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Sandia National Laboratories

# Development of NbTiN films for superconducting microwave resonators

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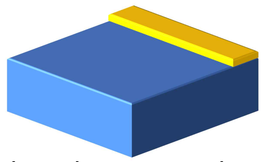
## Motivation

NbTiN thin films find applications in quantum information science and quantum materials.

Qubit-photon coupling

High kinetic inductance

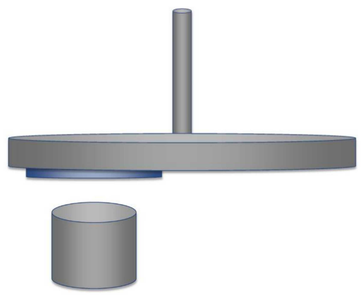


Induced superconductivity

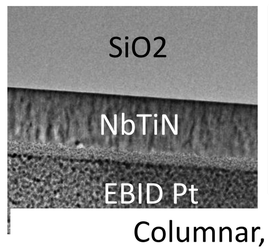
Our goals are to establish processes for fabricating high quality factor microwave resonators using NbTiN thin films and correlate the resonator performance with material properties.

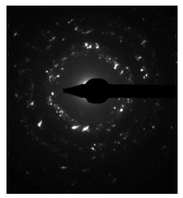
## NbTiN Sputtering

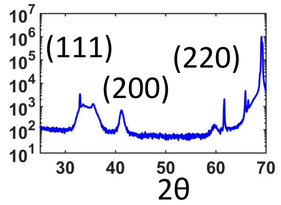
- DC magnetron sputtering
- 3” NbTi target
- Ar + $N_2$
- Substrate-target spacing ~ 1”
- No substrate heating
- Variables:
  - $N_2$/Ar ratio
  - Deposition pressure
  - Deposition time (thickness)



## Materials characterizations

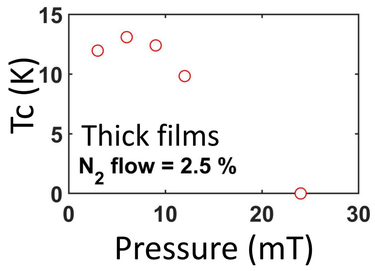


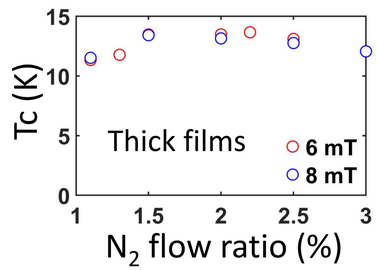





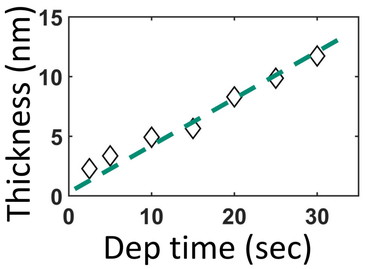

Columnar, polycrystalline FCC NbTiN

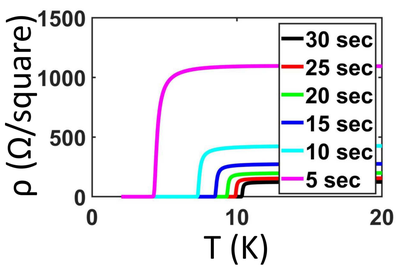
## Optimization of deposition

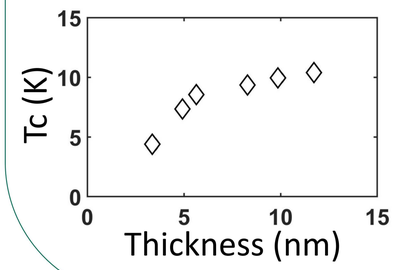


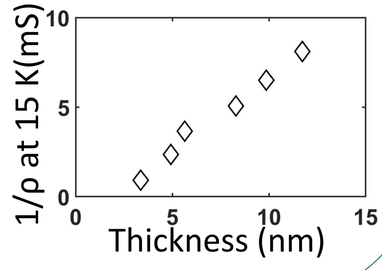




## Ultra thin NbTiN films



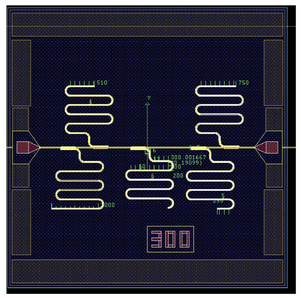



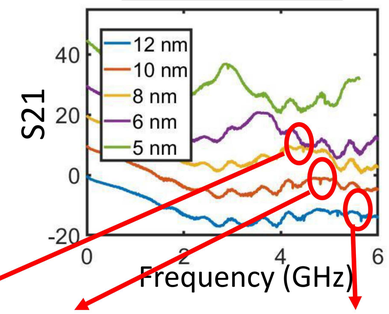




## Microwave resonators

- Five transmission line resonators
- S21 Measured at 4 Kelvin up to 6 GHz



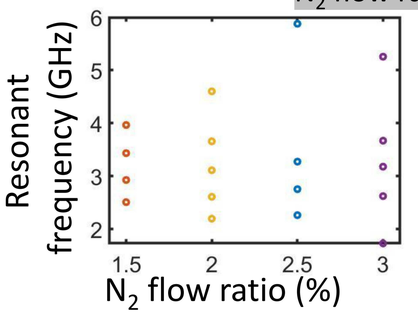
### Thickness effects

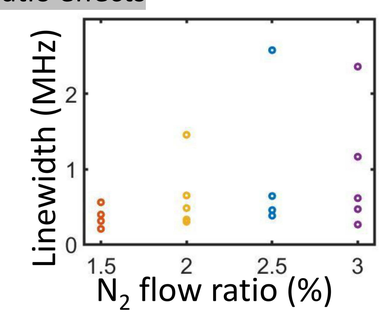






### $N_2$ flow ratio effects




## Summary

- DC magnetron sputtering processes for ultra thin NbTiN films have been developed and optimized.
- The Resonant frequencies and linewidths of NbTiN transmission line resonators are correlated with thin film properties.

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