Science & Technology Facilities Council

Development of thin films for superconducting RF cavities in ASTeC

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on behalf of collaboration team

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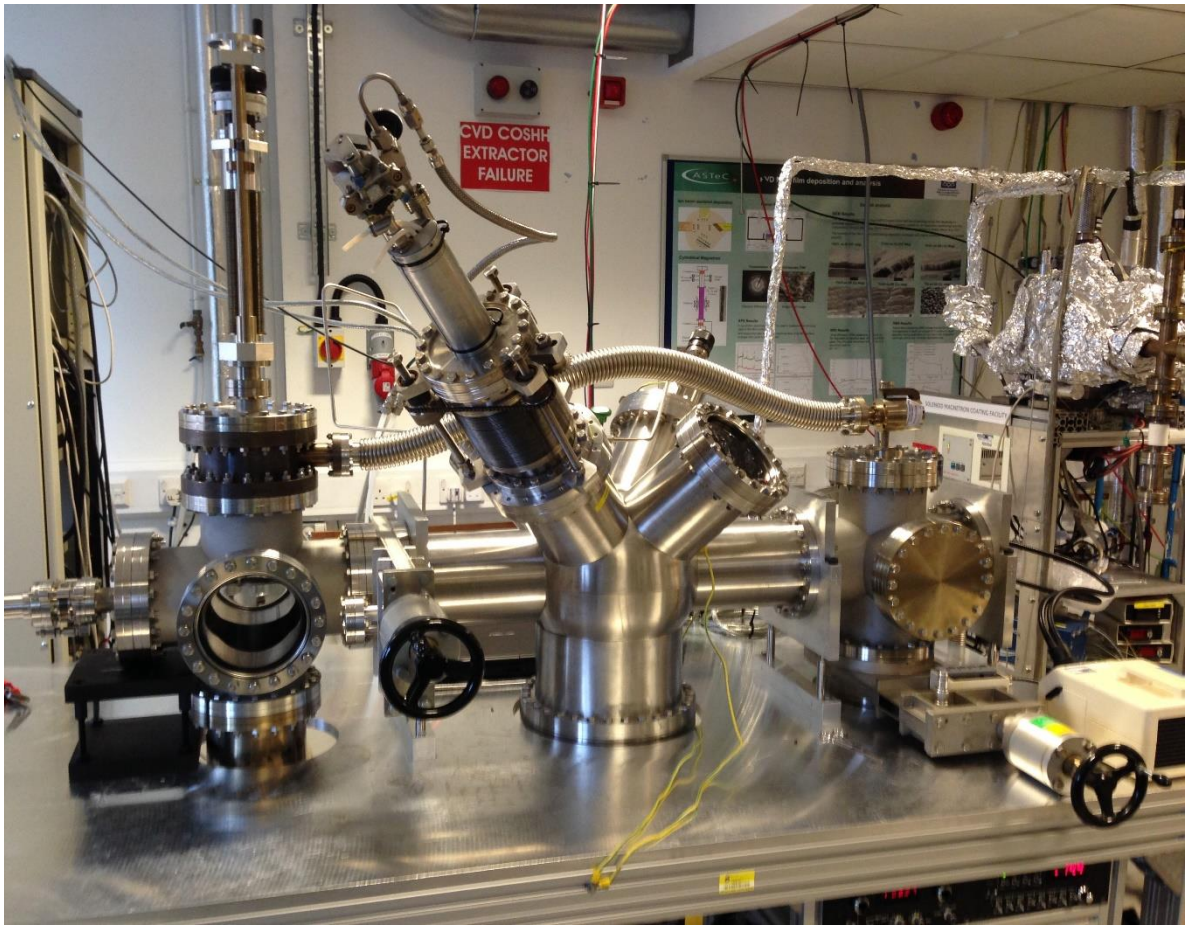
Motivation

- The aim is to develop the PVD and CVD coating technologies of superconducting materials for RF cavities and apply it on the RF cavities
- Objectives:
  - a systematic study of
    - Deposition parameters
    - Film morphology, structure, chemistry
    - AC and DC superconductivity characteristics such as T_c, B_c, RRR, etc.
    - RF evaluation of samples
    - Cavity deposition and test

UHV PVD facility

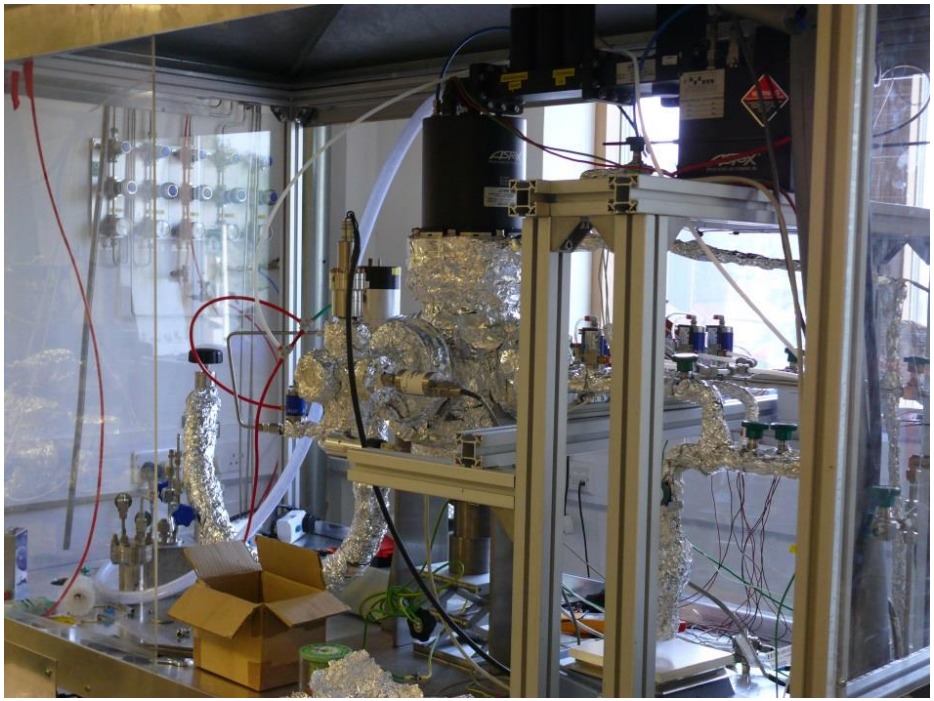
- Bakeable
- Load-lock chamber
- ≤100 mm diam.
- Three planar concentric targets with the variable distance to the substrate: 10-15 cm
- Substrate rotation
- Ion beam assist,
- $20 \leq T_s \leq 950$ ºC
- Differential RGA pumping to analyse the sputter gas.



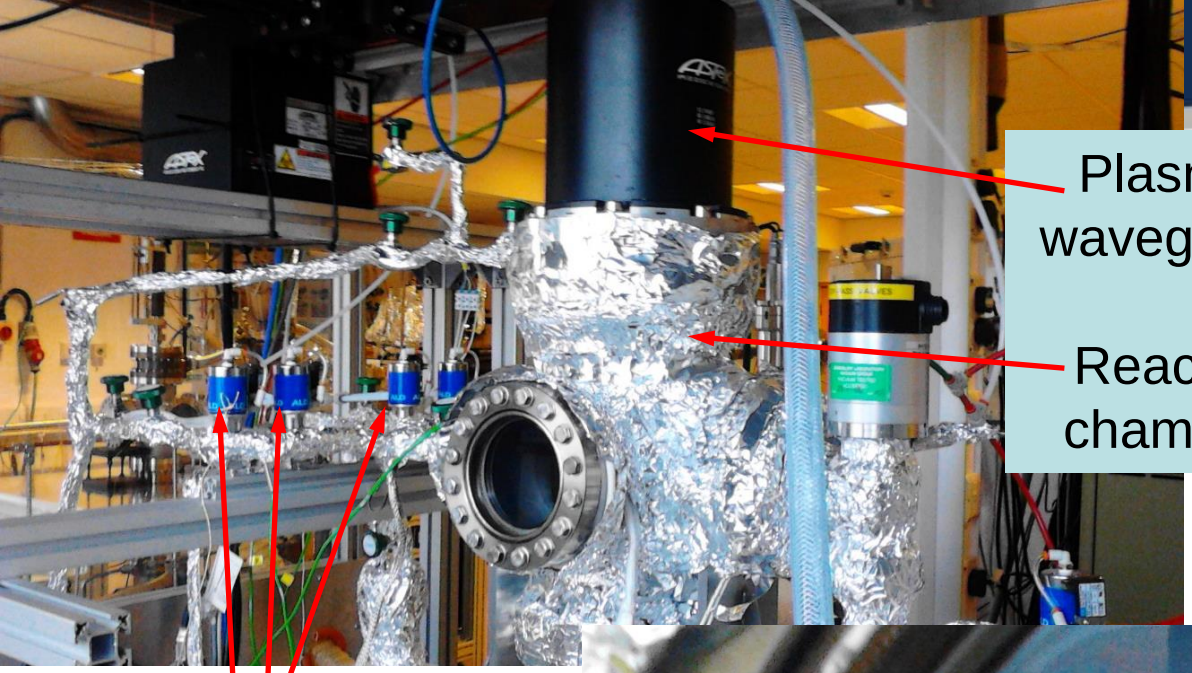
- HiPIMS and Pulsed DC,

PECVD/ALD deposition

- Base pressure:
  - 1.5 x 10^{-5} mbar at 120 ºC
- Gas flows:
  - Argon, Max 5 l/min, 200 sccm MFC
  - Hydrogen, Max 1 l/min, 100 sccm MFC
- Heater tested up to 700 ºC (could go 950 ºC)



ALD rig

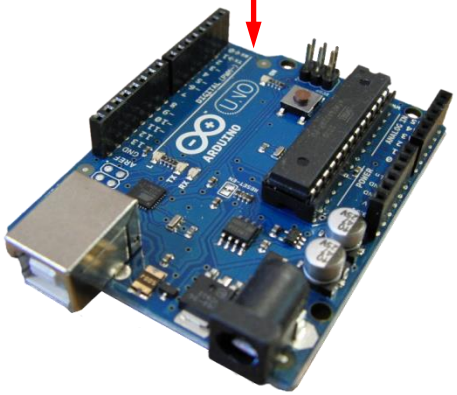


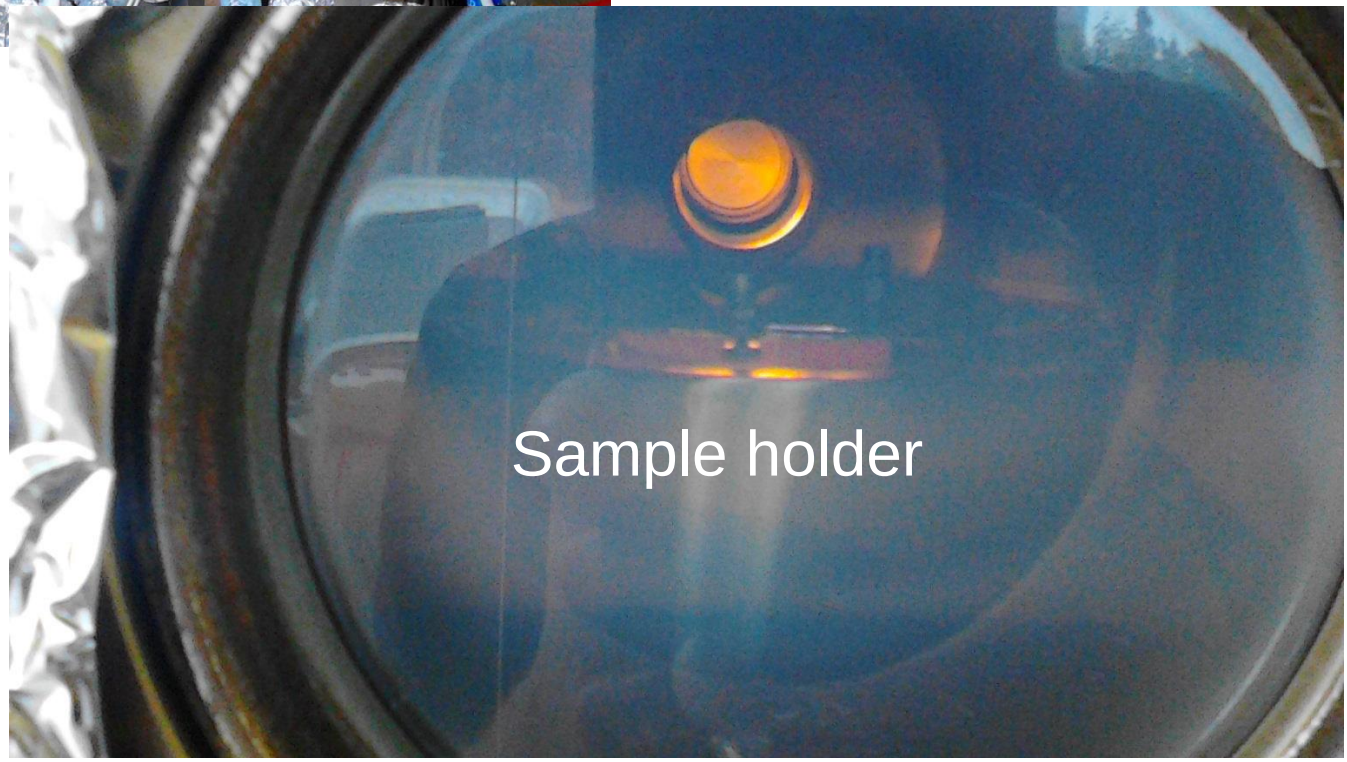
Plasma waveguide

Reactor chamber

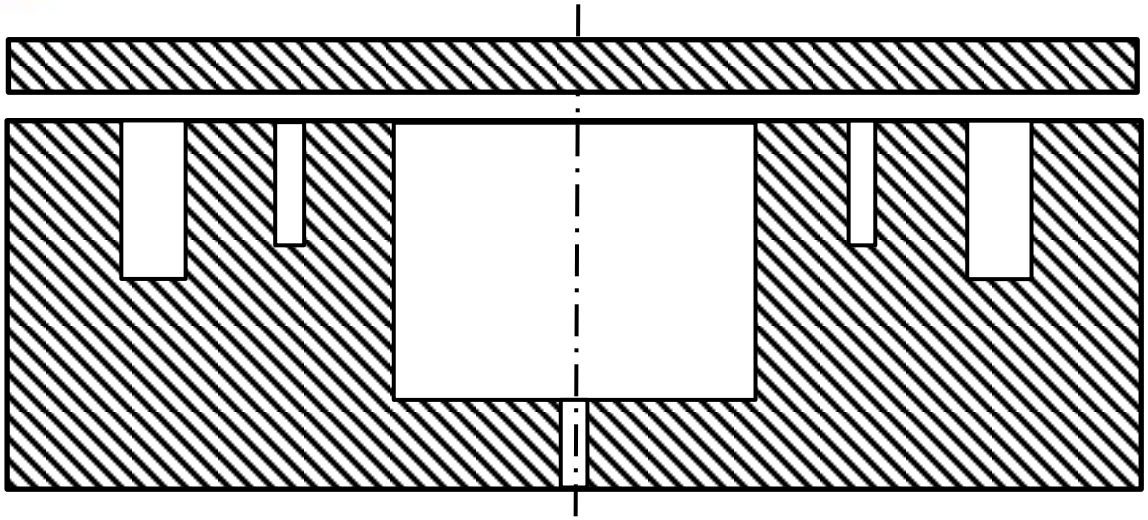
SAES gas purifiers

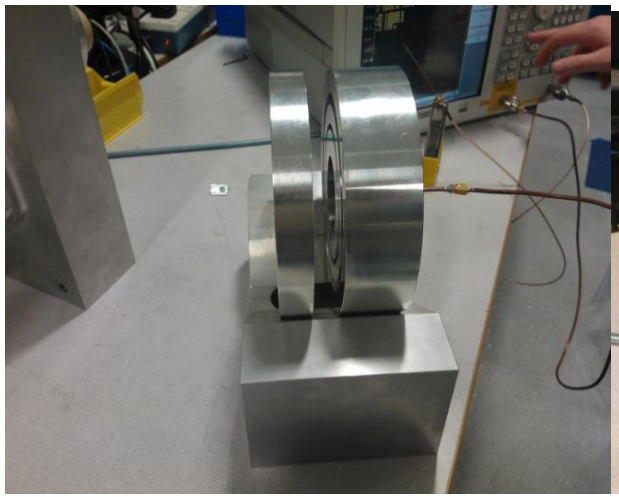
ALD valves: tested with Arduino control, switching <1 ms

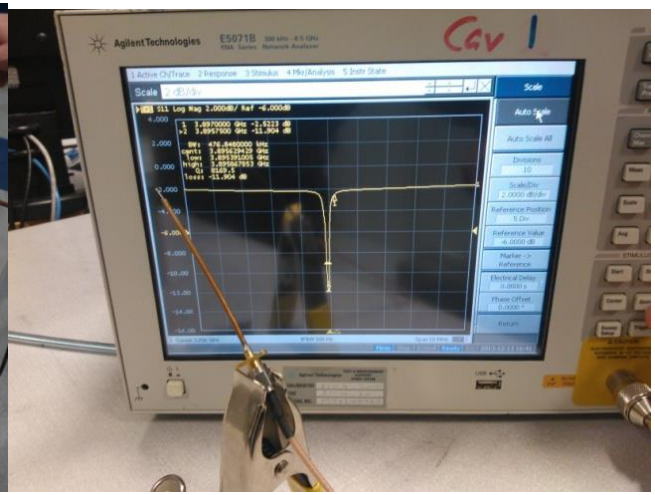




Pill BOX Cavity: Aluminium mock up RF cavity test





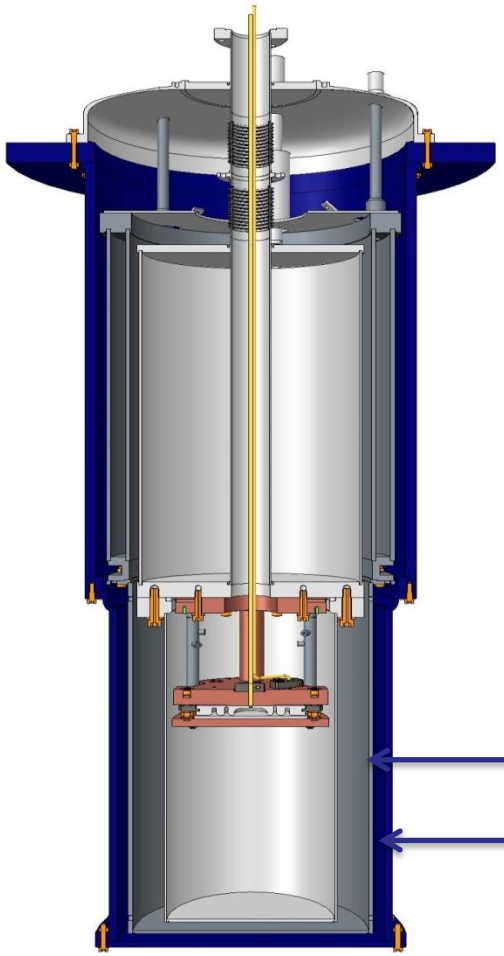


- Mock up 3.9 GHz pill box cavity has been fabricated to validate the simulation results obtained with Microwave Studio.
- An order for a niobium 7.8 GHz cavity is in place.

Samples:

- a 100-mm diam. Nb disk
- a 100-mm diam. copper disk with thin films of Nb deposited on the surface.

LHe CAVITY CRYOSTAT



Outer Vacuum Chamber

Liquid Nitrogen Chamber

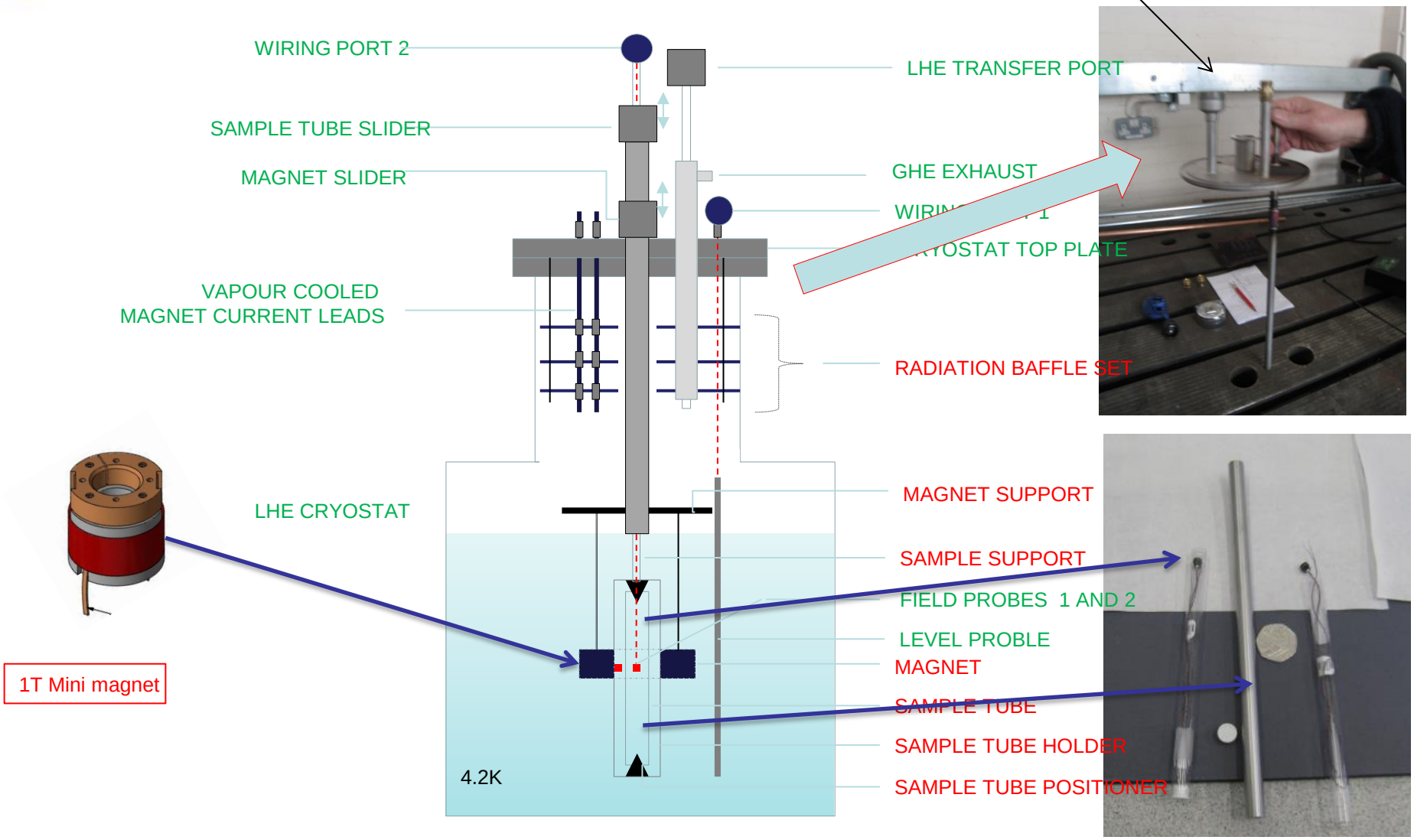
Liquid Helium Chamber

Cradle Assembly

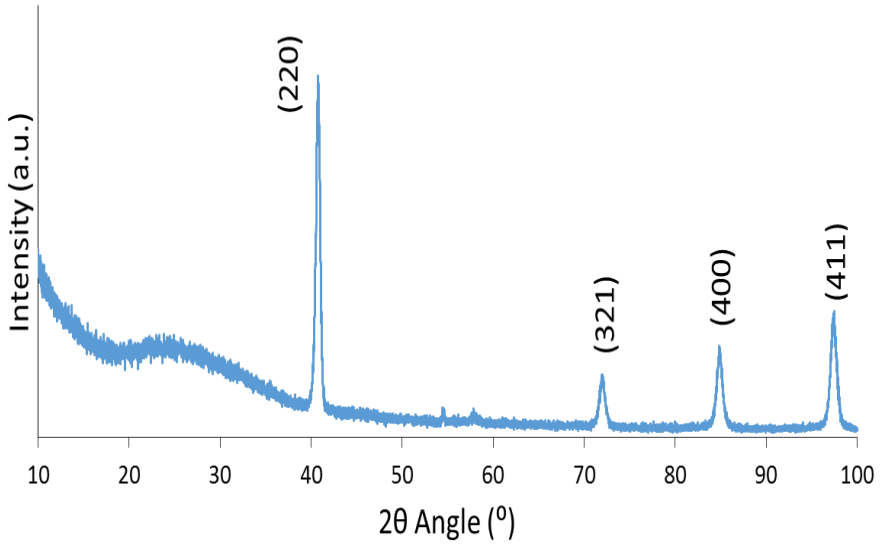
Sample Chamber

Radiation Shield

Magnetic field penetration measurement experiment suggseted by A.Gurevich



Film Morphology: XRD

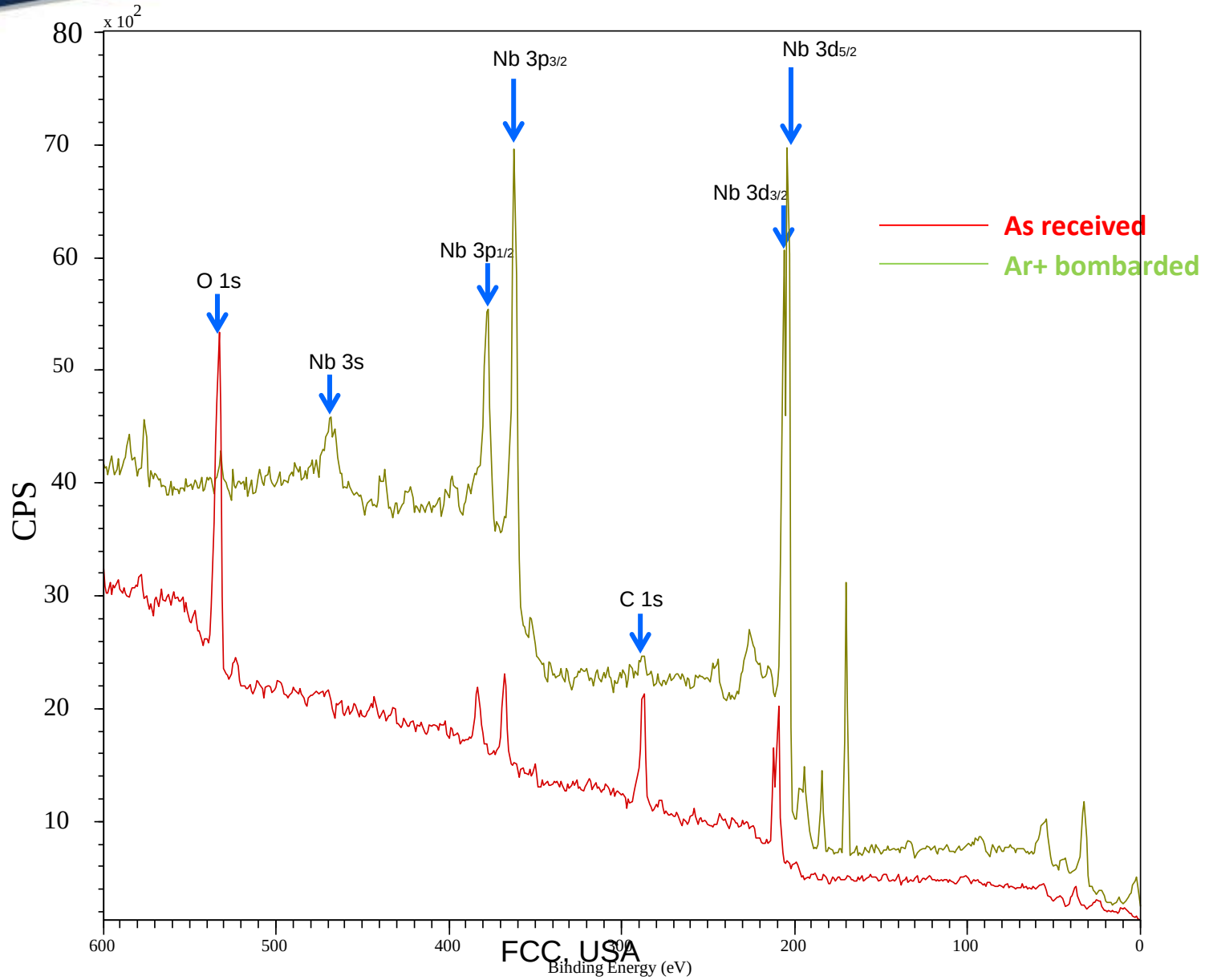


- Nb grain sizes within our films:
  18 -73 nm
- This is similar in size to the grains produced in other studies.
- The films are polycrystalline

and highly textured with the prefered direction of growth depending on the substrate orientation and deposition condition

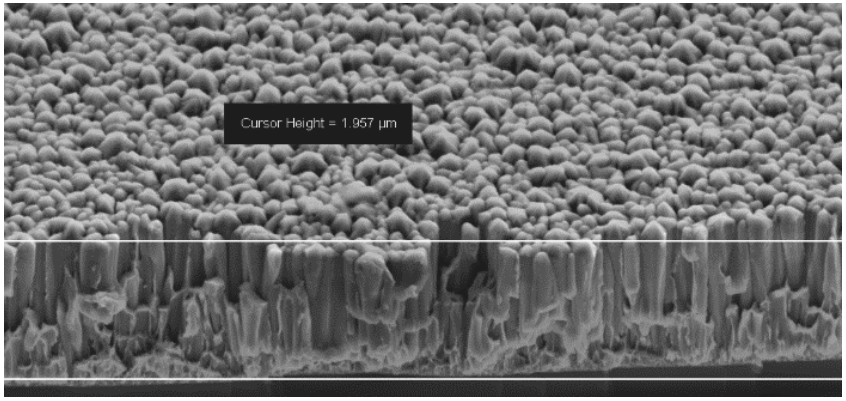
- RRR values shows no dependence to a preferred orientation

XPS analysis

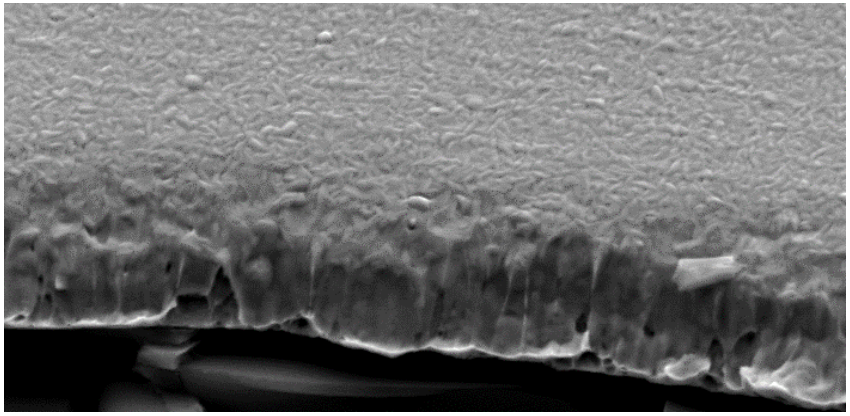


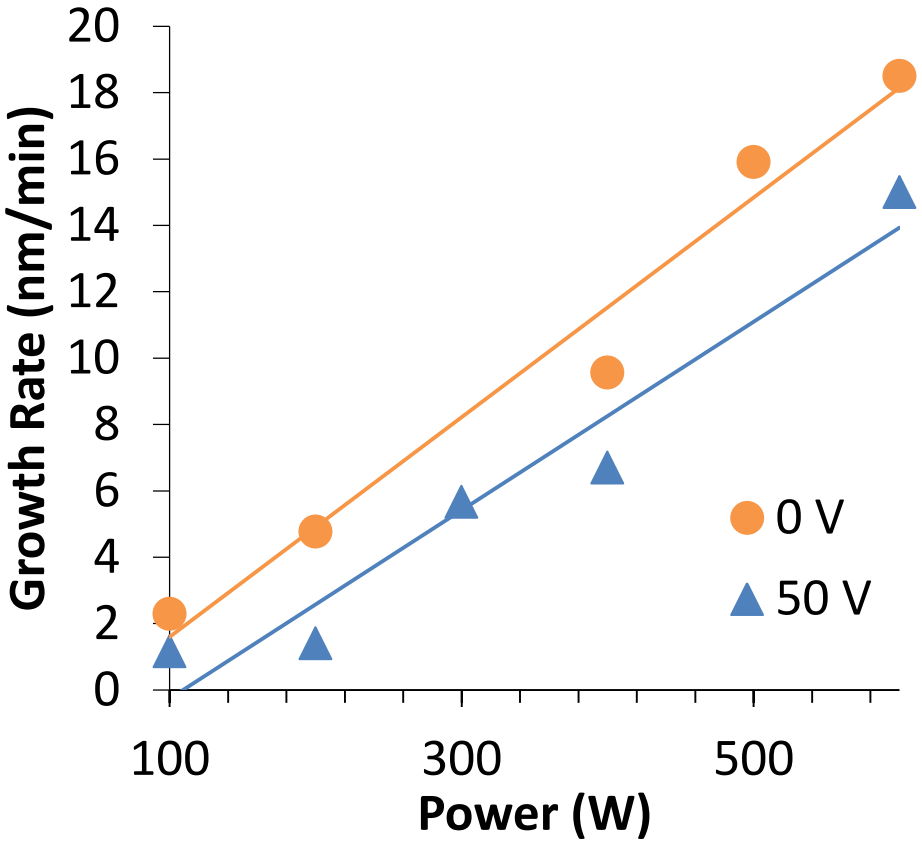
Film Morphology: SEM

samples deposited without a bias

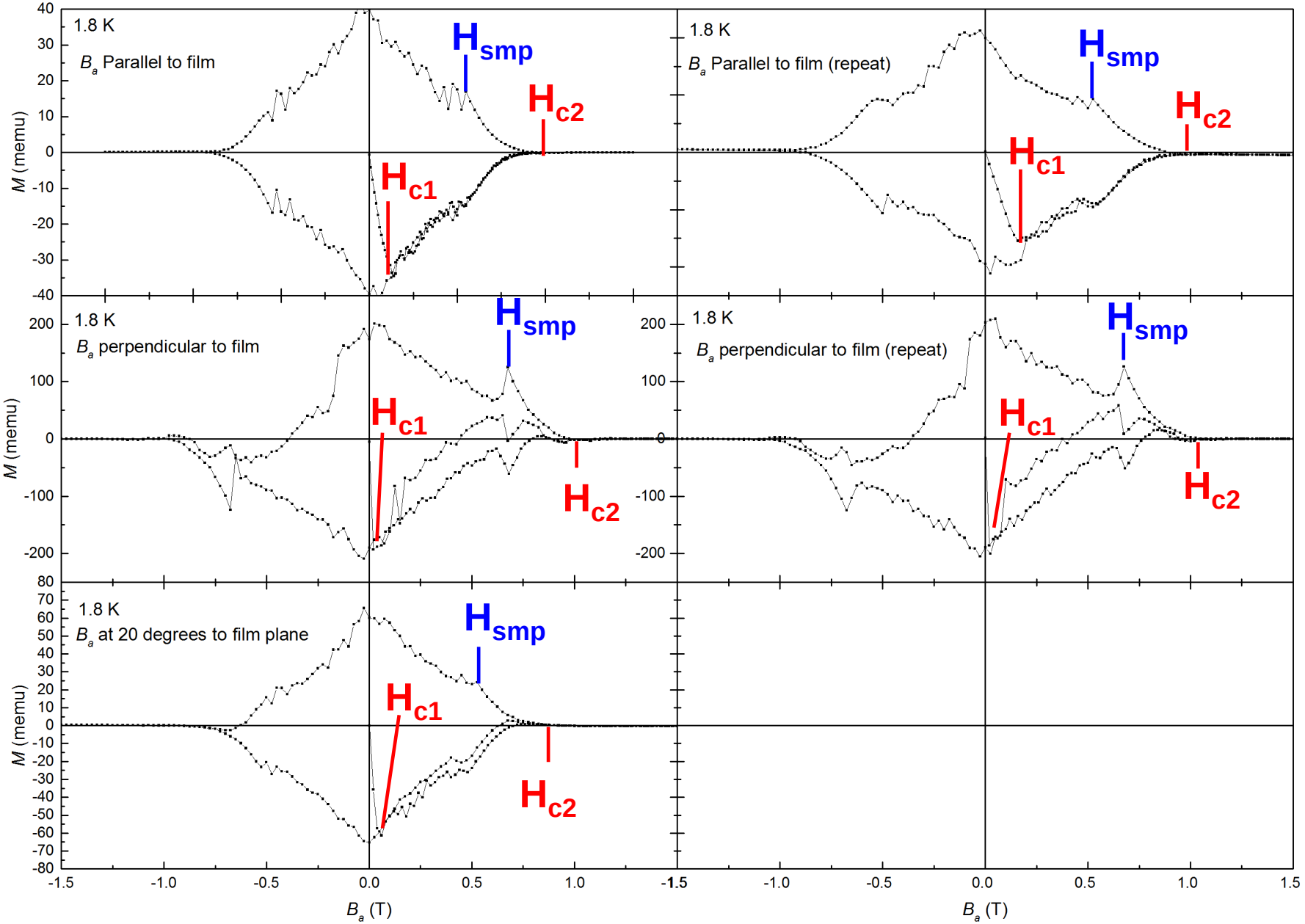


samples deposited with a 50-V bias





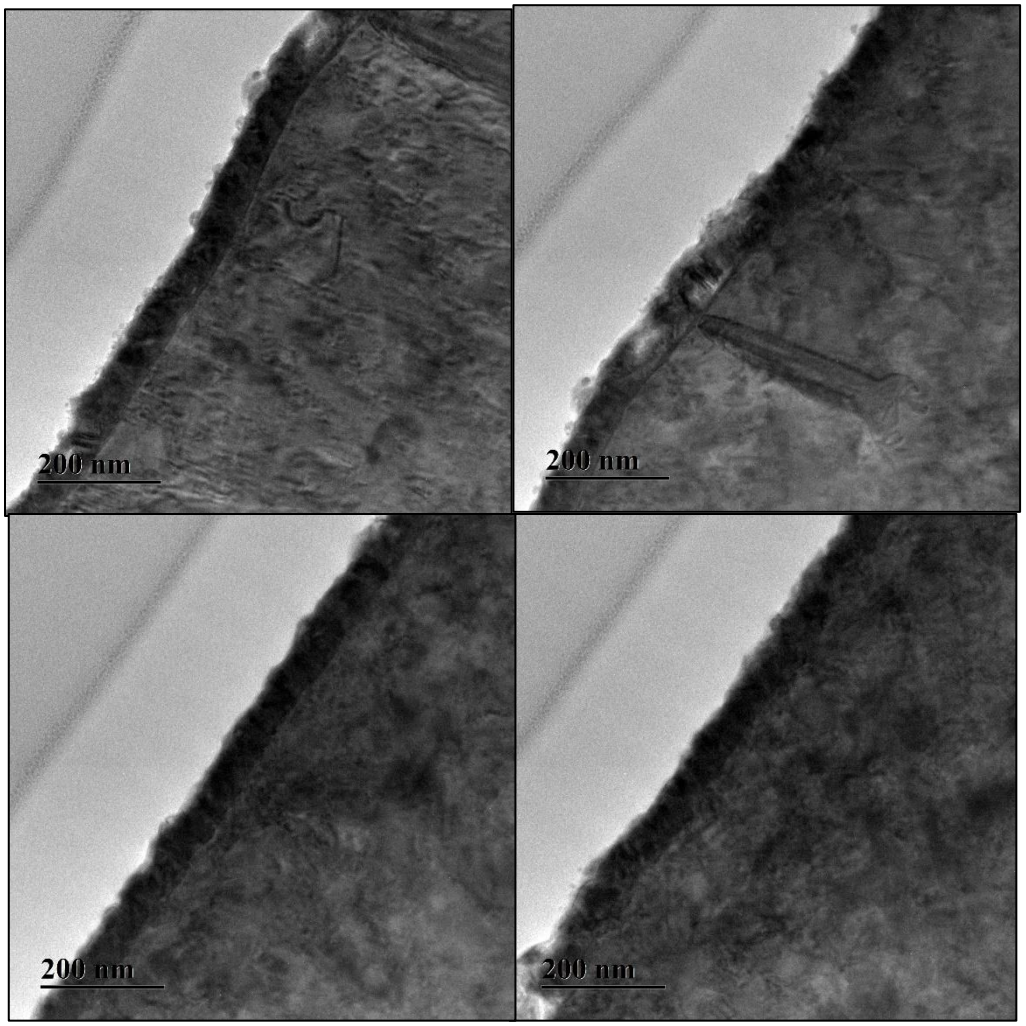
Superconductivity evaluation: DC SQUID



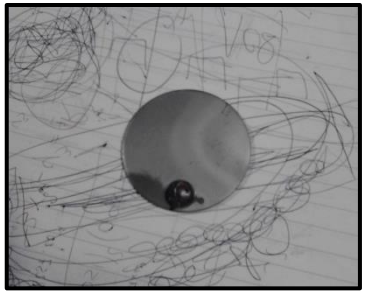
PVD SUMMARY of RESULTS

- Largest grains of 73 nm deposited by HiPIMS on MgO
- Increasing gain size expected to increase Hc1
- Hc1 has ranged from 0.1 to 0.18 T on Cu and Si substrate
- Hc2 for films deposited by HiPIMS has been approx. 0.4 T and lower than for DC sputtered films
- Low Hc2 expected of large grain films and is approaching values expected of bulk Nb (approx. 0.27 T)
- More stable pinning for films deposited onto Cu substrate when compared to Si substrate
- Films deposited onto Si show large flux jumps
- RRR approximately doubles for films deposited onto Cu when compared to Si however no correlation between RRR and Hc2
- Films with higher RRR showed fewer flux jumps

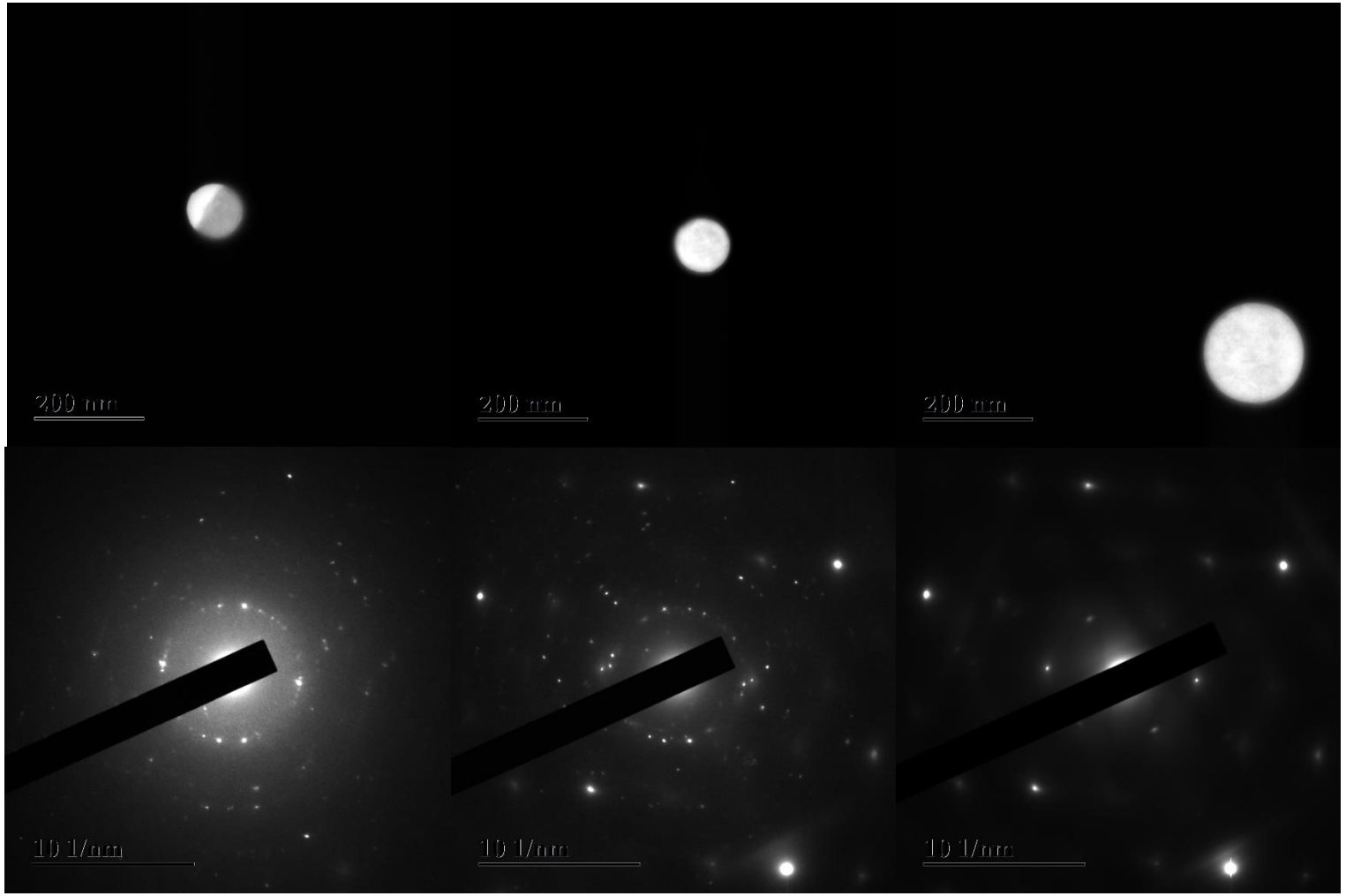
CVD deposition of Nb on Cu



- Nb(v) Cl
- Deposited at 650°C
- Tc = 8K
- RRR = 31



CVD Nb – Electron diffraction



Conclusions

- Quality of the film (morphology, RRR, H_{c2}) depends on
  - deposition parameters such as
    - Substrate temperature,
    - Ion/atom arrival ratio,
    - Substrate bias,
    - Plasma generation at the target
      - DC pulsed or DC
      - HiPIMS
    - Substrate crystallography
    - For CVD/ALD precursor and deposition Temperature

Conclusions (2)

- Sample evaluation
  - RF pill-box cavity is the best, however
    - High Cost of manufacturing and cost of LHe,
    - Time consuming
  - AC and DC susceptibility:
    - Not direct for RF (H_{c1} and H_{c2}) and a cost of LHe
    - Quicker
  - T_C and RRR is an initial of evaluation
    - RRR > 10-73, but does not corrollate with RF
    - Quick, cheap
  - Surface analysis to determine:
    - Dense or columnar
    - Grain size,
    - Composition and impurity
    - Defects density

Future plans

- HiPIMS sample deposition for
  - Nb, NbN, NbCN, Nb_3Ge MgB_2
- Plasma ALD deposition
  - Nb, NbN, NbCN, MgB_2
- Continuing RRR measurements
- AC and DC magnetisation measurements
- Magnetic field penetration SCI multilayer layer
- RF pill-box test facility
  - Testing with a bulk Nb disk (April 2015)
  - Sample measurements (May 2015)
- 3D coating (2016)

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The UK's SRF collaboration team

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