Summary SRF project at Argonne National Laboratory (started 11/09)

Investigators:

Th. Proslier*, J. Klug, N. Becker, M. Kharitonov, H. Claus, J.Norem,* ***M. Pellin.*** *ANL*

J. Zasadzinski *IIT*

A.Gurevich, N. Groll, I. Chiorescu *FSU*

Collaborators:

G. Ciovati, P. Kneisel *JLAB*

A.Romanenko, L. Cooley, *Fermilab*

C. Antoine *CEA*

T. Tajima *LNAL*

We are expanding.

- New hires:

-Staff: Thomas Proslier
-postdocs: Jeffrey Klug for the ALD & In November N. Groll for Point contact
-Nick Becker, S. Suram Ph.D. for the ALD and transport respectively

- New collaborations

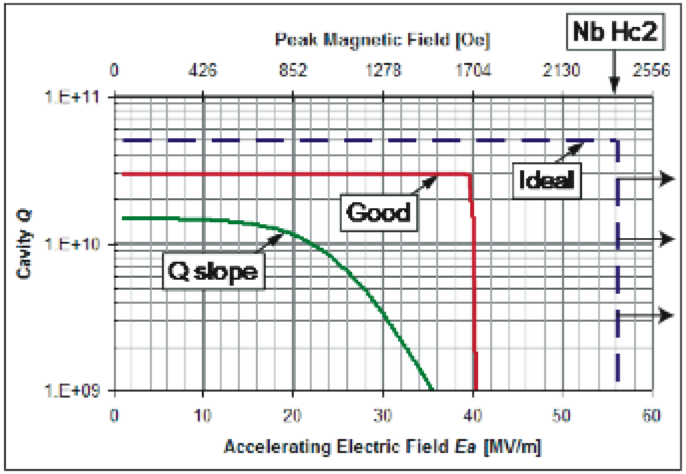
-Theory: Maxim Kharitonov at ANL (surface impedance with magnetic impurities)
-Experiment: N. Groll and I. Chiorescu at FSU
G. Ciovati at Jlab (Hot spot-magnetism)
T. Baturina & V. Vinokur
J. Zasadzinski & students
A.Gurevich (FSU)

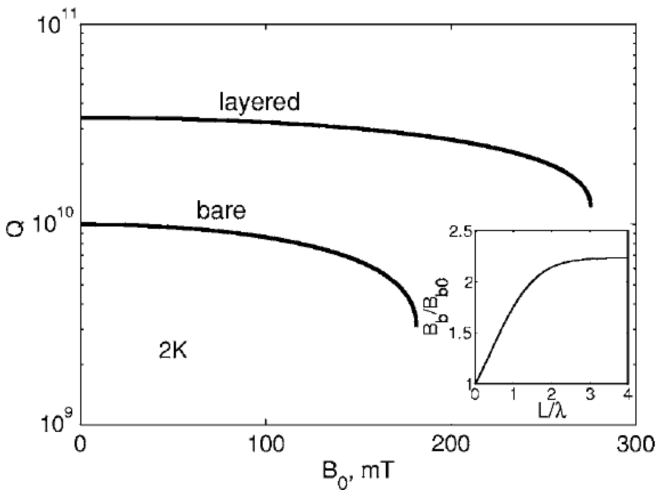
- New major facility

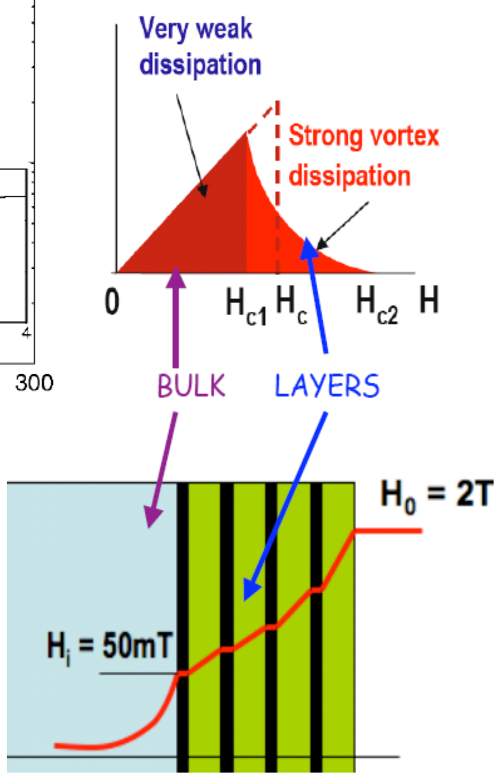
-Plasma ALD system ordered, should be coming in < 15 days

Program & Goals

1. Improve the average SRF cavity performance by understanding and improving the performance of current Nb cavities.







2. Build new cavity layered structures that allow transformationally higher gradients.

   - With a technique that can allow cavities to be fabricated.

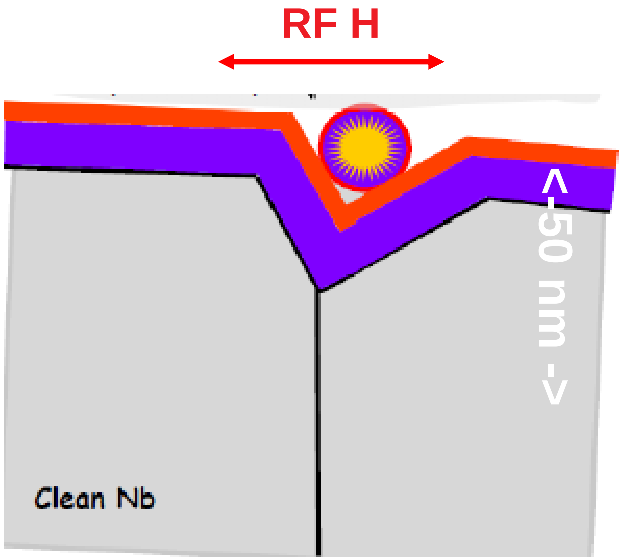
HEP challenges and ANL SRF program

<u>Cavity gradient, Quality factor and production cost are crucial for future of HEP</u>

- SRF program: Look for paradigm changing solution
  higher performances (accelerating gradient E_{max})
  Beyond Niobium material limits

- Goals: New materials and structures to increase performances
  Understand dissipation -> higher Q
  Multilayer structure: higher E_{max} and Q

- Where are we:
  Magnetic impurities dissipation & how to solve it
  Growth of superconductors by ALD + multilayer.

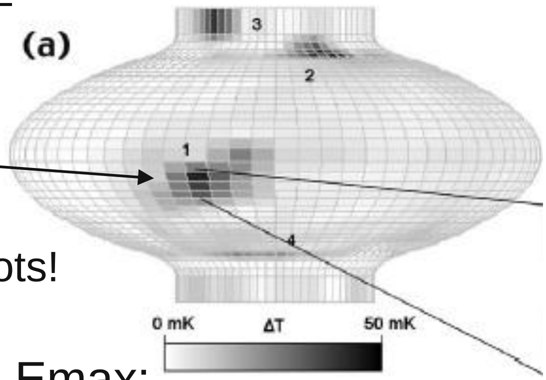


Magnetic Impurities Explain Losses (low Q, Q slope etc.)

- Existence of magnetic impurities at the surface of Niobium has been confirmed.
  - Point Contact Tunneling (PCT) – initial measurements
  - Electron paramagnetic resonance (EPR),
  - Superconducting Quantum Interference Devices (SQUID)

- Magnetic impurities explain the residual surface resistance.
  - The only model that can do it

- We can correlate magnetic impurities with “hot spots”
  - Experimental collaboration with Jlab (J. Ciovati)
  - thicker oxide (EPR) and more mag. Impurities at hot spots!

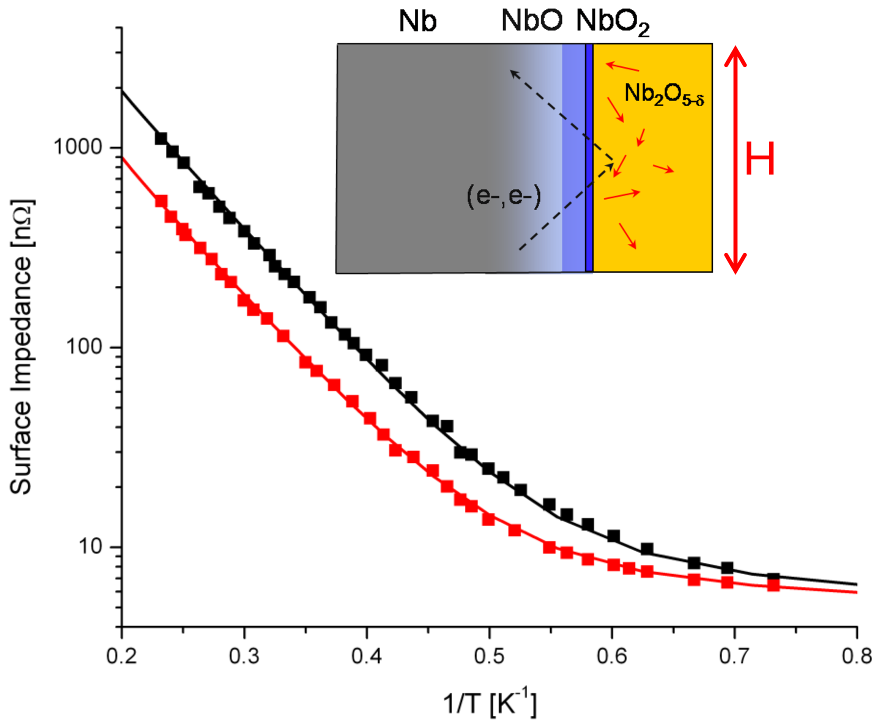


- Solid evidence that magnetic impurities cause lower Q and Emax:
  - Increase Q and Emax by getting rid of the oxides => cleaner surface
  - Nb coupons improved after ALD coating and post annealing in UHV

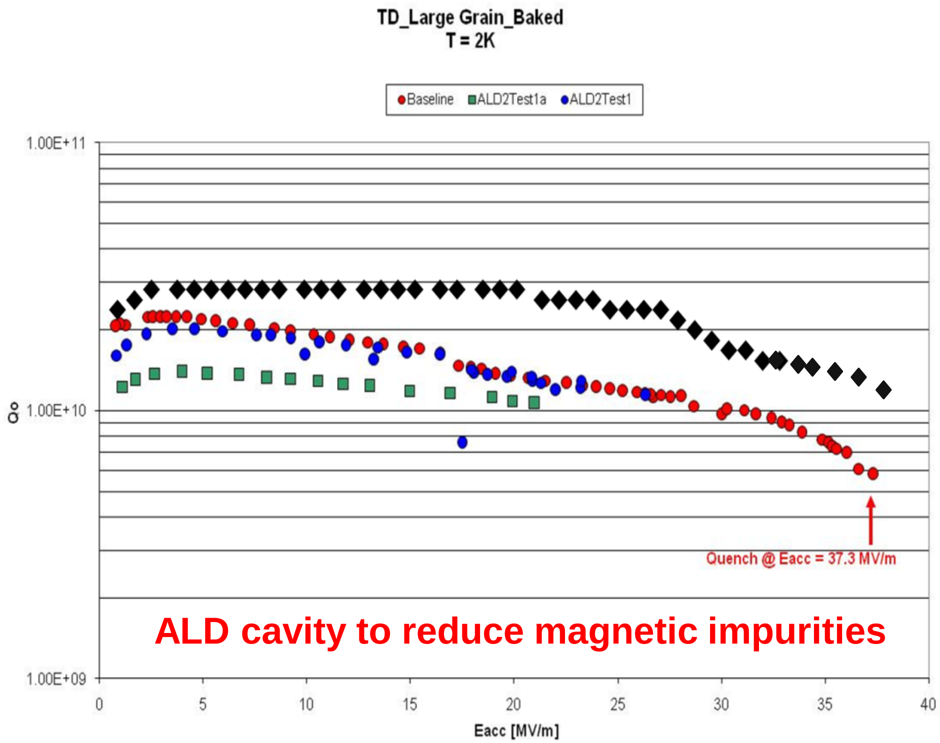
- **Cavity tests:**
  - Cavities tests show always a higher Q (x2) after coating/annealing
  - Optimized Interface Nb/protective layer and successful layer test on cavity.

Theory: we can now explain the residual resistance

Model assumes: Homogeneous moment density on λ + London limit + dirty limit
3 parameters:
η, α : describe effect of magnetic impurities on the superconductor -> concentration
normal conductivity σ_0 -> mean free path, ℓ.



Bake 120C

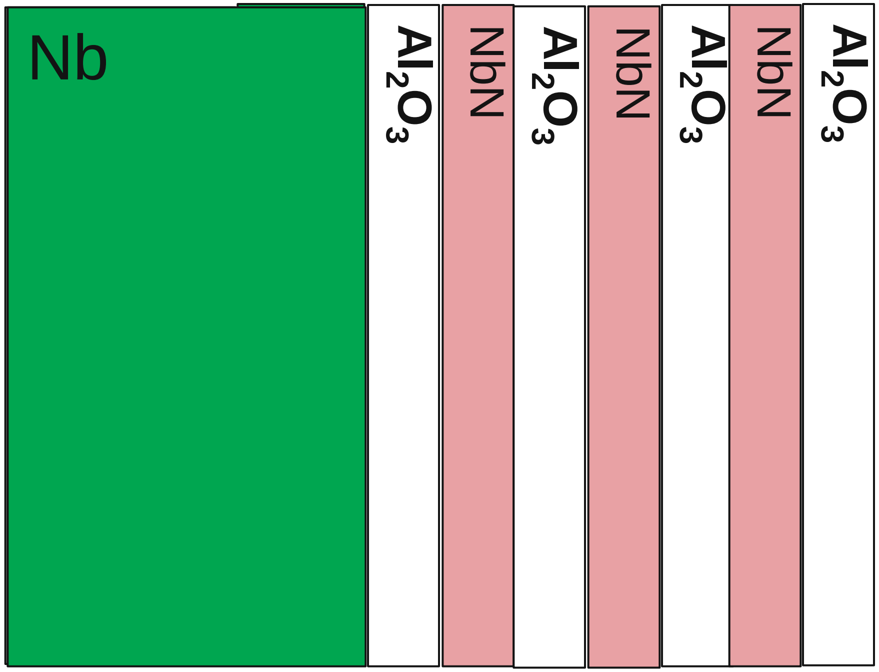


Higher Q reproducible

Th. Proslier, M. Kharitonov submitted to PRL (2010)

We have set the basis for build new cavity layered structures that allow transformationally higher gradients

- Layered structures raise the critical magnetic field at which vortex losses form.
- ALD allows fabrication of such structures with atomic scale precision without regard to aspect ratio of the object.
- We need to develop ALD synthetic chemistries for superconducting material growth (expect plasma ALD to help)



Accomplishing this goal would also allow using the narrow current flow region to advantage. Layered structures with Al cavities for instance.

We are producing Superconductors with higher Tc than Nb by ALD

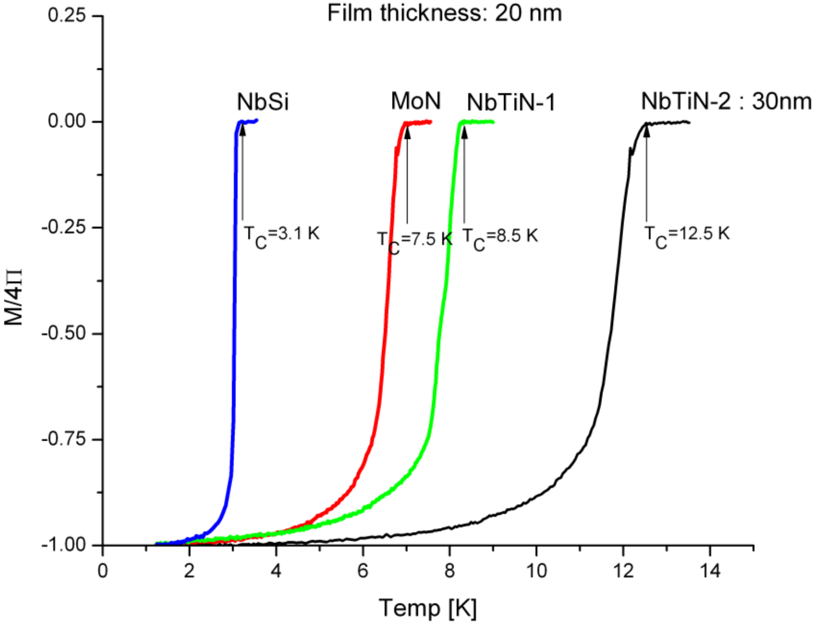
- We can now synthesize better Superconductors than Niobium using ALD:
  - NbN with new ALD chemistry is very pure.
  - NbTiN Tc=8.5 K for 20 nm thick film (Nb=7K for equiv. thickness)
  - We have modified the reactor (all welded, load lock, gas filters) to reach higher temperature and higher purity.

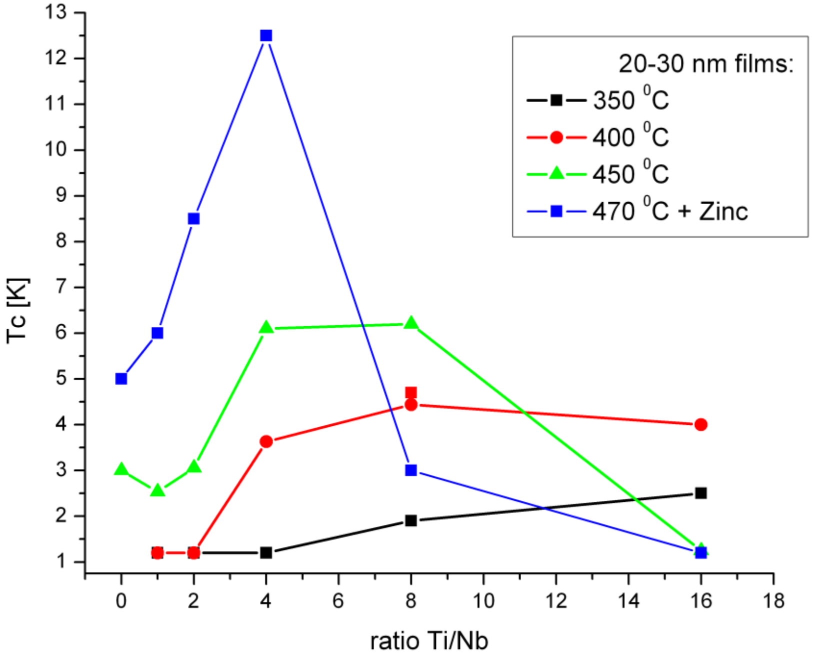
- New materials for other superconductors candidates: Lower cost & better performance
  - Understanding ALD chemistry for Nb compounds such as silicides, borides, germides and carbides. We made NbSi (3.5K), NbC, NbNC, MoN (7.5 K) for very thin film by ALD
  - Next compound to grow are: **Iron pnictides (FeSeTe..) and MgB_2.**
  - Aluminum cavity (Niowave): cheap & industrial process known down to chem polishing.

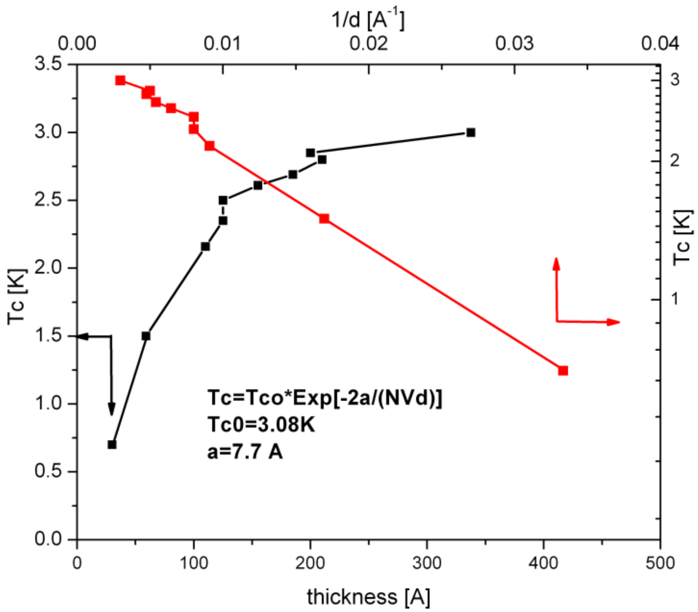
- We are developing technology to measure thin superconducting films made by ALD:
  - In-depth characterization at Argonne: chemical, structural, superconducting.
  - Low temperature ALD films can be use for other application:
    control Tc of NbSi by thickness -> bolometers
  - With Spain and Russia: Ultra low temperature transport measurement

- **Multilayer structure MgB2/Insulators with LNAL:**
  - Various oxides: Alumina-Yttria-MgO to optimize the performance. (Yttria is the best)
  - Oxide free insulators: AlN!

ALD survey results:







- Superconducting properties homogeneous > 50 cm
- Tune Tc with the film thickness & chemical composition
- New compounds: MgB_2 and Pnictides
- New precursors and chemistry.

Future possibilities :

- Far beyond Niobium based cavity performances

- Operating temperature at 4.2K:
  ALD growth study of Pnictides and MgB_2.

- Cheaper material & process:
  Aluminum cavity all coating steps in-situ, no need for post-surface treatment.
  Thin films instead of bulks.