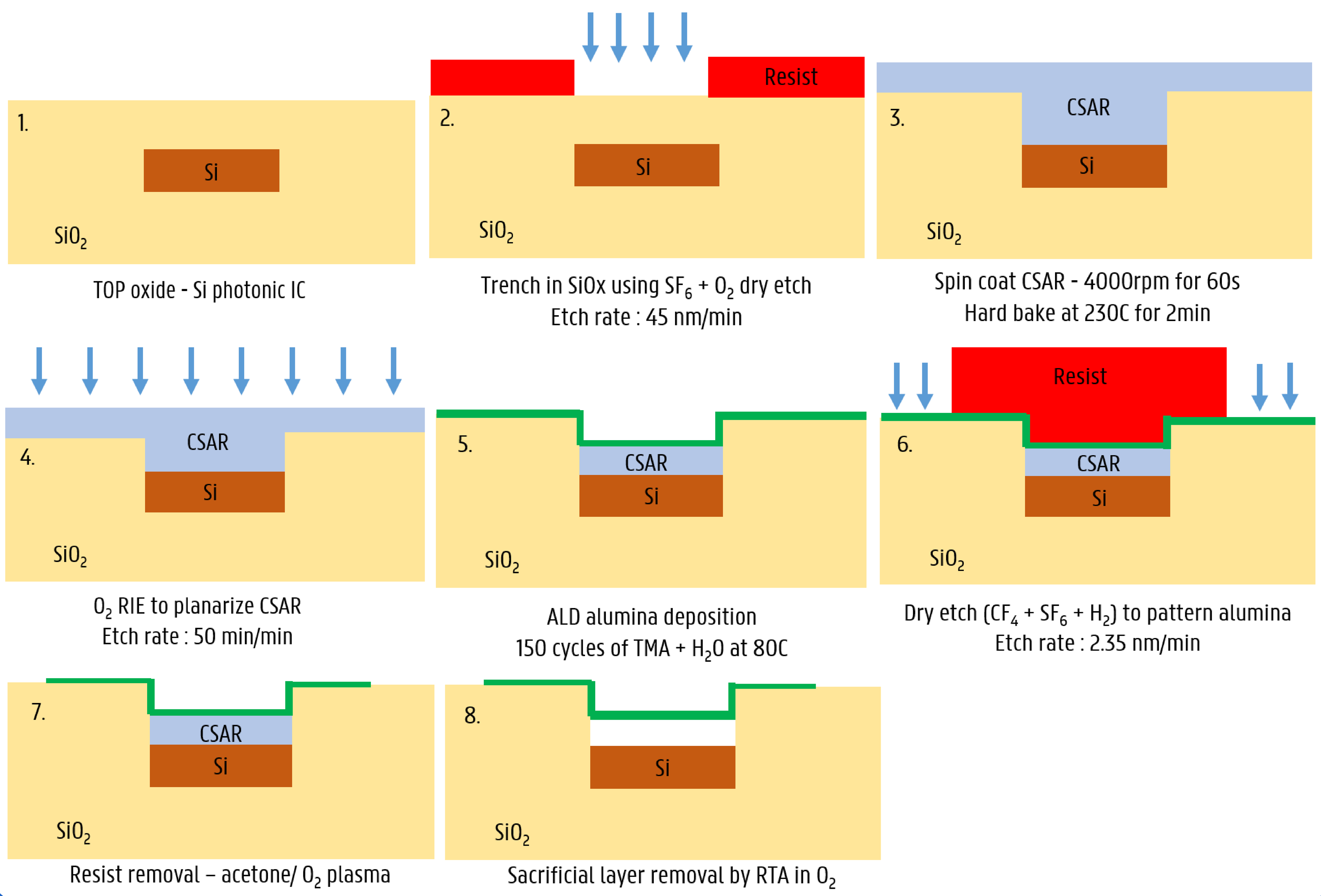
## Introduction

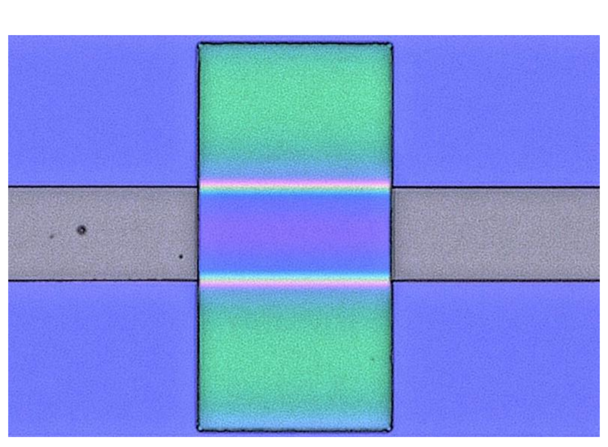
- Atomic layer deposition (ALD) is the high-precision growth of mechanically robust [1], uniform and ultra-thin (<10nm) membranes of a wide range of dielectrics on broad array of substrates.
- ALD films possess very desirable mechanical properties[2] such ultra-low mass and stiffness for applications in static and resonant nano-opto-mechanical force [3] and mass sensing [4].
- Here we have developed a wet etching free fabrication of free-standing ALD alumina membranes using an e-beam resist polymer as a sacrificial layer. [5]

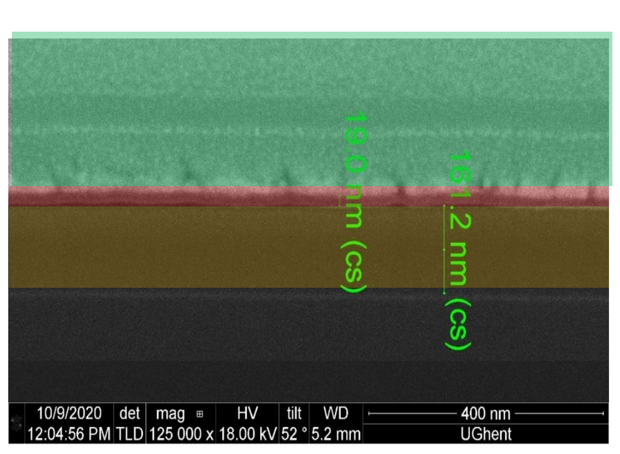
## Fabrication Process Flow

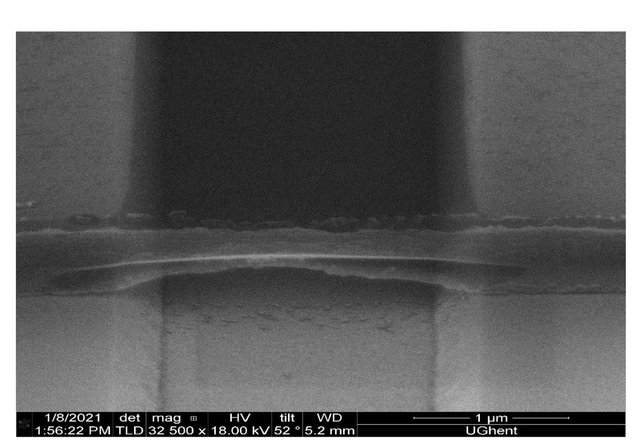
- CSAR-62 (all-resist 6200.13) is used as scaffold for the atomic layer deposition of alumina as well as a sacrificial layer for a liquid free suspension of the membrane.
- Polymer is removed by rapid thermal annealing at 350°C in air/$O_2$ for 30min.




## Fabricated devices







**Optical micrograph** : Patterned Alumina(Green) over CSAR(rainbow). Si(Gray) trench surrounded by SiOx(Blue).

**SEM Cross-section** : 19nm of Alumina(Red) over 161nm of CSAR(yellow). Au(Green) film for SEM imaging.

**SEM** : Alumina membrane suspended over a 2um trench in SiOx. After CSAR removal using RTA.

## References

[1] Wang, Luda, et al. "Ultrathin oxide films by atomic layer deposition on graphene." Nano letters 12.7 (2012): 3706-3710.

[2] Ilic, B., S. Krylov, and Harold G. Craighead. "Young's modulus and density measurements of thin atomic layer deposited films using resonant nanomechanics." Journal of Applied Physics 108.4 (2010): 044317.

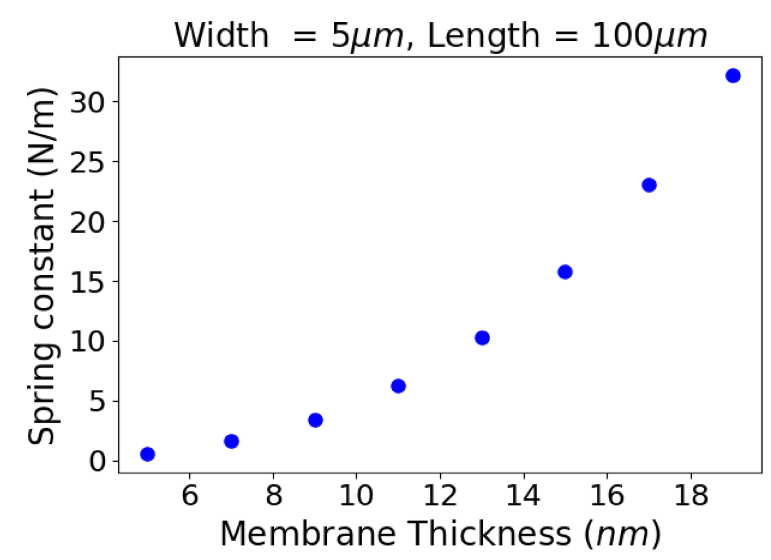
[3] Wiederhecker, Gustavo S., et al. "Controlling photonic structures using optical forces." nature 462.7273 (2009): 633-636.

[4] Ekinci, K. L., and M. L. Roukes. "Nanoelectromechanical systems." Review of scientific instruments 76.6 (2005): 061101..

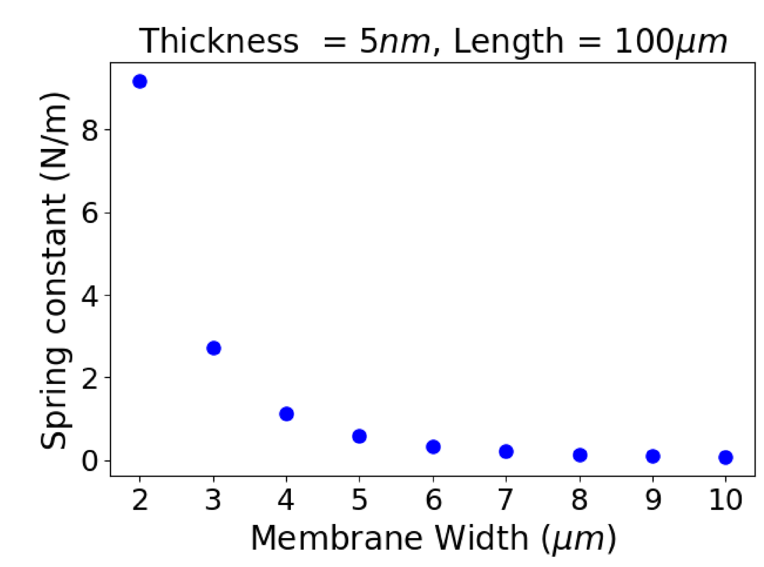
[5] Teh, W. H., et al. "Cross-linked PMMA as a low-dimensional dielectric sacrificial layer." Journal of microelectromechanical systems 12.5 (2003): 641-648.

## Simulation

### Mechanics - Static Spring constant

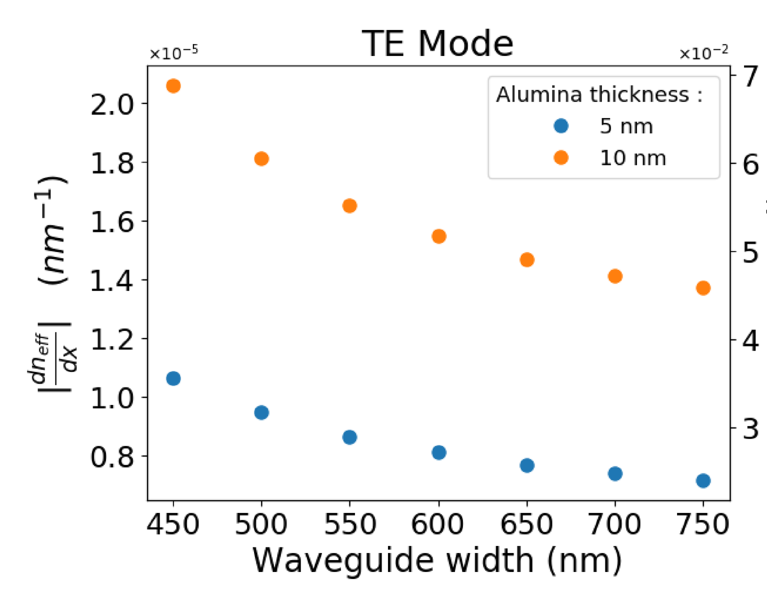



**Thickness dependence** : for fixed membrane width and length.

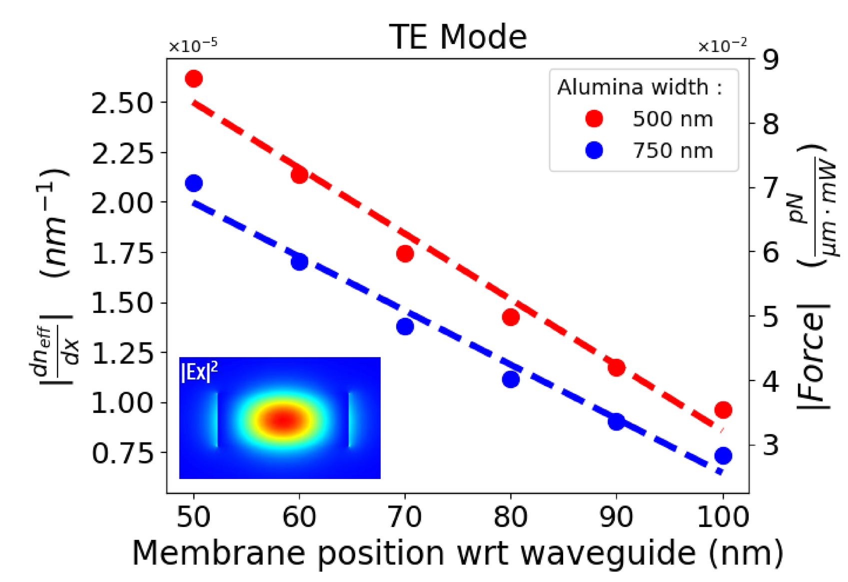



**Width dependence** : for fixed membrane thickness and length.

### Optics – Gradient force



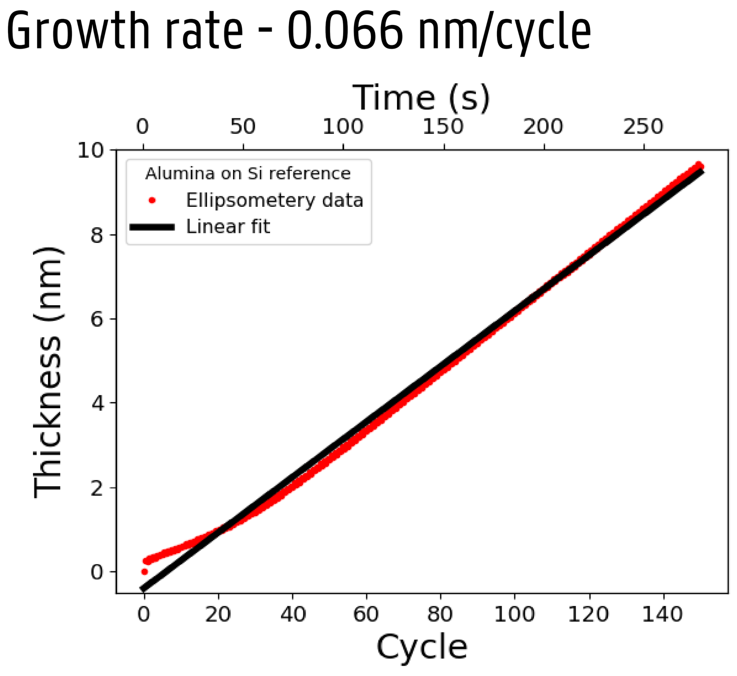

**Force dependence waveguide width :** for different thickness



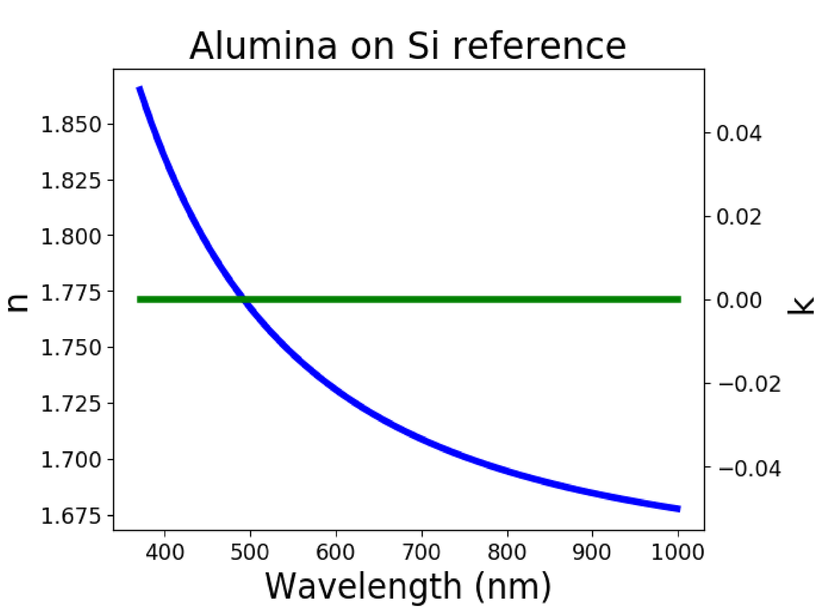

**Force dependence membrane position :** for different waveguide widths

## ALD Process

- Precursor gases for alumina - Tri-methyl-aluminium (TMA) and water.
- Deposition is done at 80°C, below the glass transition temperature of CSAR (125°C).
- Growth rate - 0.066 nm/cycle




Thickness vs ALD cycles and deposition time for alumina on blank Si substrate.




Real and imaginary part of refractive index of alumina on Si.

## Conclusions & Future Work

- We show that ultra-low mass and low stiffness free-standing ALD membranes can be fabricated for the silicon photonics platform using an all-dry stiction free method.
- Future work includes optimization of suspended membrane release. Integration of the membranes over Si waveguides and resonators. Finally, the optical gradient force measurement using pump-probe technique.

## Acknowledgement

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