Optimization of low-loss lithium niobate nanowaveguide fabrication

Rebecca Cheng[1], Cheng Wang[2], and Marko Lončar[2]

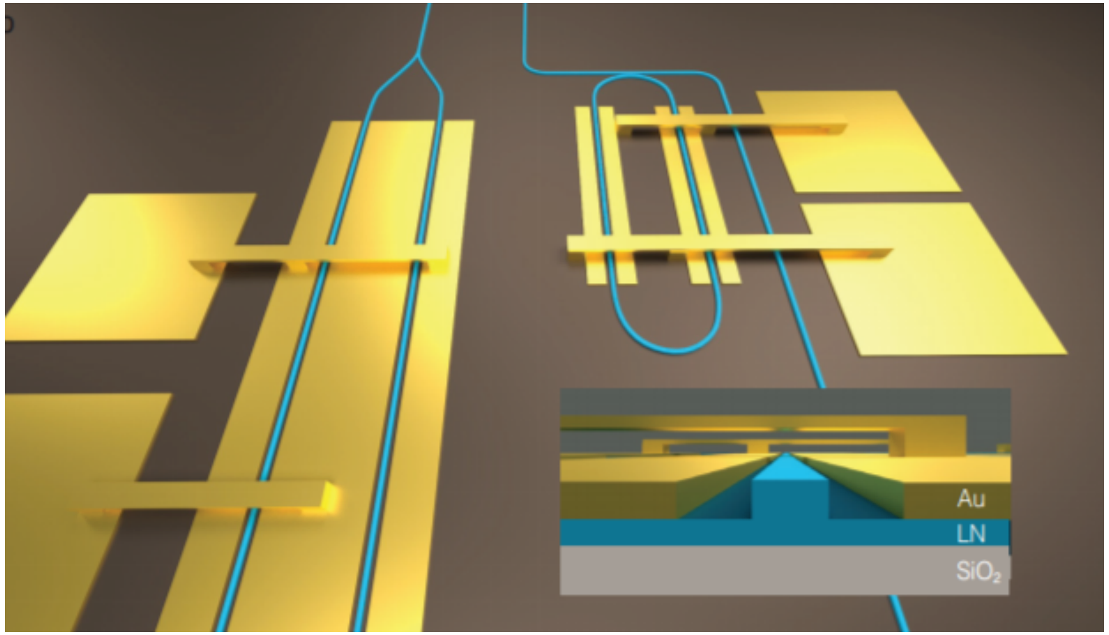
[1] *Brown University*

[2] *Harvard University, School of Engineering and Applied Sciences*

NNCI REU 2017

Introduction

- Waveguides restrict wave expansion to guide waves with small loss of energy
- Used as components in integrated optical circuits and for transmission in optical communication systems



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Lithium niobate (LN)

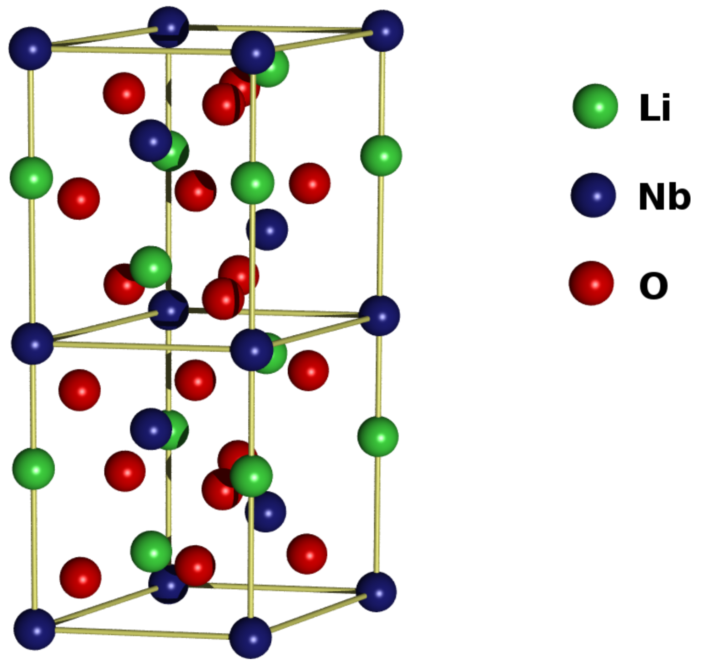
- Compound of lithium, niobium, and oxygen ($LiNbO_3$)
- Favorable material for electro-optic devices

Pros:

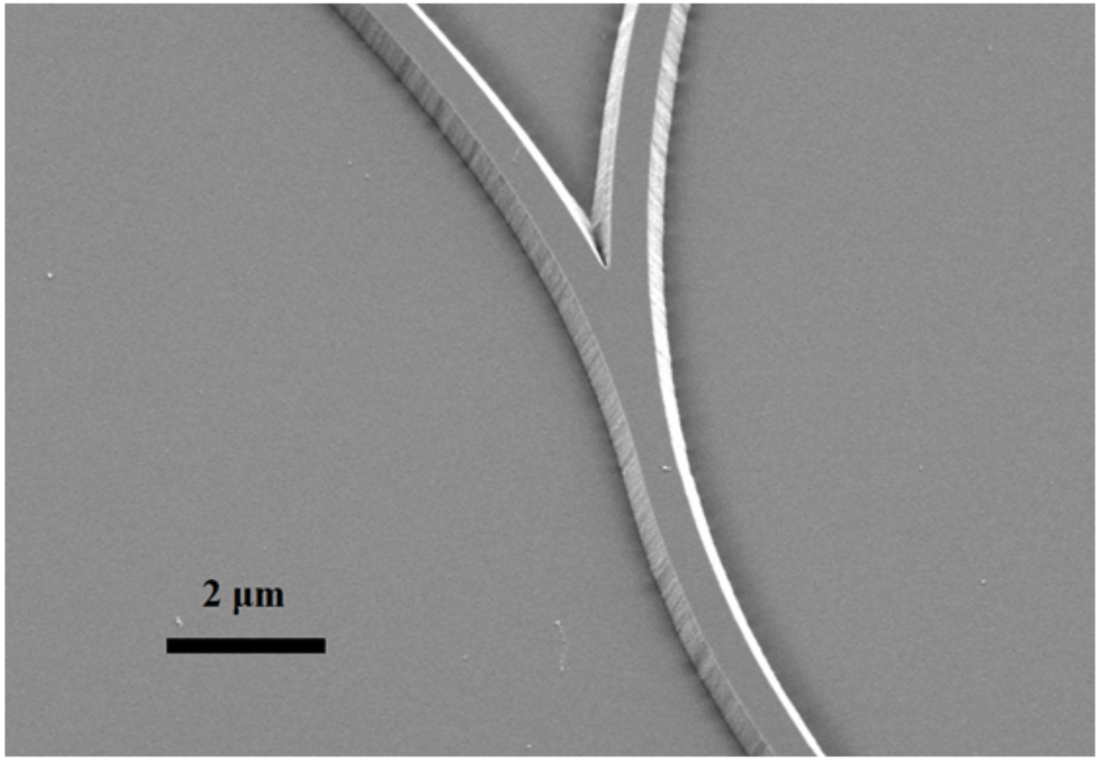
- High bandwidth
- Signal quality
- Acentrosymmetry
- Relatively good temperature stability

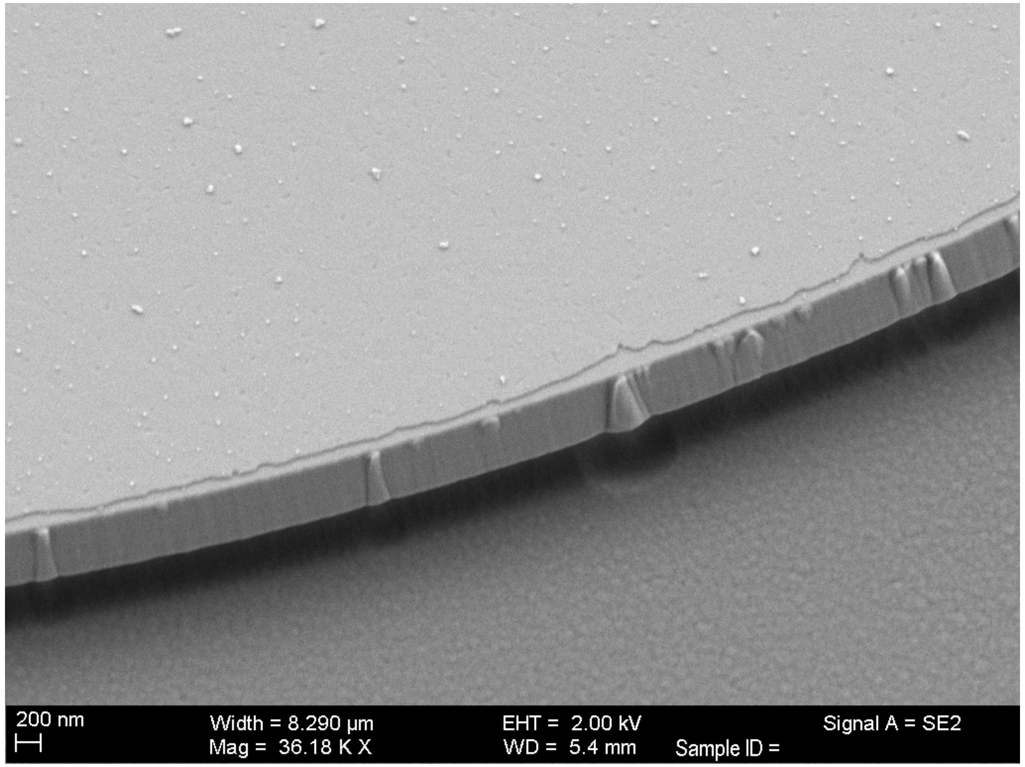
Cons:

- Difficult to scale down
- Expensive and bulky

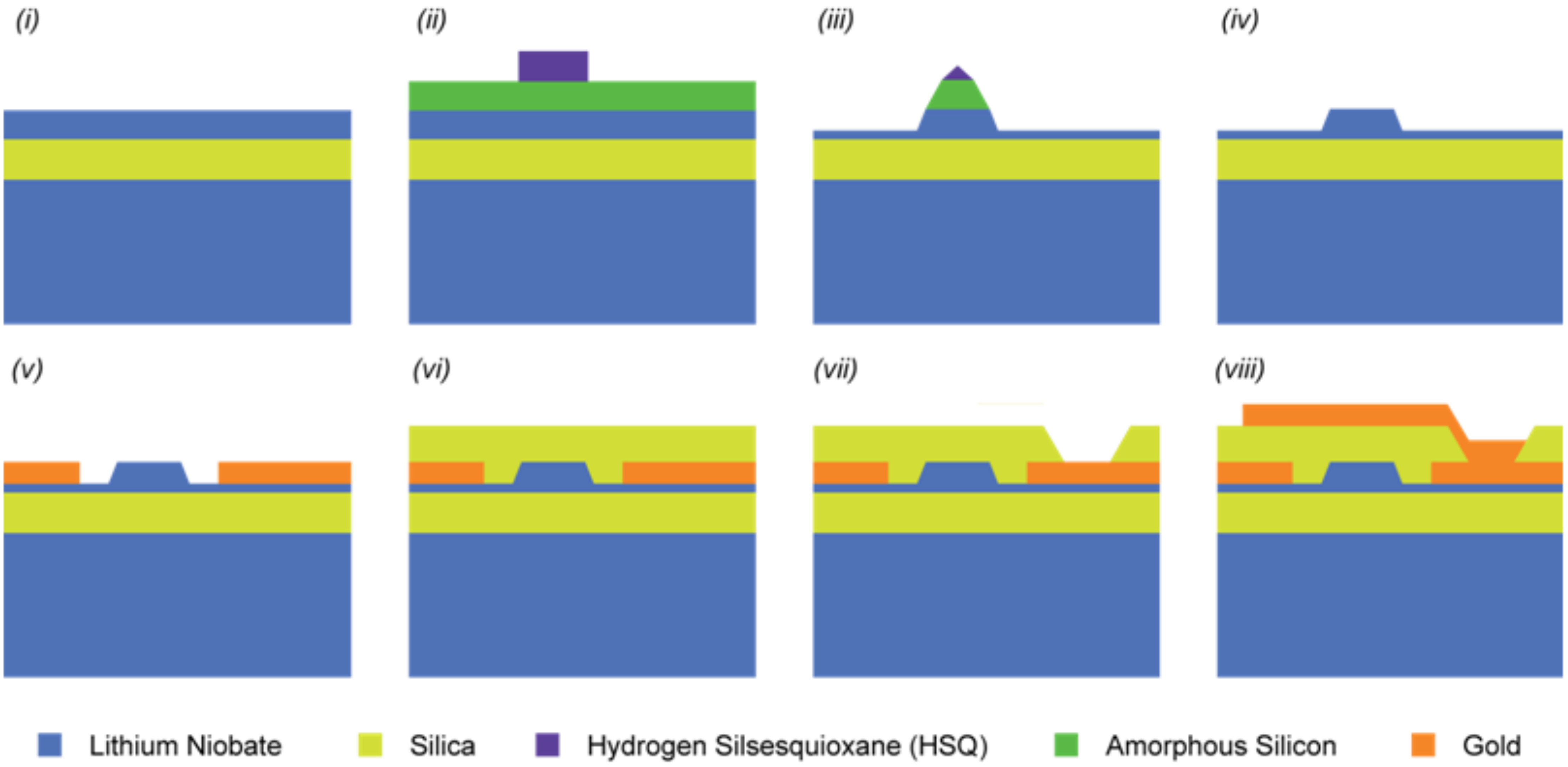


- Lončar group: nanofabrication techniques developed to create nanoscale LN devices
- Current fabrication process has very visible roughness
- Lower efficiency and quality factor from optical scattering
- Want to decrease roughness while still being able to etch sufficiently deep





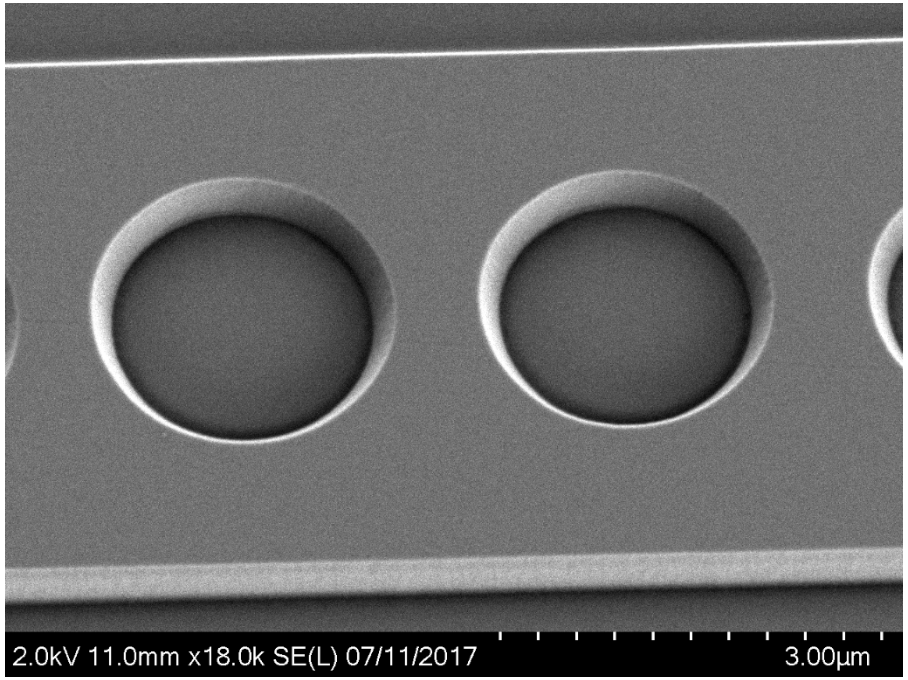
Fabrication process

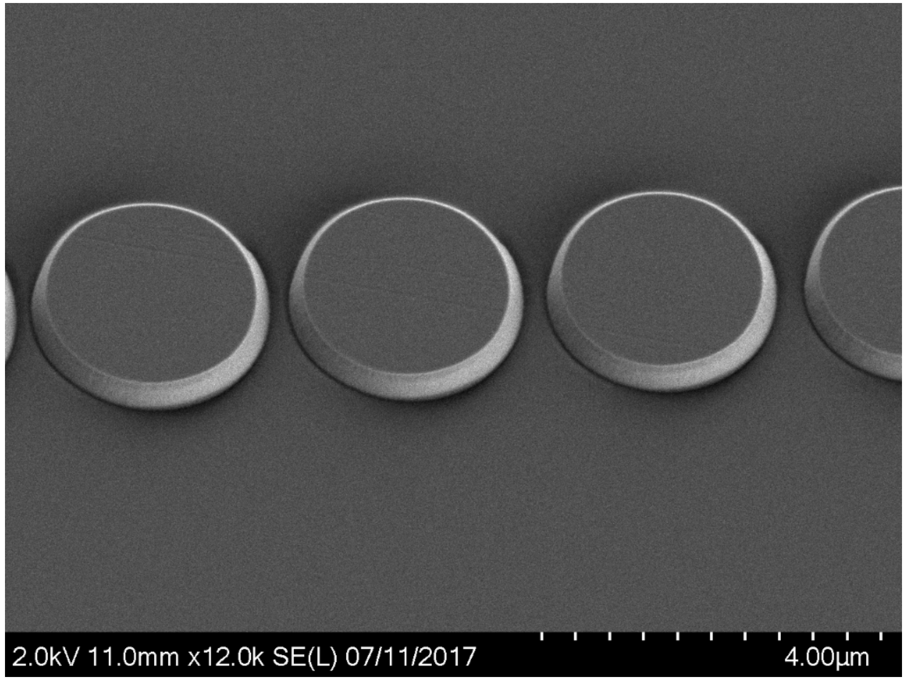


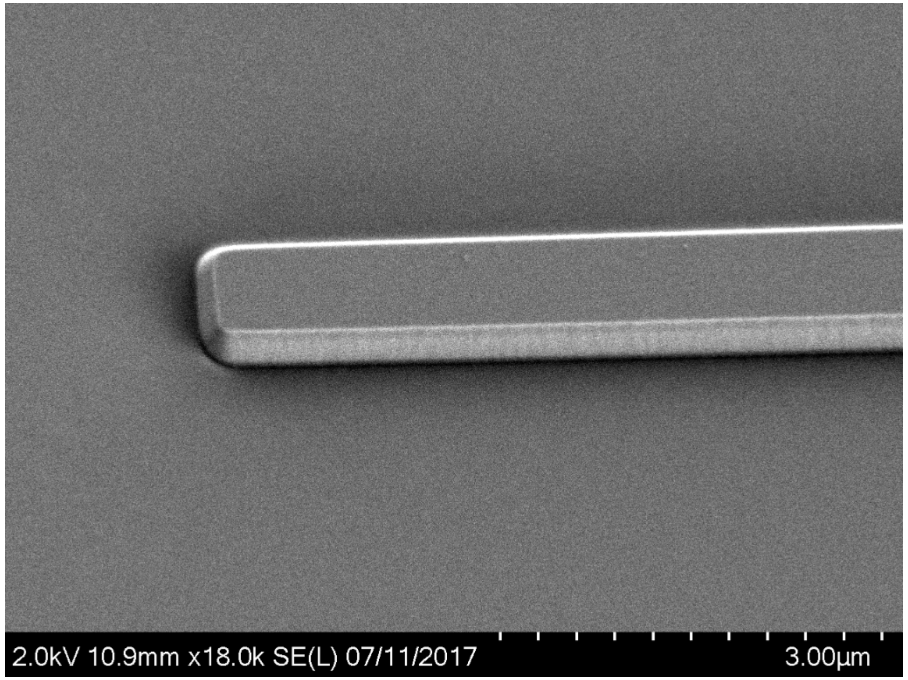
Project procedure

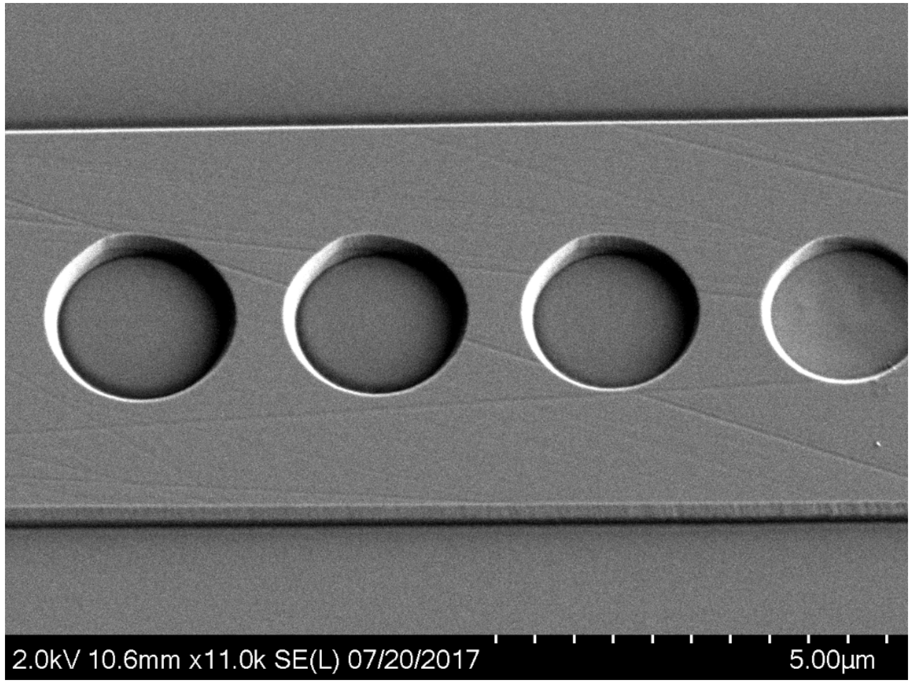
- Dry etching – remove material by hitting with ions
- Deep Oxide Etcher (DOE)
- 3 parameters of interest:
  - Chamber pressure
  - Antennae power
  - Bias power
- Examined roughness and etch depth on SEM and profilometer
- Brief look at temperature dependence
- Tested limits of the etch depth

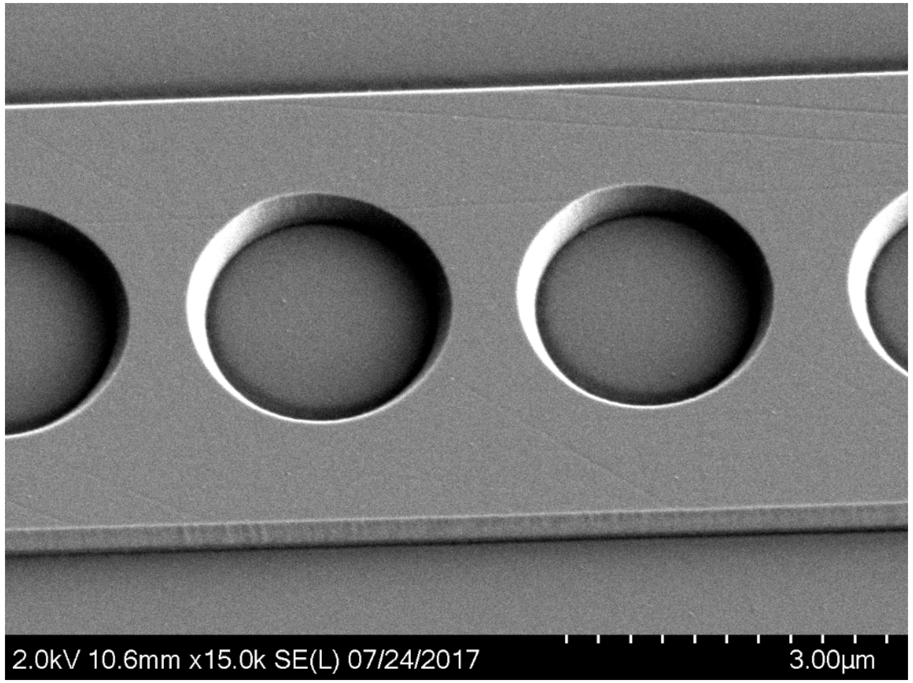
Chamber pressure: 3 mTorr
Antennae power: 800 W
Bias power: 105 W
Bias voltage: 224 V
Etch depth: ~250 nm

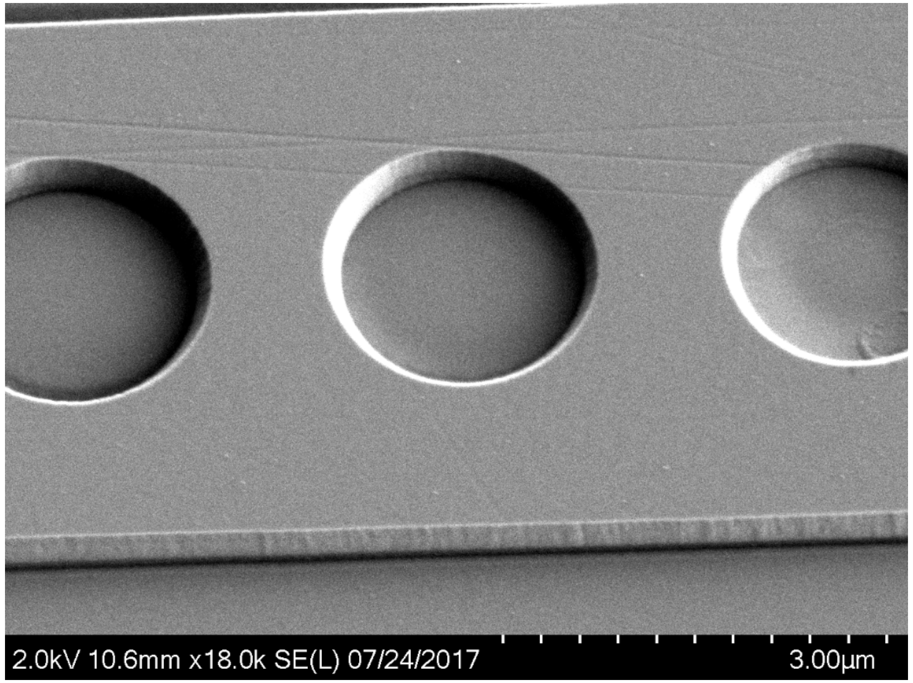






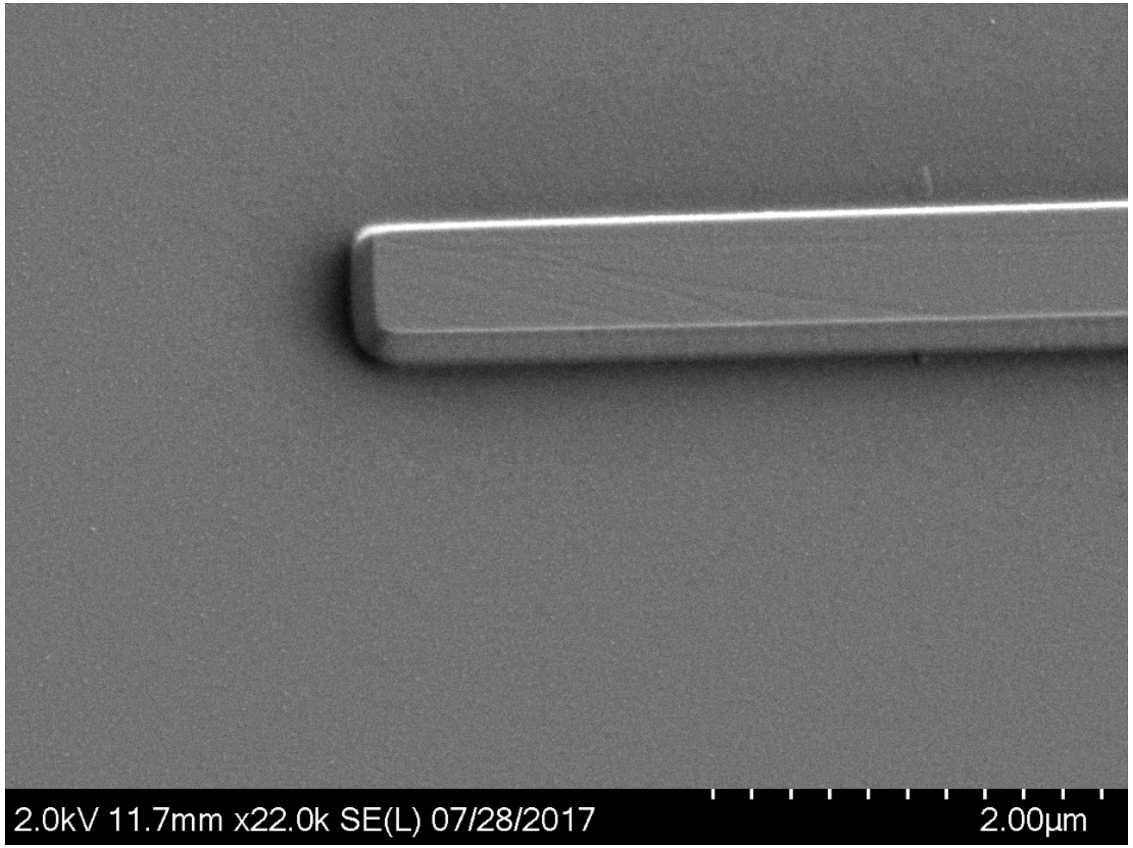

2.0kV 10.6mm x11.0k SE(L) 07/20/2017
5.00µm

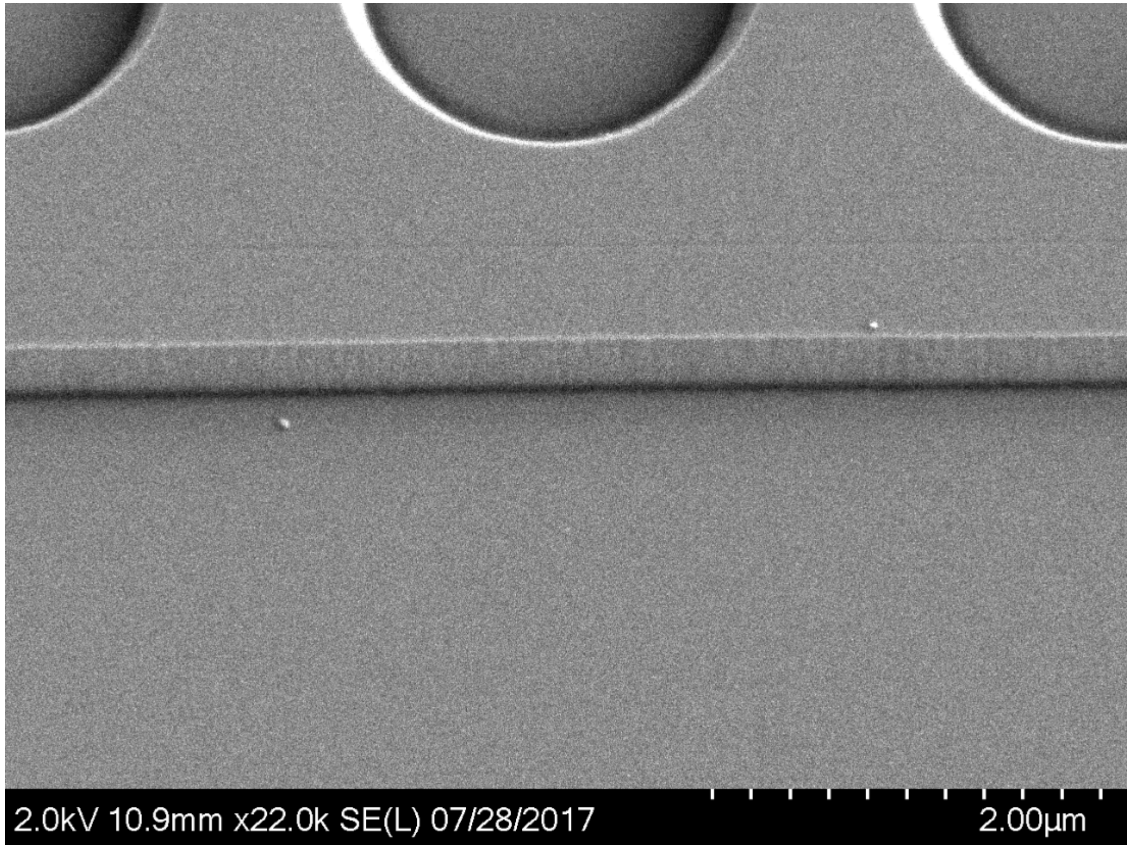

2.0kV 10.6mm x15.0k SE(L) 07/24/2017
3.00µm


2.0kV 10.6mm x18.0k SE(L) 07/24/2017
3.00µm


2.0kV 10.6mm x13.0k SE(L) 07/20/2017
4.00µm

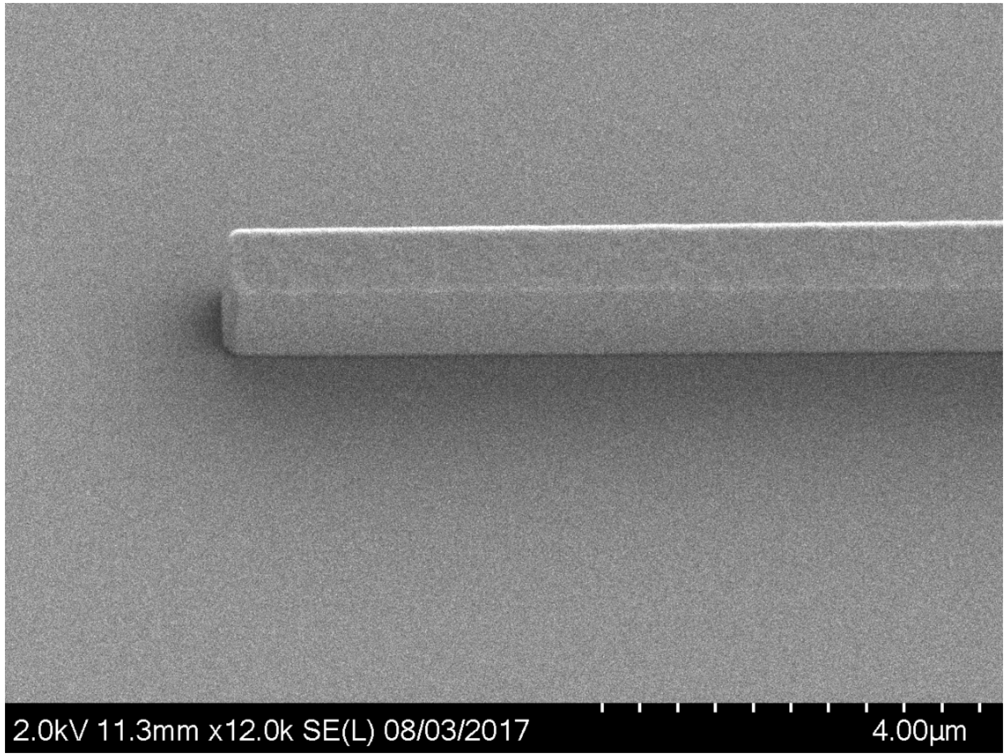
- New aim: ~225 V bias voltage at 3 mTorr and 800 W
- Test first with a condition etch on a carrier wafer
- Better control over the smoothness of the etch

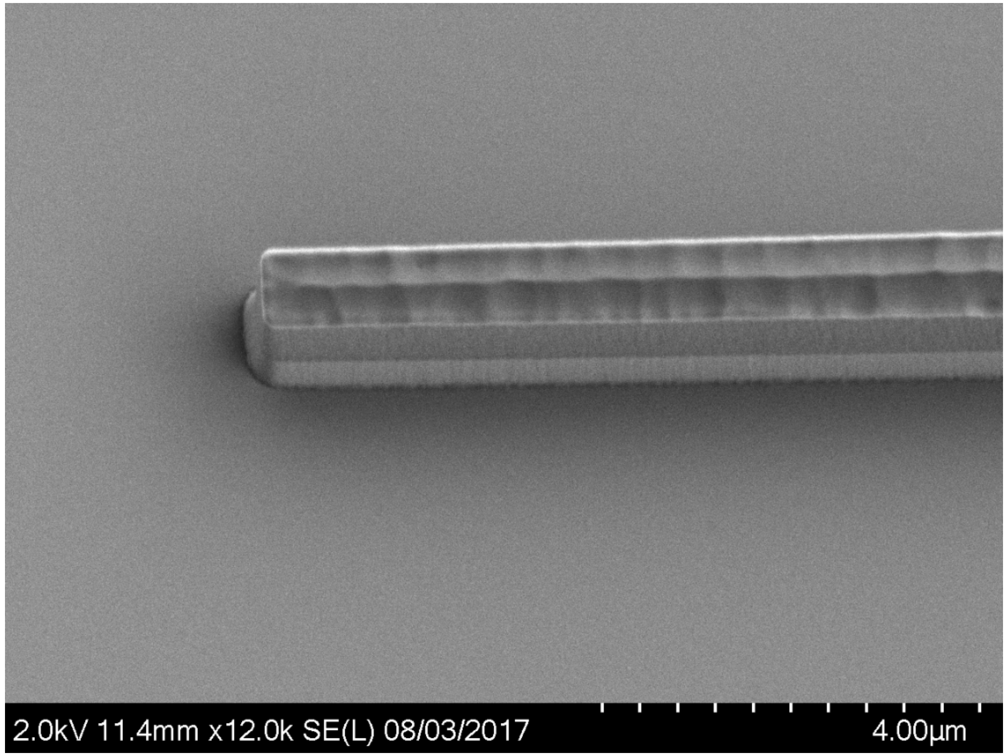




Limits of etch depth

- Imaged resist before and after a 7 minute etch to see how much resist was left after etching
- Our thin film LN waveguides will need an etch depth of ~400 nm





Conclusions

- We have successfully decreased the roughness of the etch significantly for our dry etching method
- Final recipe has an etch rate of ~0.8 nm/s
- Etching recipe has good selectivity, so we will be able to etch the 400 nm we need for our devices with resist to spare
- Will apply this etch to our thin film LN waveguides
- Would like to find better ways to keep the etch bias voltage (and thus etch rate) more consistent and dependable

Acknowledgements

- Cheng Wang
- Mian Zhang
- Amirhassan Shams-Ansari
- Marko Lončar
- Kathryn Hollar
- Sara Wenzel
- Harvard University CNS
- National Nanotechnology Coordinated Infrastructure (NNCI)
- National Science Foundation (NSF)