The EII Cavities program at CERN: Atomic layer deposition

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FCC Week 2022

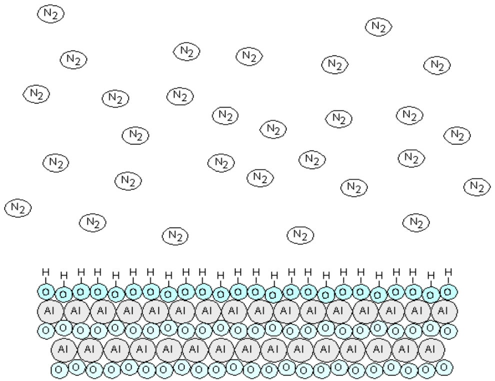
31th of May 2022

Contents

Atomic Layer Deposition

$$Al_2O_3 = TMA(Al(CH3)_3) + H_2O$$

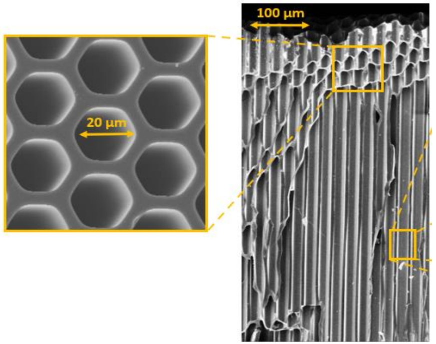
Thin films (≤ 1 µm) synthesis technique based on **self-limiting** surface chemical reactions. Sequential injection of **vapor phase** precursors . Layer by layer growth. Cycles.



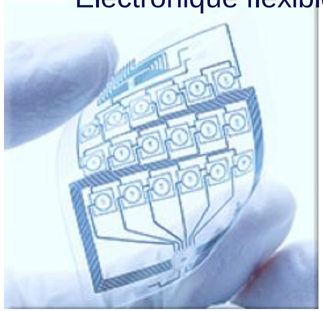
- *Advantages*:
  - Thickness and composition control down to the atomic level.
  - Pin-hole free films.
  - Excellent conformality on complex-shaped and large area substrates.
  - Large palette of materials.
  - Low temperatures (RT-450°C)

- *Limits*:
  - Slow deposition (0.3 to 10 Å/min).
  - New materials require new chemistry.

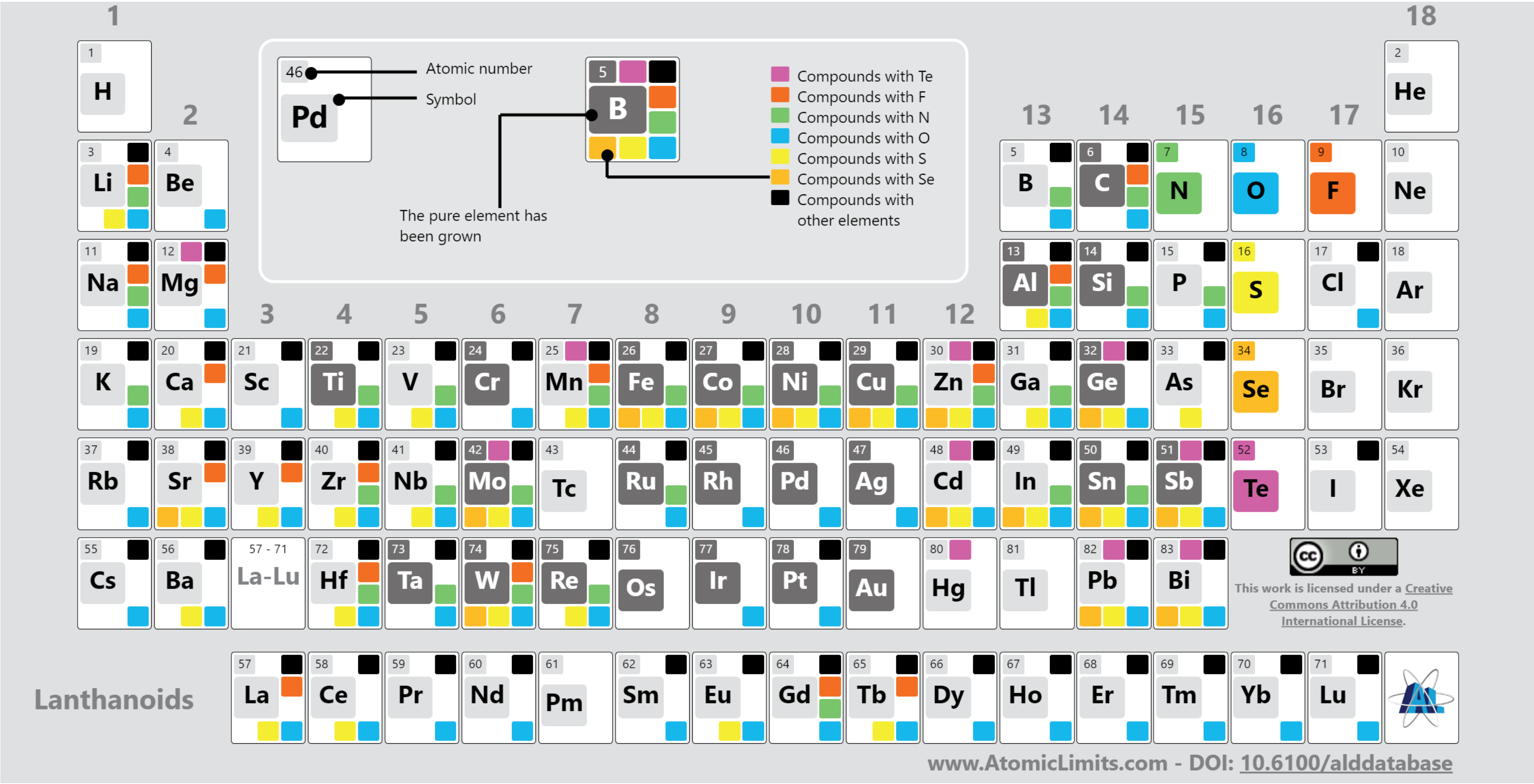
- *Applications*:
  - Micro-electronic, Photovoltaic, Catalysis, Batteries, Detectors…



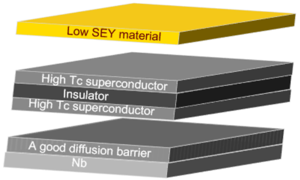
Electronique flexible

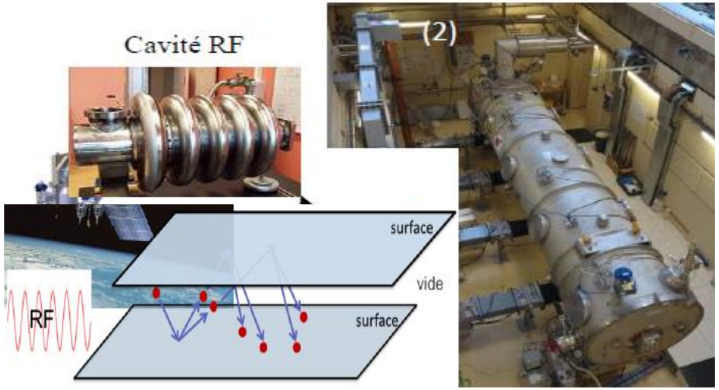


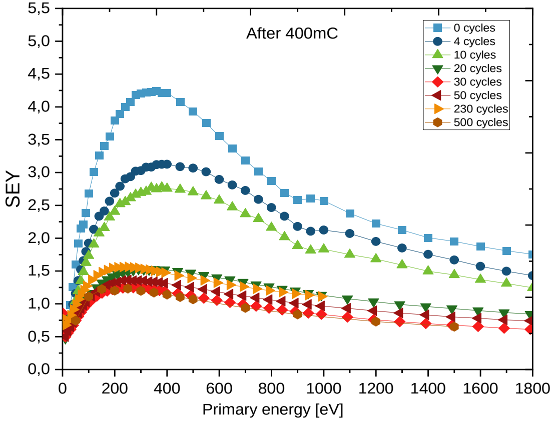
Atomic Layer Deposition – Materials

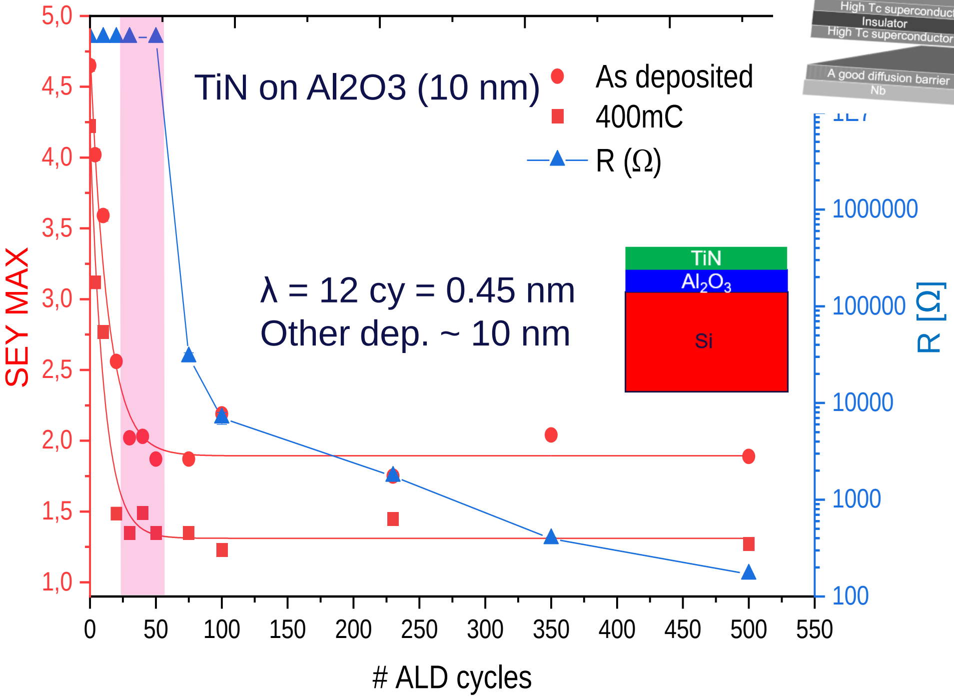


Secondary electron yield – Mitigate Multipacting





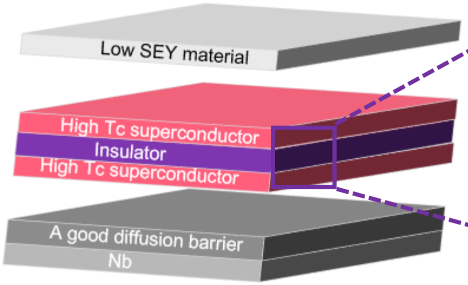




- ➢ Control thickness and chemical composition – uniformity
- ➢ Tune SEY and electrical conductivity
- ➢ Wide variety of substrates (Nb, Cu…)

CEA-ONERA

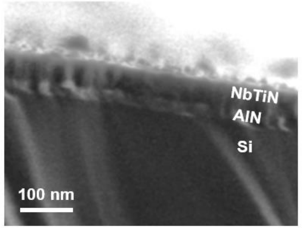
Multilayers – increase SRF cavities performances (Q and E_{max})



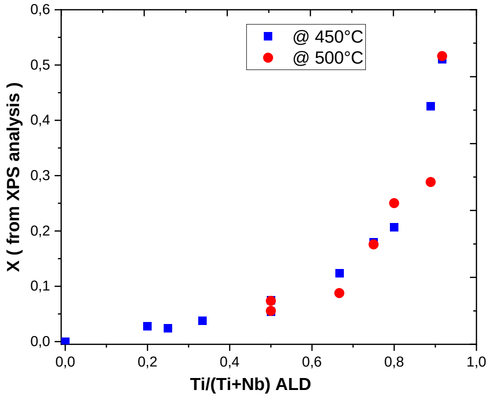
Superconducting alloys – NbTiN/AlN

- Motivation: NbTiN has good superconducting performance (T_c = 17 K)
- AlN as an insulating layer.
- Chemistry: Combination of *TiN and NbN cycles:*

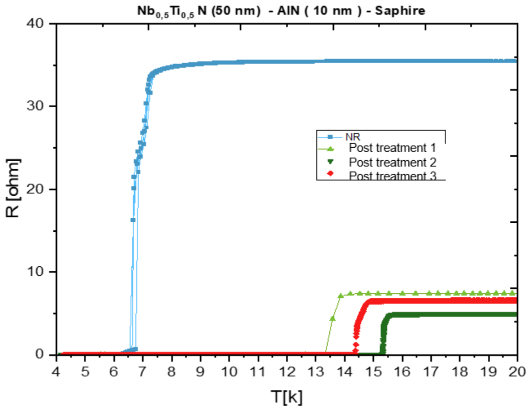
$$n\ (TiCl_4 + NH_3) + m\ (NbCl_5 + NH_3) = Nb_{1-x}Ti_xN$$



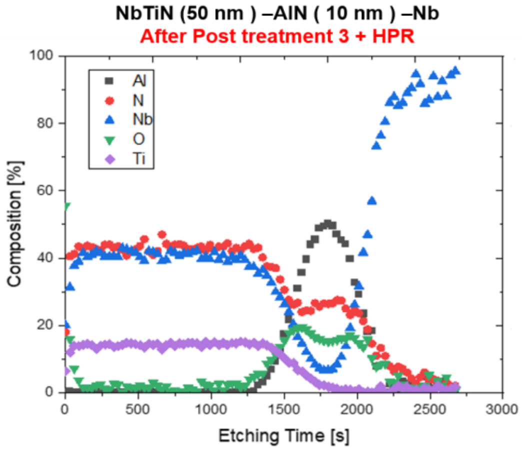
- ***Tune chemical composition***



- ***Good superconducting properties***

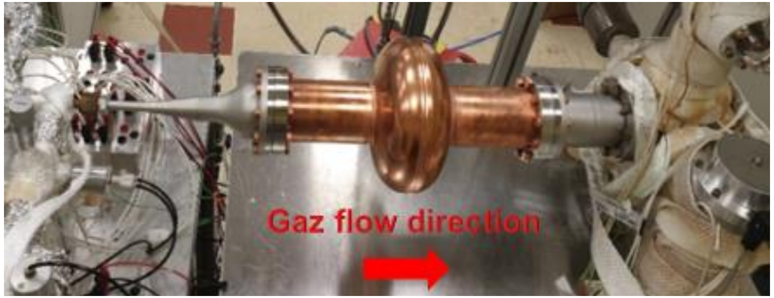


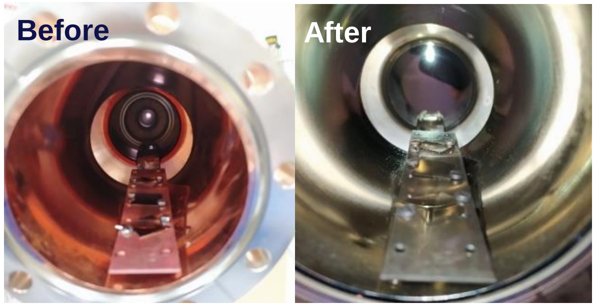
- ***Compatible with SRF cavities treatments***



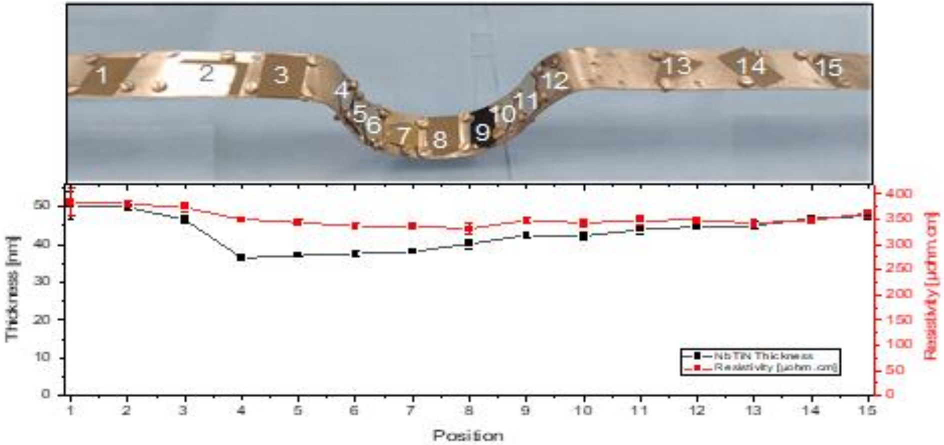
- All conditions are met to apply/test this theory on ***SRF cavities***.

From coupons to Cavities…

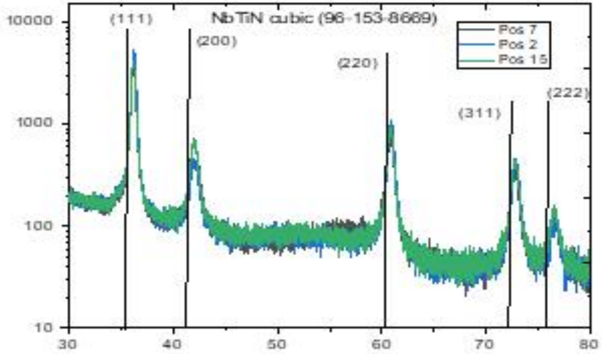




Test 2 : purge 20s



GIXRD diffraction patterns on different samples



- ➢ Optimized deposition parameters on RF cavities.
- ➢ Homogeneous deposition (thickness, Tc and structure) over 1,3 GHz Nb and Cu test cavity.

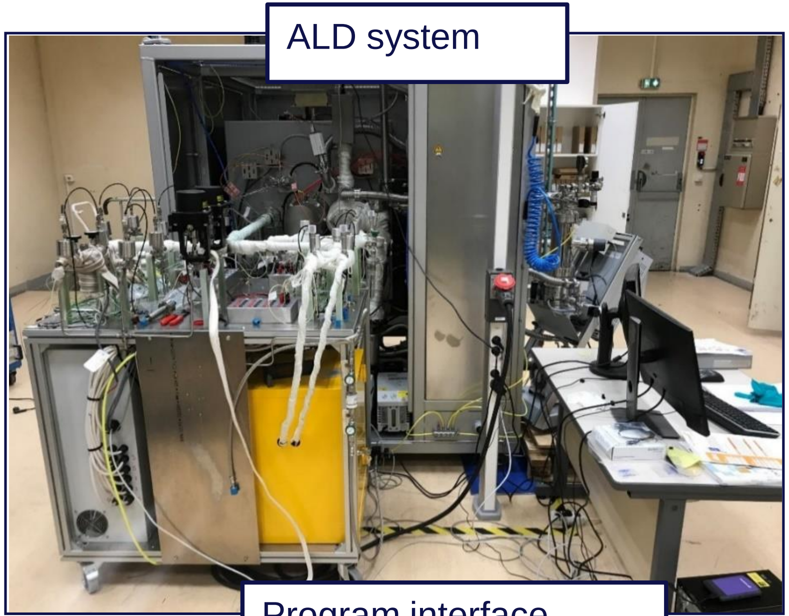
Cavity dedicated ALD apparatus

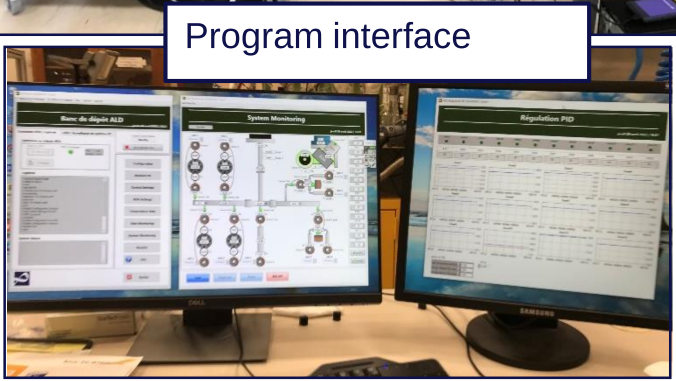
- <u>High vacuum oven</u>:
  - 650°C – 10^{-6} mbar / 900°C 1bar N_2
  - Volume retort: Φ = 49 cm, L= 110 cm (Cavities sizes > 0.6 GHz)

- <u>ALD system</u>:
  - 9 precursor lines (2 gases, 2 liquids, 4 solids, 1 Ultra high temp.).
  - RGA synthesis monitoring.

- <u>Interface and control:</u>
  - Labview program of ALD system and Oven.
  - Automatic synthesis parameter control and monitoring.

- <u>Status:</u>
  - Deposition tests on samples
  - Future: Deposition on cavities





Conclusion-Perspectives:

- ✓ SEY: ALD of TiN film is promising to reduce multipacting inside RF cavities.
- ✓ Growth of NbTiN and the multilayers AlN/NbTiN by ALD with good superconducting properties, homogeneous composition and thickness control over large surface areas (RF cavities).
- ✓ Control doping and surface engineering -> no post treatment chemistry.

Future Goals :

- ➢ SEY: Test the Al_2O_3-TiN structure on Niobium RF cavities.
- ➢ Multilayer: Test the NbTiN-AlN structure on Niobium RF cavities.
- ➢ Doping: Test ALD doping procedure on SRF cavityies
- ➢ New directions:
  - ALD on Copper complementary to HIPIMS: insulating barrier - Nucleation and thermo-currents.
  - ALD for detectors/optics.

FCC

Thank you for your attention

Questions ?

Acknowledgements

<u>Yasmine Kalboussi</u>[1], Baptiste Delatte[1], Claire Antoine[1], David Longuevergne[2], Diana Dragoe[3], Jocelyne Leroy[4], Sandrine Tusseau-Nenez[5], Aurélie Gentils[2], Stéphanie Jublot Leclerc[2], Fréderic Miserque[6], Mohamed Belhaj[7], Junling Zheng[8], David Hrabovsky[9], G. Rosaz[10], Thomas Proslier[1].

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