3rd Annual meeting
12th IFAST WP9 meeting

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LOT, Institut für Werkstofftechnik, Universität Siegen

(Novel accelerator technology for efficient light sources NOVALIS)

16 April 2024

Tasks at Uni Siegen

1. Deposition studies:

   Nb, NbN, NbTiN, Nb_3Sn as well as MgB_2 sputter-coatings on

   metal (Cu, Nb...) as well as insulating (AlN, Al_2O_3, MgO...) substrates

2. Substrate preparation

3. Sample characterization: microstructure, SC and RF properties

4. Developments and upgrades

2. Deposition studies:
$Nb_{1-x}Ti_xN_y$ in CC800

1. co-NbTiN: HiPIMS Nb, DC Ti
Parameter window optimisation at constant composition [Nb/Ti ratio]

2. co-NbTiN: HiPIMS Nb, DC Ti
Optimal deposition parameters $\Rightarrow$ variation of the composition $Nb_{1-x}Ti_xN$

3. HiPIMS-NbTiN: NbTi alloy target on the HiPIMS cathode
- **DC-NbTiN** deposition $\Rightarrow$ for SS and SIS structures
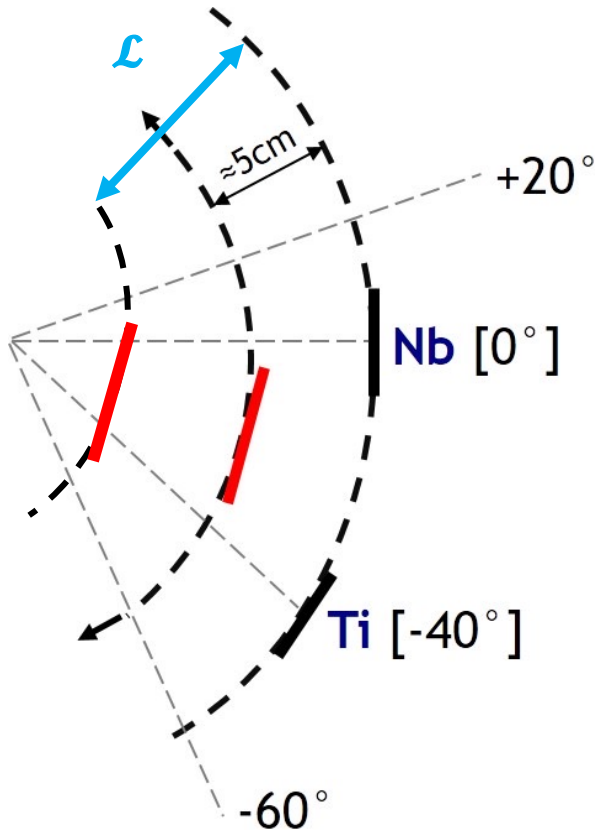- Parameter window optimisation of **HiPIMS-NbTiN**

4. Nitriding of NbTi films
Deposition of DC/HiPIMS-NbTi from a single target $\Rightarrow$
- nitrogen doping in N_2 atmosphere at elevated temperatures
- immersion in N_2 plasma

5. SIS (or SS) multilayer structures:
HiPIMS-Nb / DC AlN / co-NbTiN; DC-Nb / DC AlN / HiPIMS-NbTiN;
variation of the number of layers: SISIS...

1+2. Co-sputtering of NbTiN

Parameter	Influence
Power on Nb target (HiPIMS) (Ti is fixed at 400W)	High: delamination, **NbN** parasitic phases Low: bad performance
N_2/Ar ration (flow)	$N_2 \leq 10\%$ better
Deposition pressure	Low: larger grains, but **Ti**-side phases High: single NbTiN phase, pyramid-head columns
Deposition temperature	Low: bad performance High: mixture of phases (NbTiN + Ti-side phases)
Target-substrate distance $\mathcal{L}$	Act as variation of the deposition pressure Rocking angle can be narrowed
HiPIMS parameters	Pulse width and frequency have minor affect
Power on Ti target (DC)	Low impact on parasitic phases suppression

1. Co-sputtering of NbTiN: substrate-target distance

co-NbTiN at L = 9cm

co-NbTiN at L = 13cm

SAZ_070 T_C = 13.5
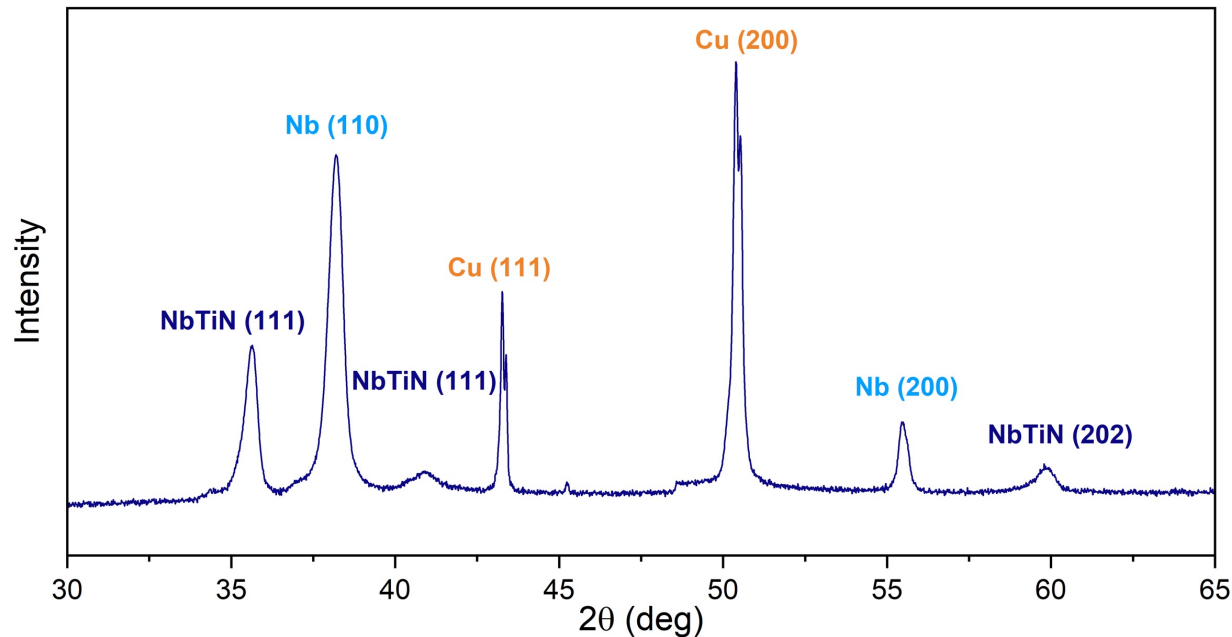SAZ_073 T_C = 10.3
SAZ_074 T_C = 12
@IEE, Eugen

co-NbTiN
SAZ_092 T_c=13.4(1)
SAZ_098 T_c=13.6(3)
SAZ_105 T_c=14.1(1)
SAZ_099 T_c=14.3(2)
SAZ_101 T_c=15.1(1)

@INFN-LNL, Dorothea, Christian

NbTiN (111)
NbTiN (200)
Cu (111)
co-NbTiN at 1.3 Pa
T_c=**14.3(4)**
co-NbTiN at 1.1 Pa
T_c=**15.1(2)**
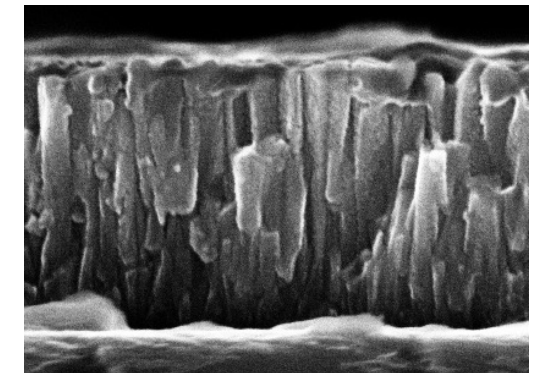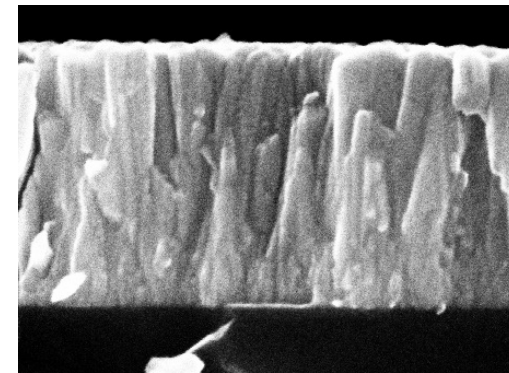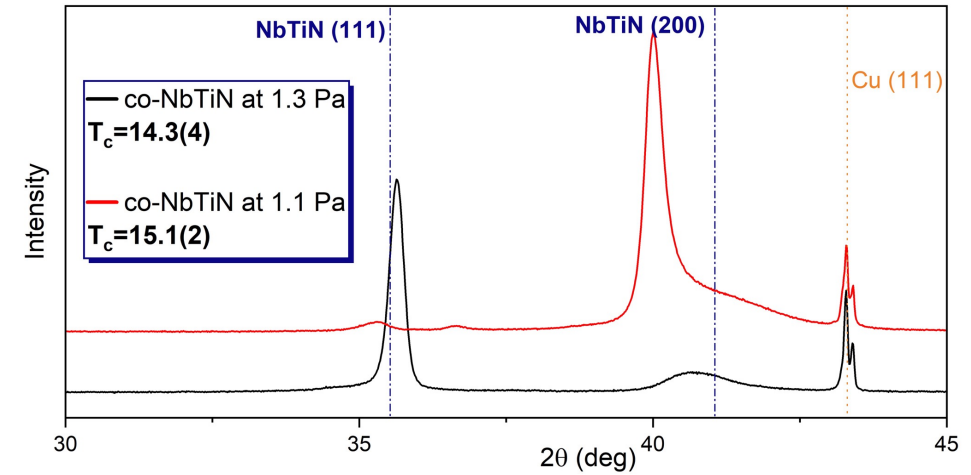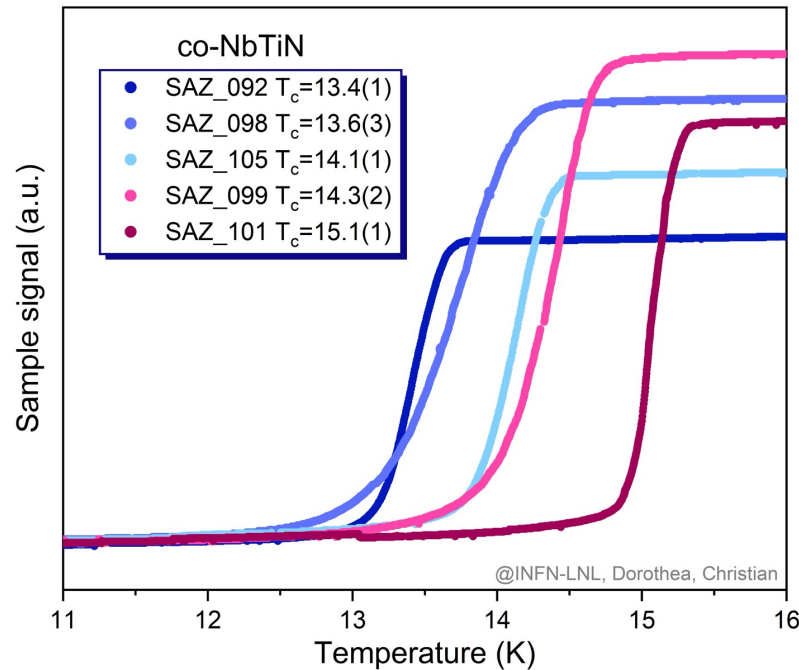
"$Nb_{0.82}Ti_{0.18}N$" at 1.1 Pa   "$Nb_{0.73}Ti_{0.27}N$" at 1.3 Pa

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1. Co-sputtering of NbTiN: multilayer structure

Conditions for co-NbTiN:
$\mathcal{P}(\text{Nb}) = 400\text{W}$, $\mathcal{P}(\text{Ti}) = 400\text{W}$, 9% of N_2, $p_{dep} \approx 1.3\text{Pa}$ ($T_c = 14.3(2)$), L = 13cm
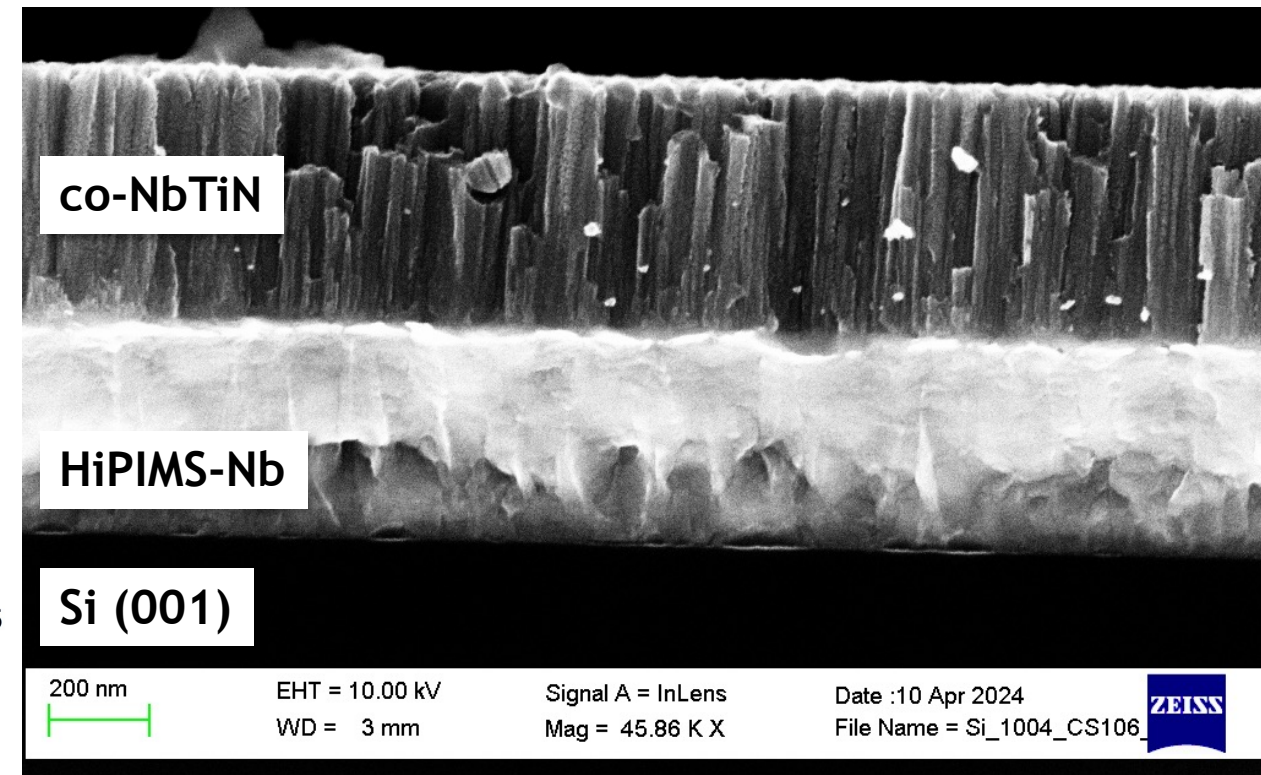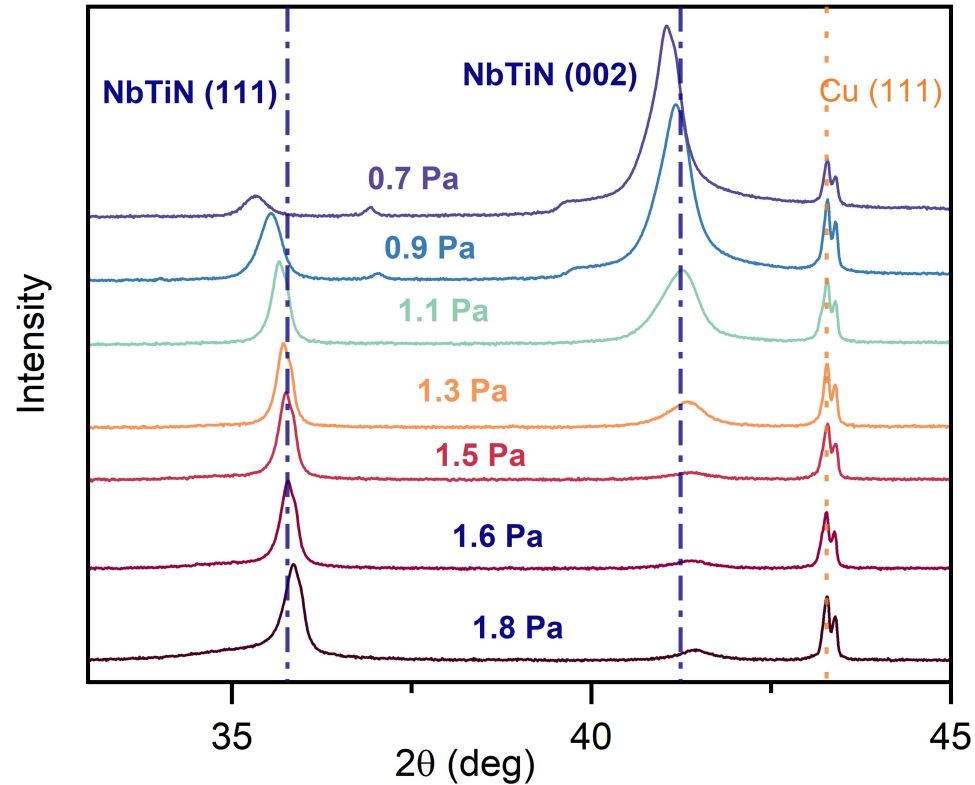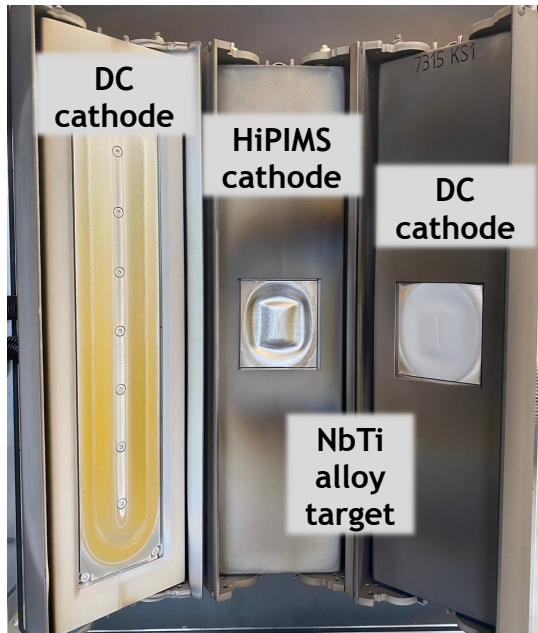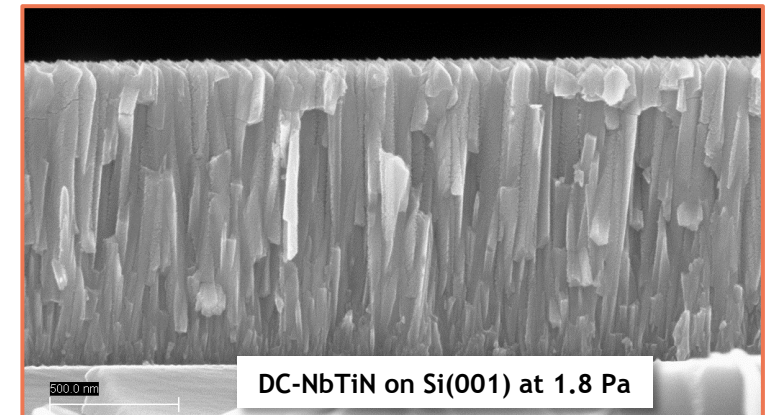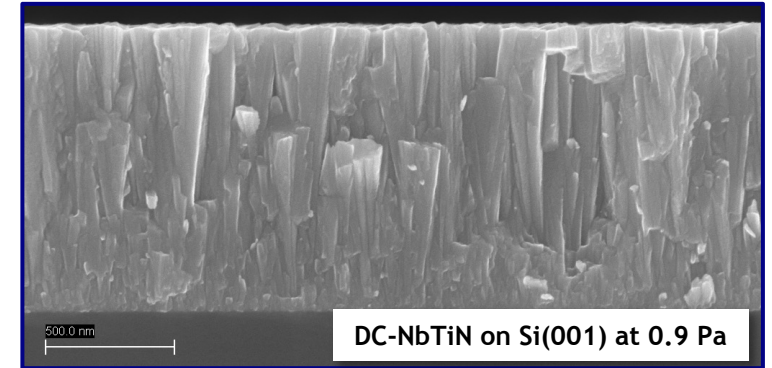
DC cathode

HiPIMS cathode

DC cathode

NbTi alloy target

NbTiN (111)

NbTiN (002)

Cu (111)

0.7 Pa

0.9 Pa

1.1 Pa

1.3 Pa

1.5 Pa

1.6 Pa

1.8 Pa

Intensity

2θ (deg)

Conditions: $\mathcal{P}$(NbTi) = 400W, 9% of N_2

DC-NbTiN on Si(001) at 0.9 Pa

DC-NbTiN on Si(001) at 1.8 Pa

3. DC-NbTiN: substrate bias

Conditions: $\mathcal{P}$(NbTi) = 400W, 9% of N_2, 1.8 Pa

DC-NbTiN on Si(001) at 50V

DC-NbTiN on Si(001) at 100V

DC-NbTiN on Si(001) at 150V

3. DC-NbTiN: substrate bias

Conditions: $\mathcal{P}$(NbTi) = 400W, 9% of N$_2$, 0.9 Pa

DC-NbTiN on Si(001) at 100V

DC-NbTiN on Si(001) at 150V

Conditions: $\mathcal{P}$(NbTi) = 400W, 9% of N$_2$, 1.8 Pa

DC-NbTiN on Si(001) at 100V

DC-NbTiN on Si(001) at 150V

DC cathode

HiPIMS cathode

DC cathode

NbTi alloy target
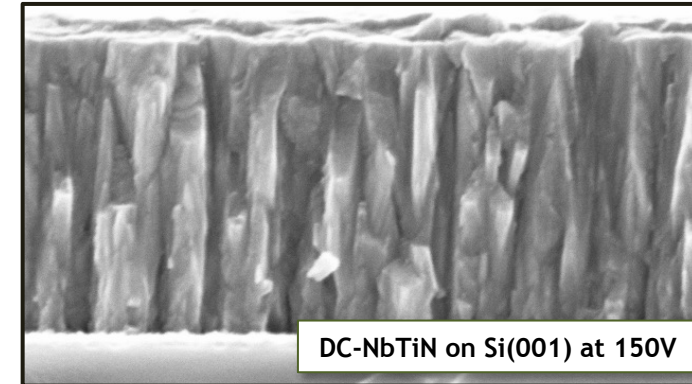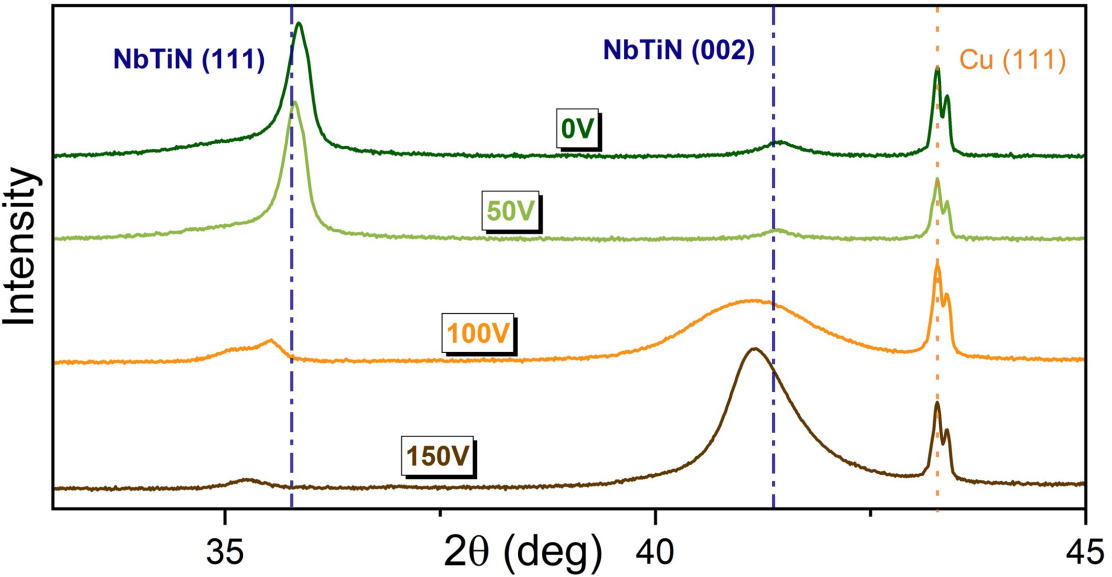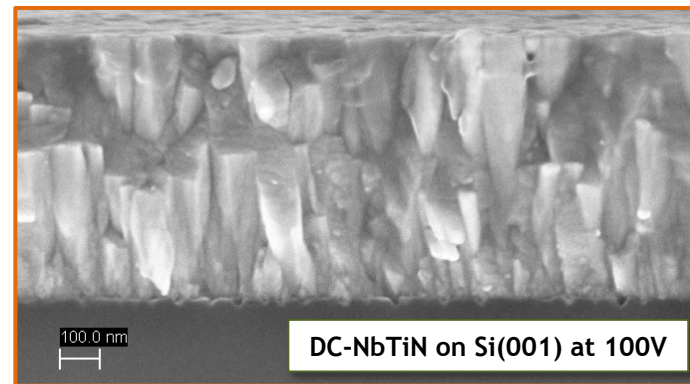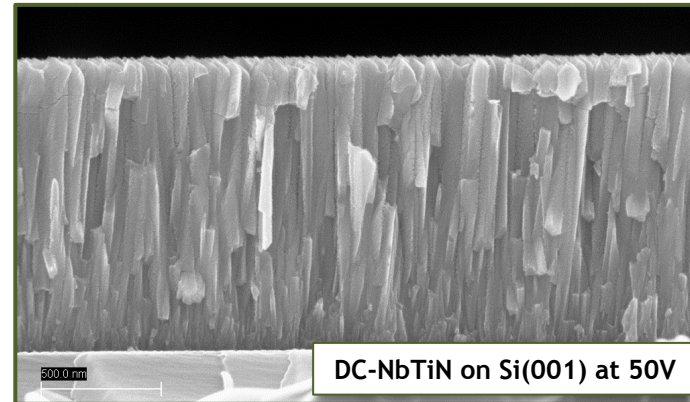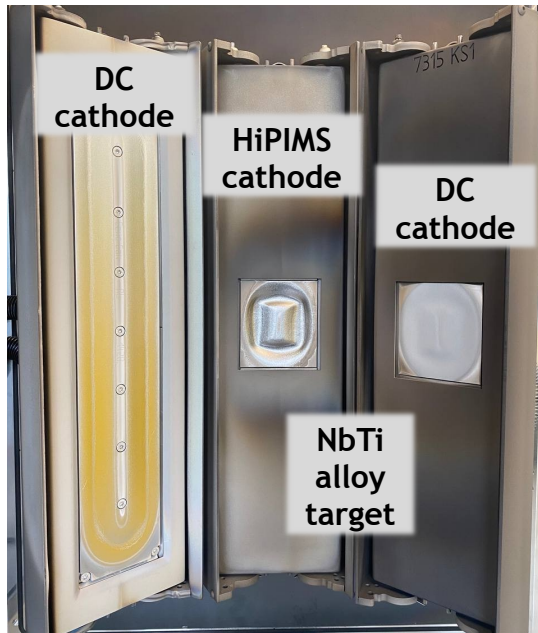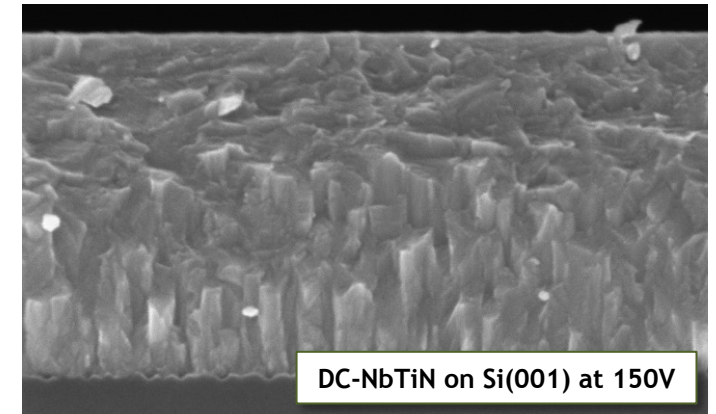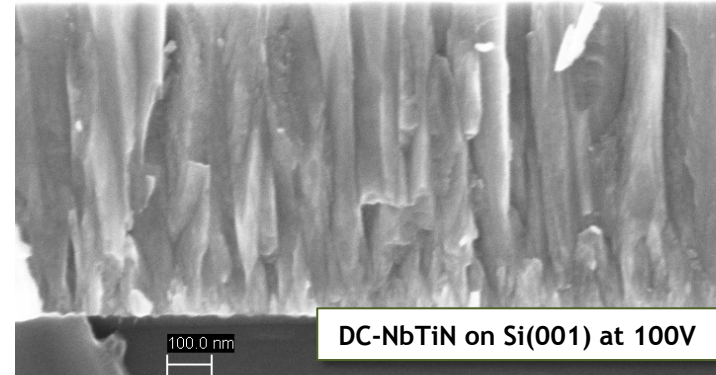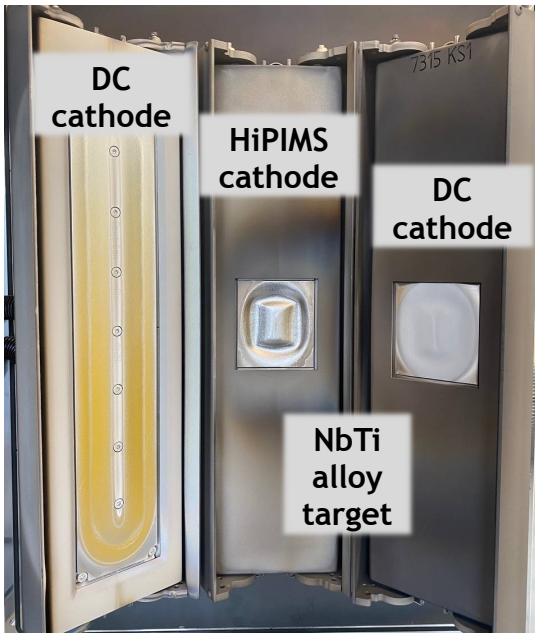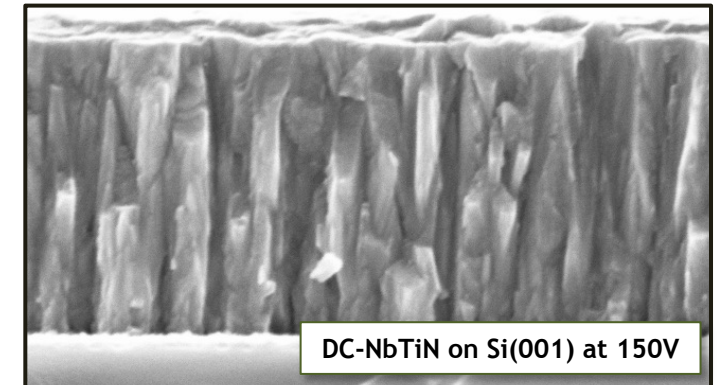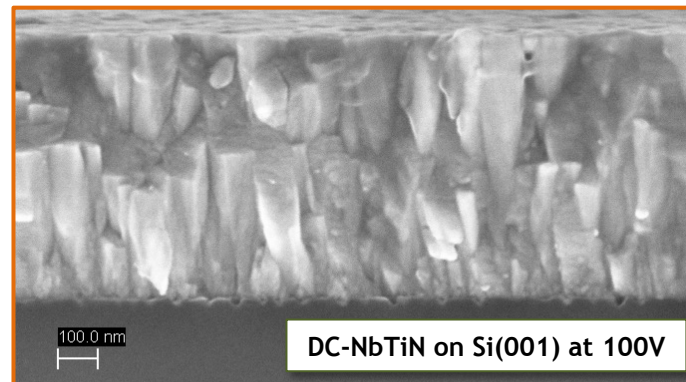
3. DC-NbTiN: superconducting properties

DC-NbTiN:
no clear influence of deposition parameters on SC properties
→ need to measure more samples

@IEE, Eugen
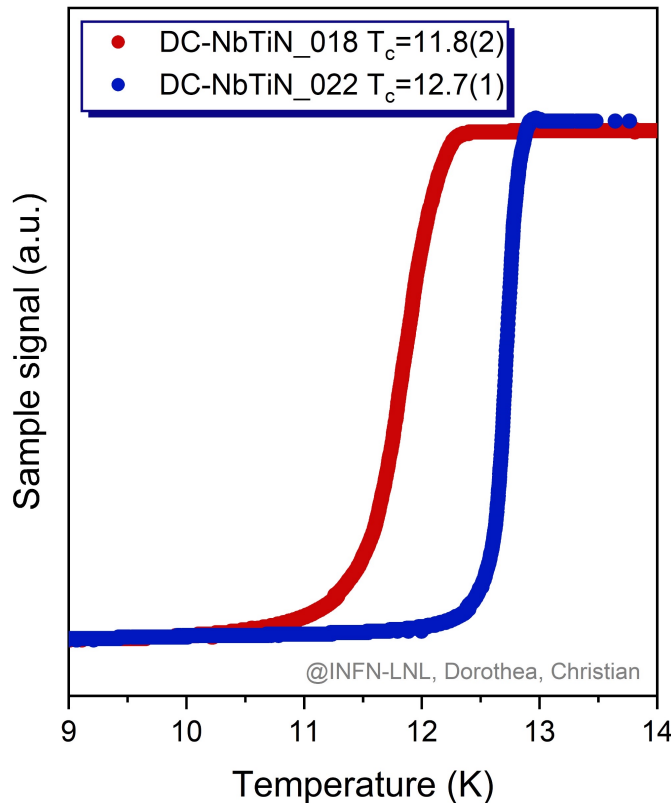
Sample name	B_{en} (Oe)	Tc (K)	Conditions
DC_001_recentre	870	13.8	P(NbTi) = 400W, p = 1.8Pa, T_{dep} = 180°C
DC_002_recentre	paramag.	14.1	P(NbTi) = 500W, p = 1.8Pa, T_{dep} = 180°C
DC_003_recentre	670	13.7	P(NbTi) = 400W, p = 1.5Pa, T_{dep} = 180°C
DC_018	-	11.8(2)	P(NbTi) = 400W, p = 0.9Pa, T_{dep} = 260°C
DC_022	-	12.7(1)	P(NbTi) = 450W, p = 1.1Pa, T_{dep} = 260°C

Legend in graph:
- DC-NbTiN_018 T_c=11.8(2)
- DC-NbTiN_022 T_c=12.7(1)

Graph axis: Sample signal (a.u.) vs Temperature (K)

@INFN-LNL, Dorothea, Christian

DC-NbTiN on Si(001) at 0.9 Pa (DC_018)

DC-NbTiN on Si(001) at 1.8 Pa (DC_001)
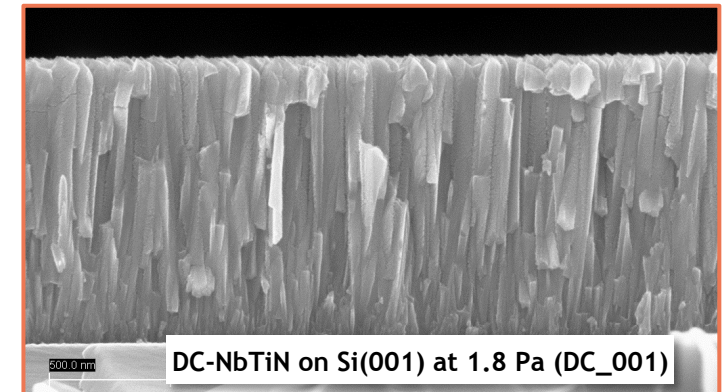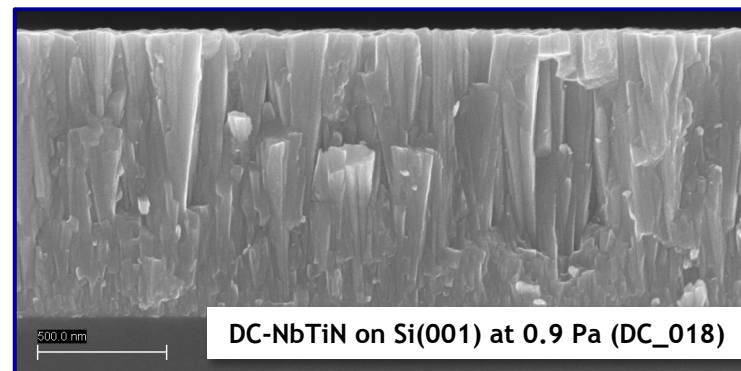
3. HiPIMS-NbTiN: cathode power

Conditions:
10% of N$_2$, p_{dep} ≈ 1.83Pa, Bias 50V, T_{dep} = 150°C,
HiPIMS parameters:
1000Hz 200μs, 20% duty cycle
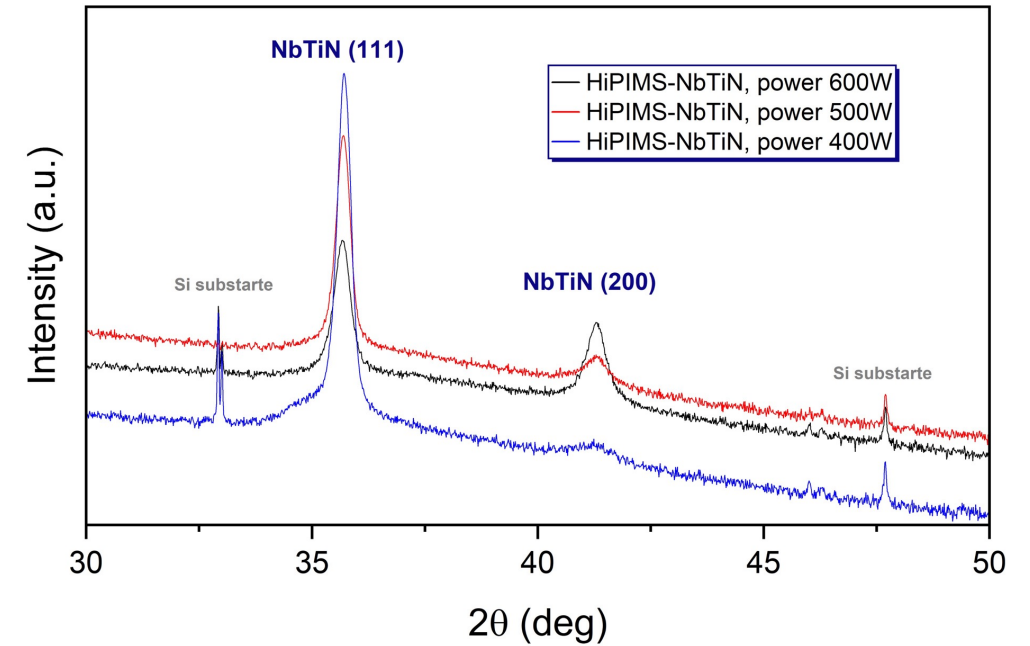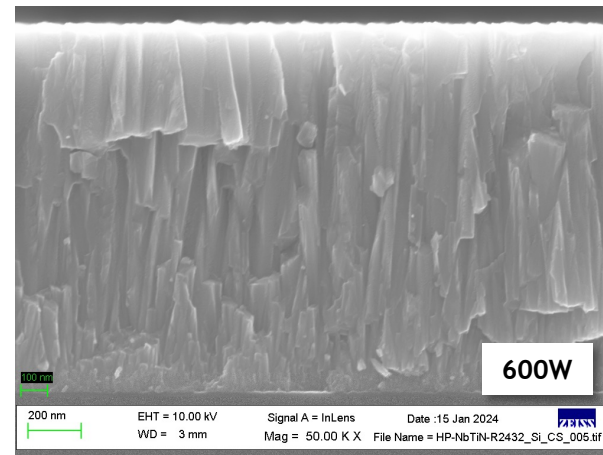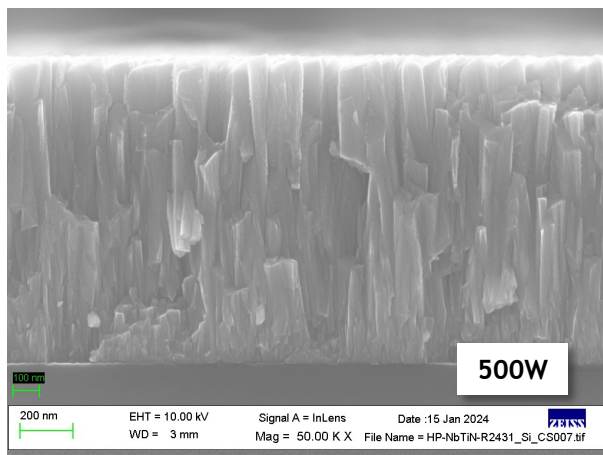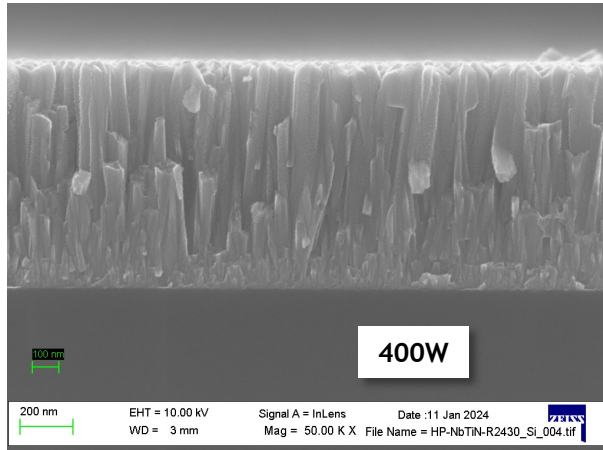
@Bharath Reddy

3. HiPIMS-NbTiN: deposition pressure

HiPIMS-NbTiN at 1.8 Pa

HiPIMS-NbTiN at 1.2 Pa
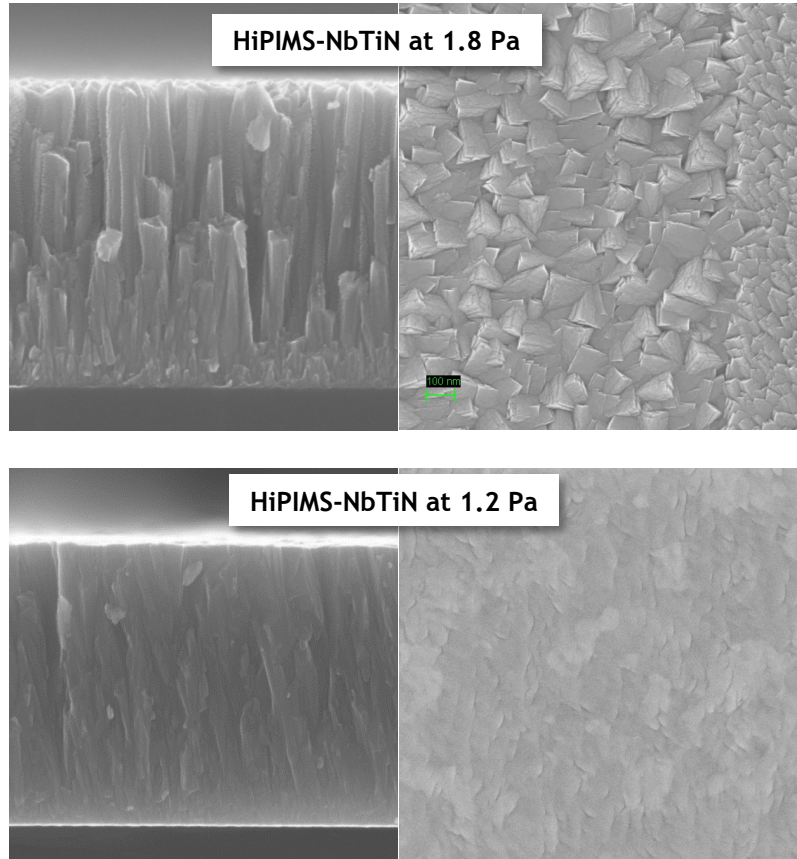
Conditions:
$\mathcal{P}$(NbTi) = 400W, 10% of N_2, Bias 50V,
T_{dep} = 150°C, HiPIMS parameters: 1000Hz 200μs, 20% duty cycle
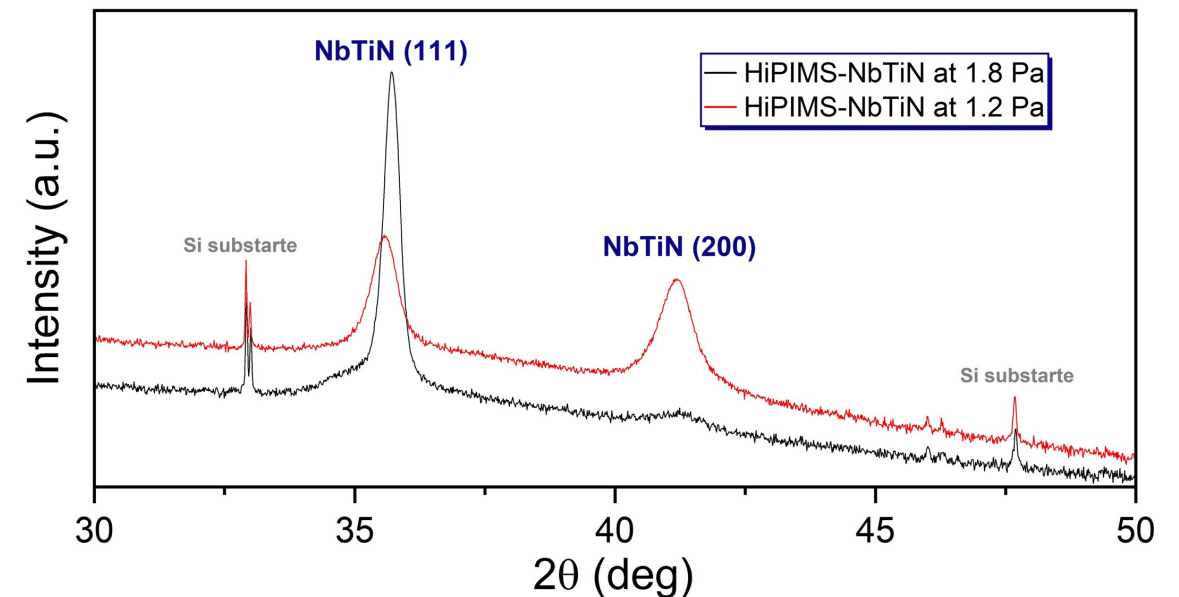
@Bharath Reddy

4. Developments and upgrades: PVD-SEY chamber in Lab1

Load lock chamber

PVD chamber

SEY chamber

RFMS co-sputtering of MgB$_2$
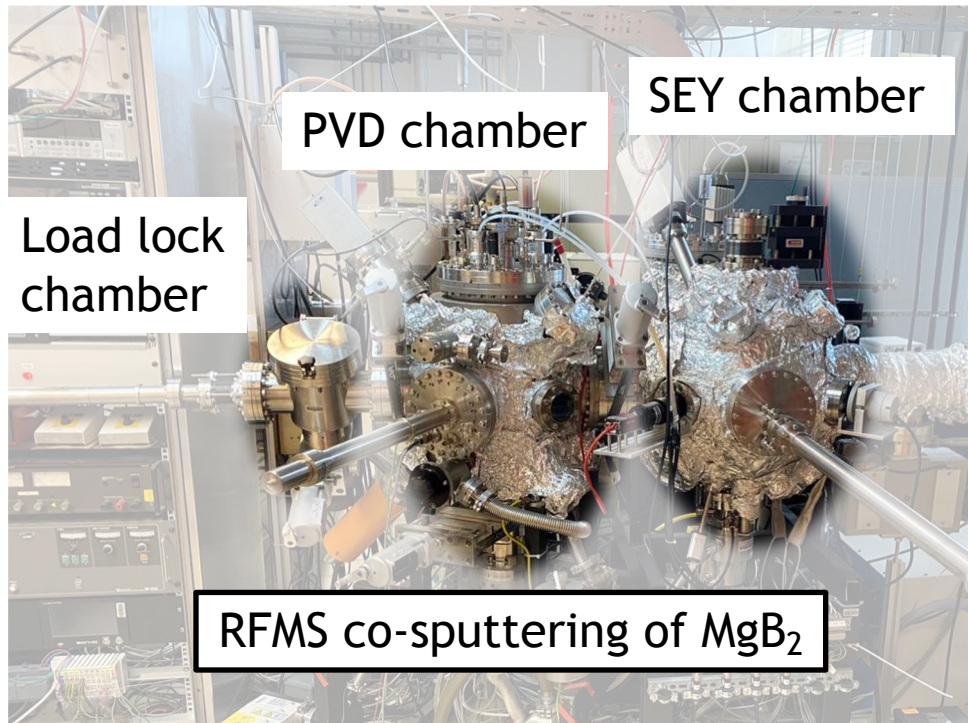
PVD chamber:

- Targets were delivered only two weeks ago

- Now – target replacement

SEY chamber:

- ELG is installed

- After target replacement – vacuum check

E-Gun for SEY chamber
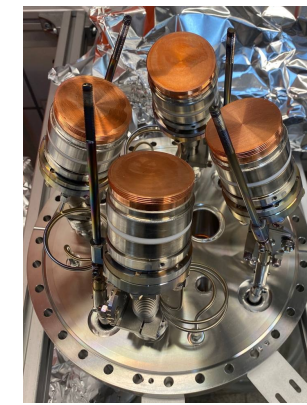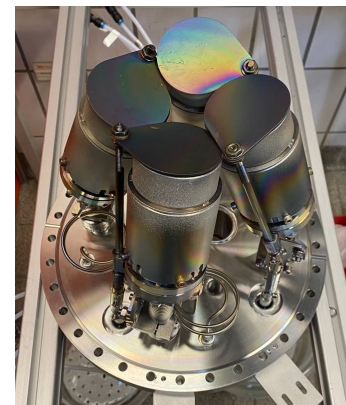
4 cathodes arrangement
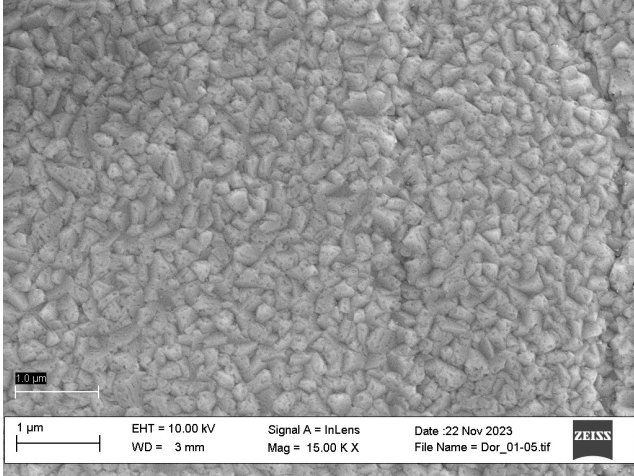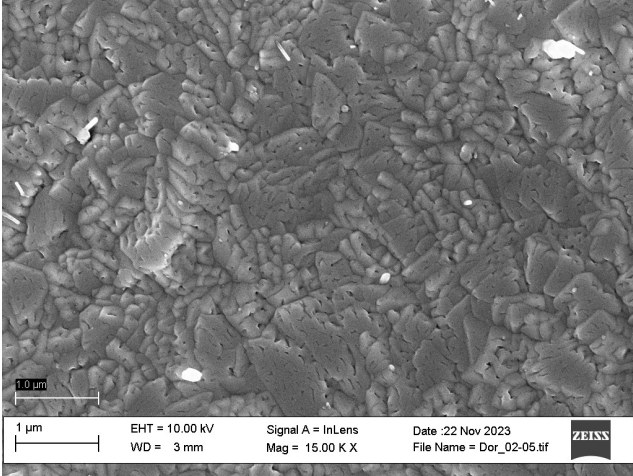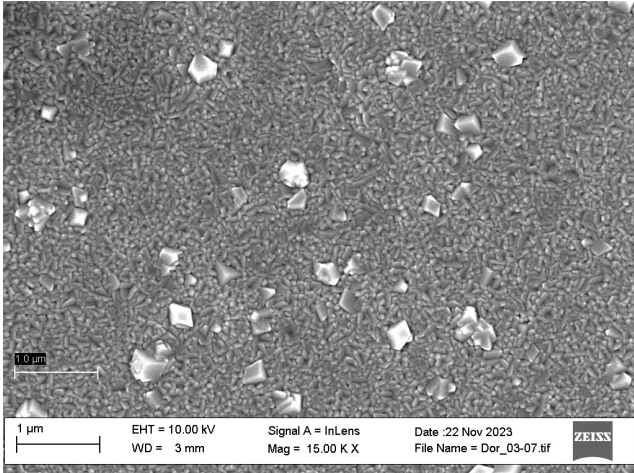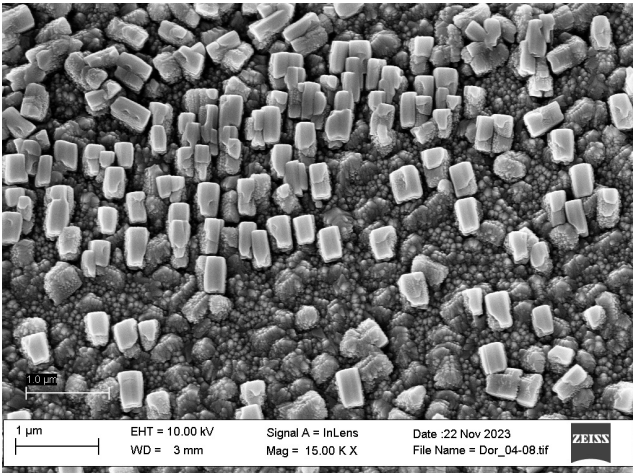
Plans and outlook

- Deposition of multilayer (SS or SIS) structures with **co-NbTiN** and **HiPIMS-Nb**

- Optimization of DC-**NbTiN** deposition

- Deposition of multilayer (SS or SIS) structures with **DC-NbTiN** and **HiPIMS-Nb**

- Development of HiPIMS-**NbTiN** deposition

- Start of **MgB$_2$** deposition in another deposition chamber by RF co-sputtering

- Sample characterization: XRD, SEM, AFM, SC properties

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THANK YOU FOR YOUR ATTENTION!
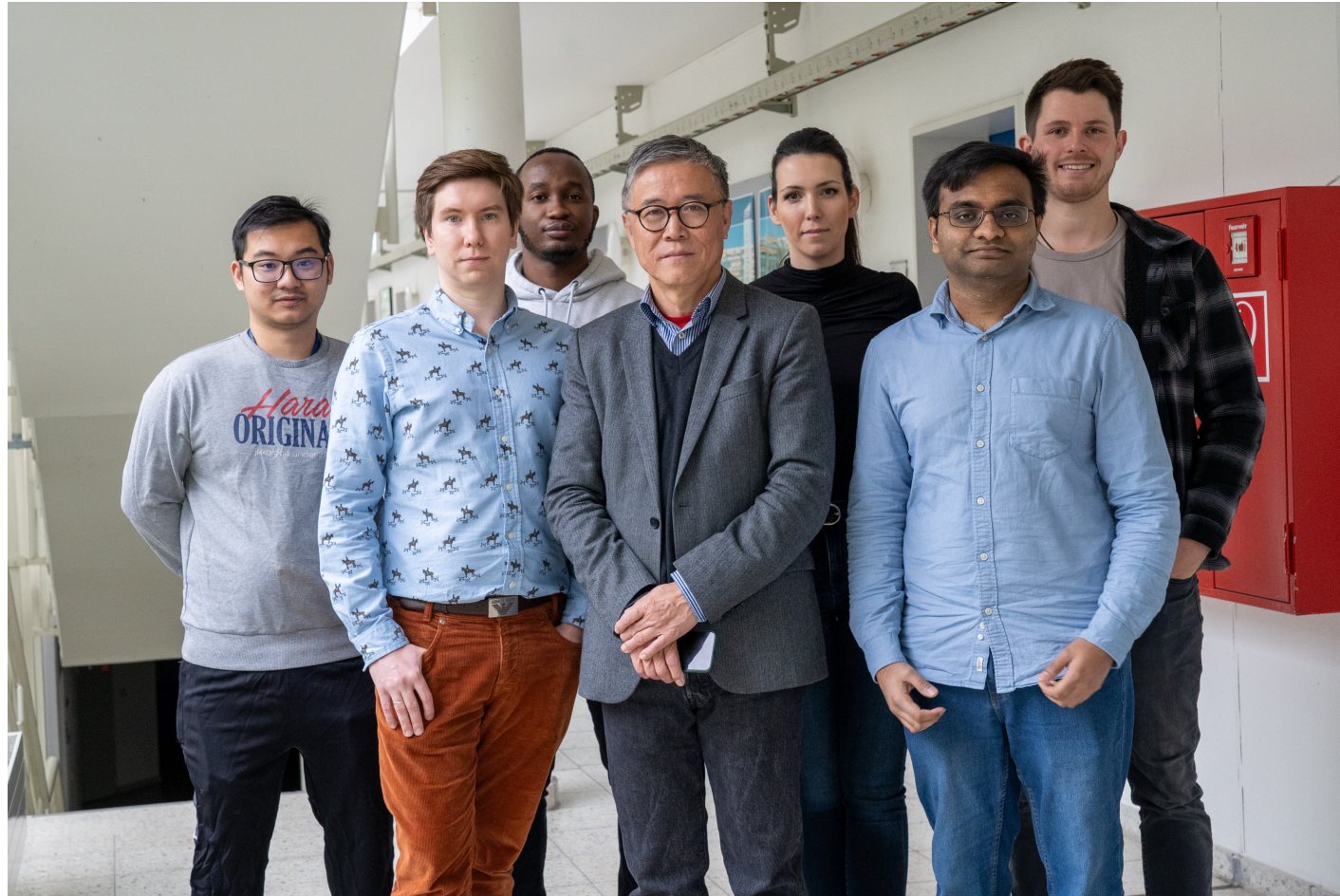
	No Nb buffer layer	50µm Nb buffer layer
600°C		
500°C		
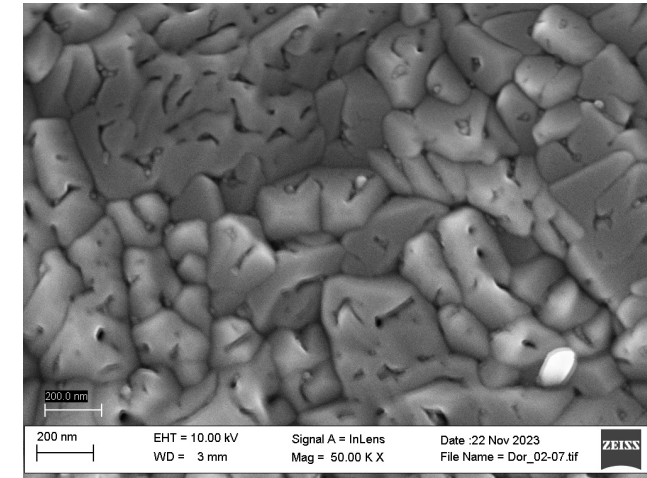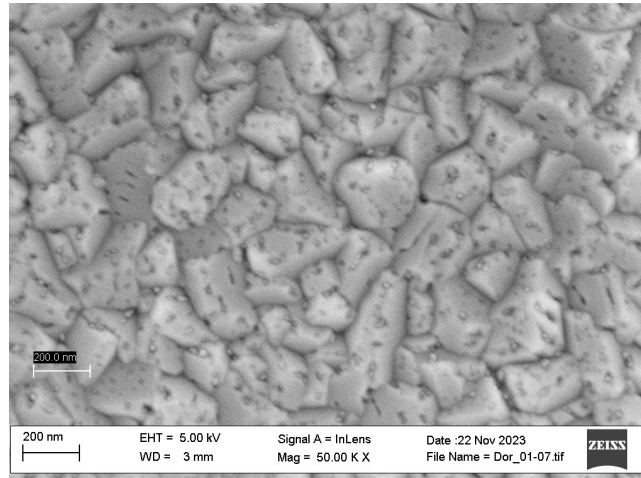
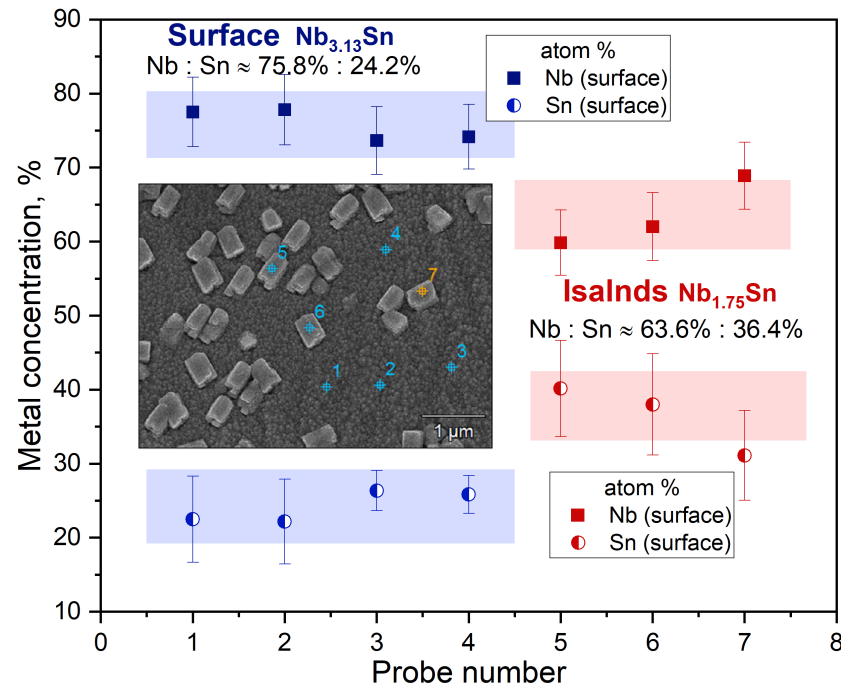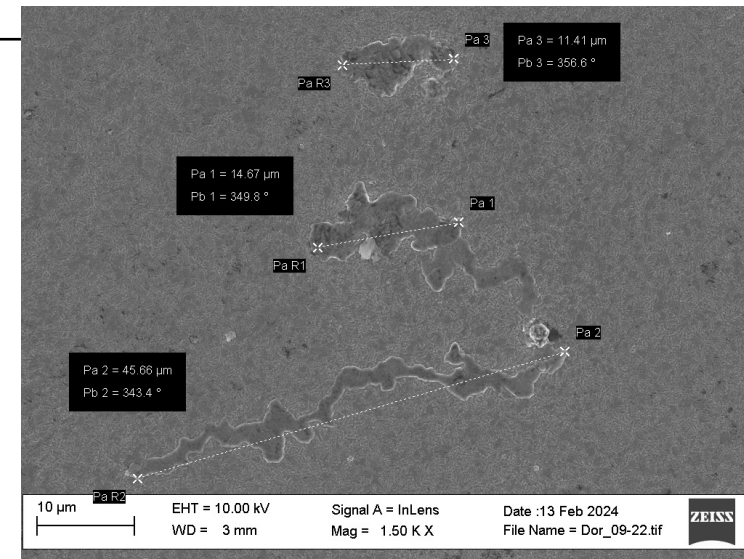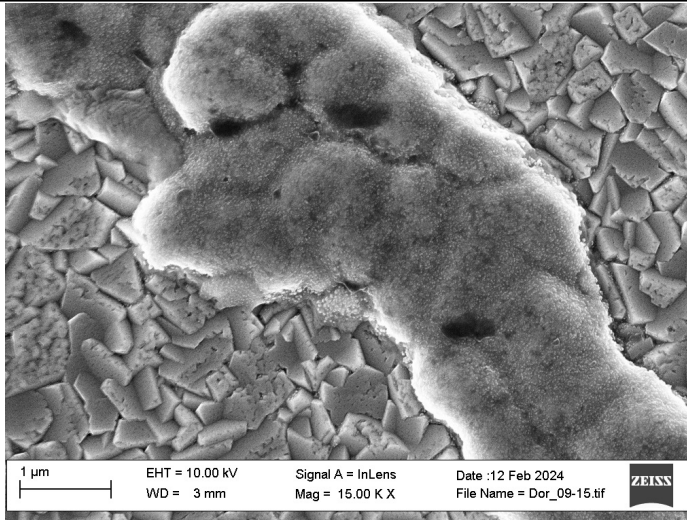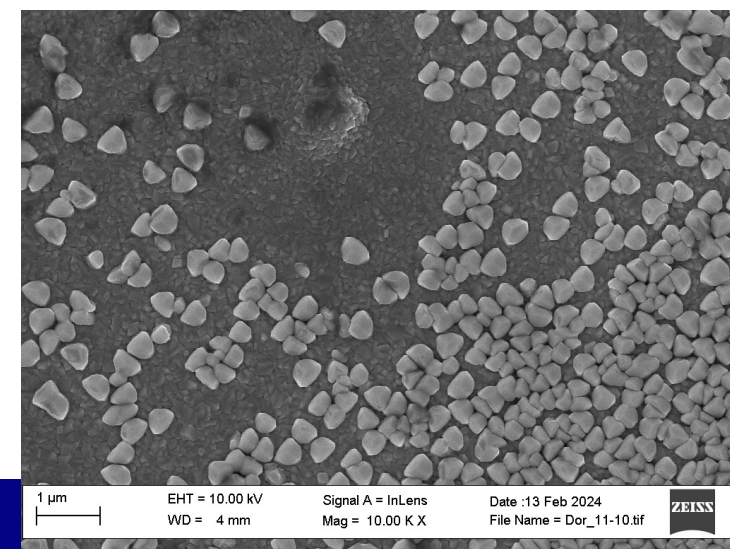|	No Nb buffer layer	50µm Nb buffer layer
600°C		
500°C		
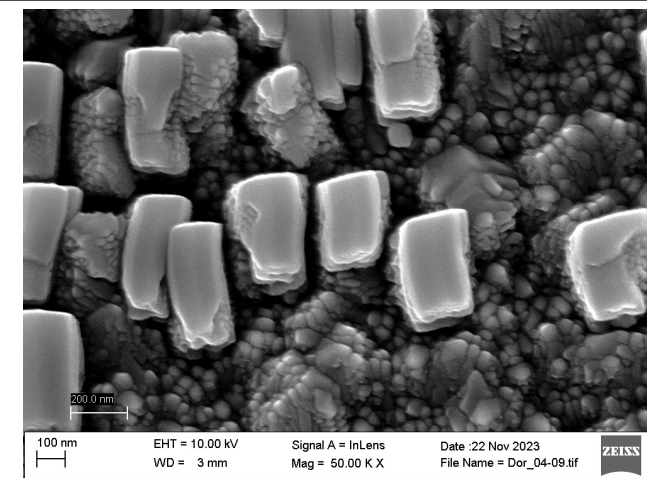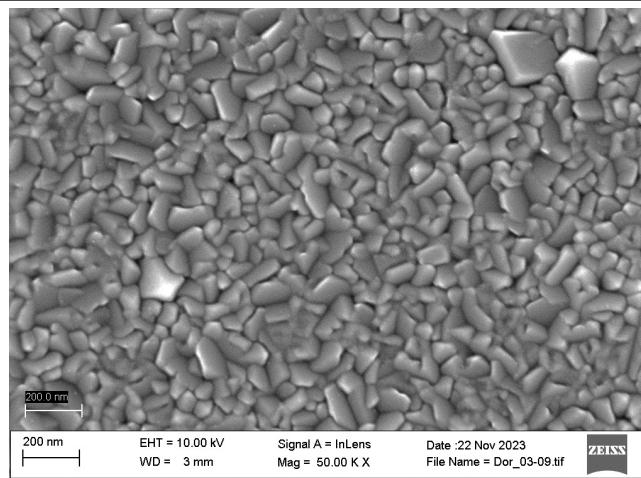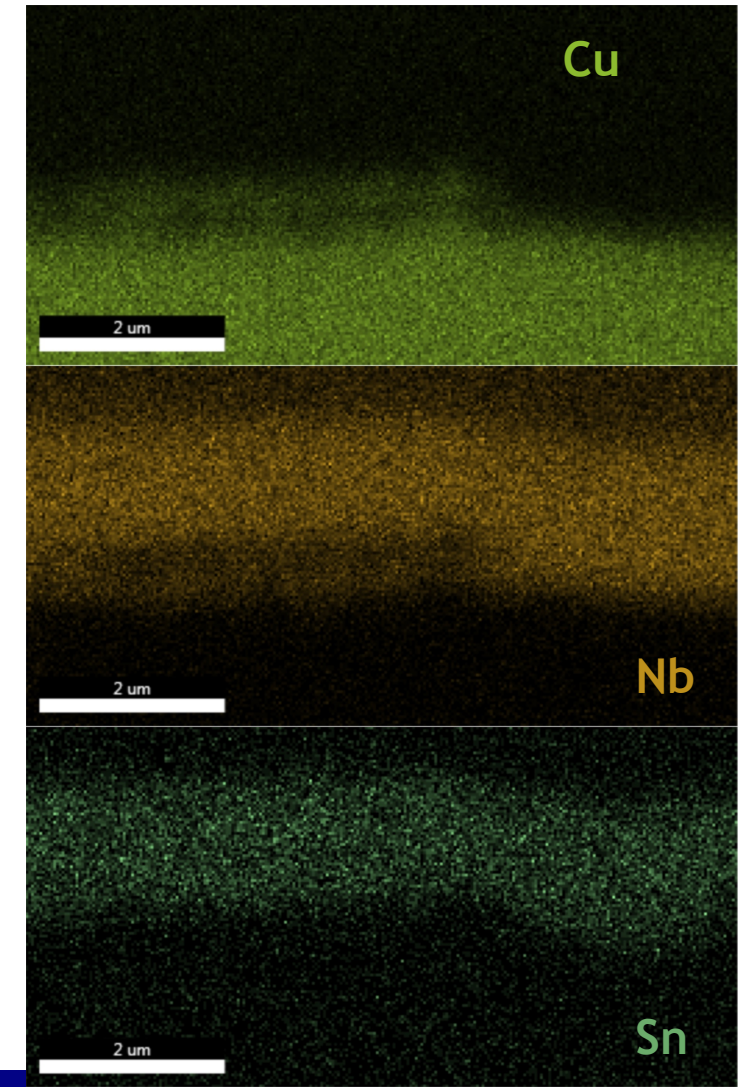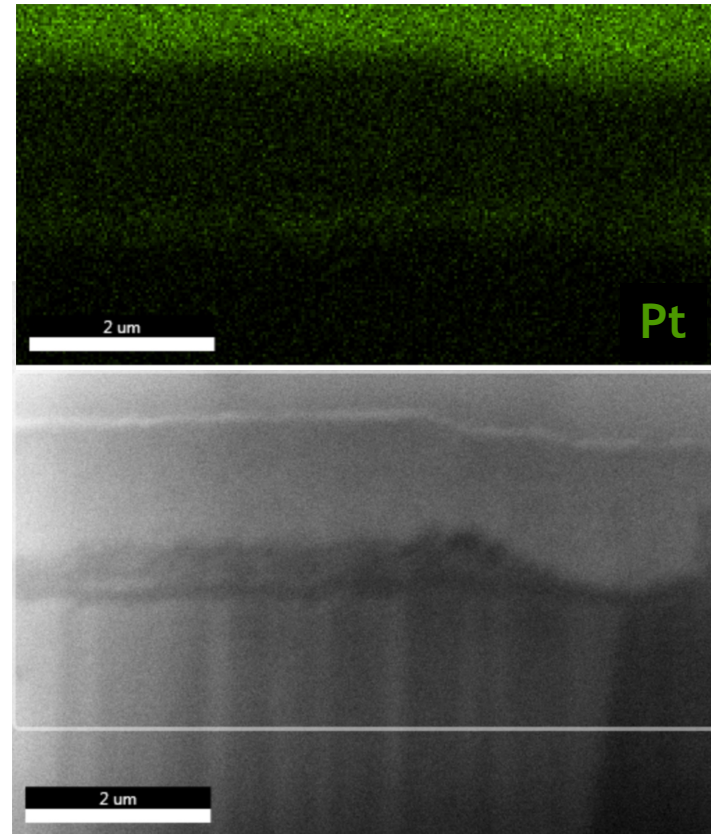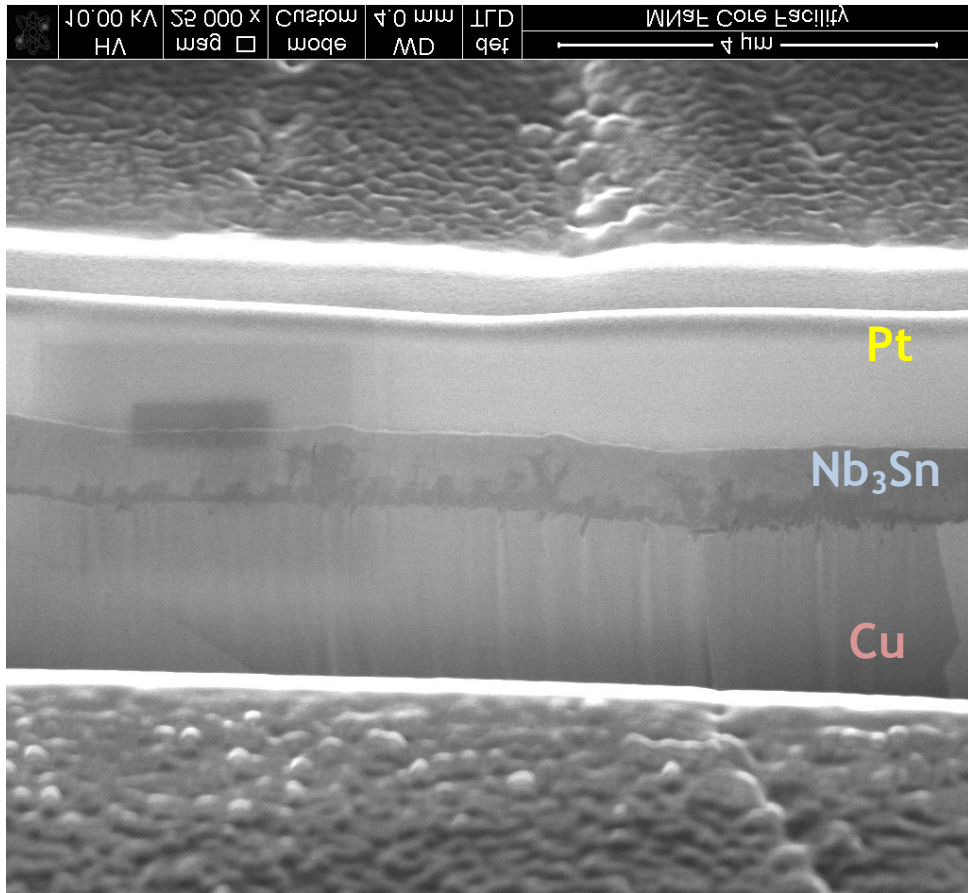
Nb$_3$Sn/ Cu (600°C):

Nb$_3$Sn / Nb(50μm) / Cu (500°C):

Cooperation with IFNF-LNL: Nb$_3$Sn on Cu

1µm Nb buffer layer: Nb$_3$Sn (1µm) / Nb (1µm) / Cu

600°C

500°C

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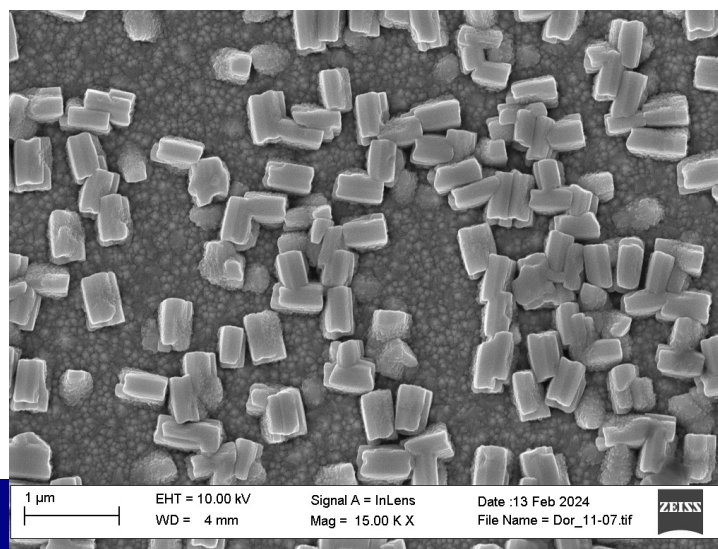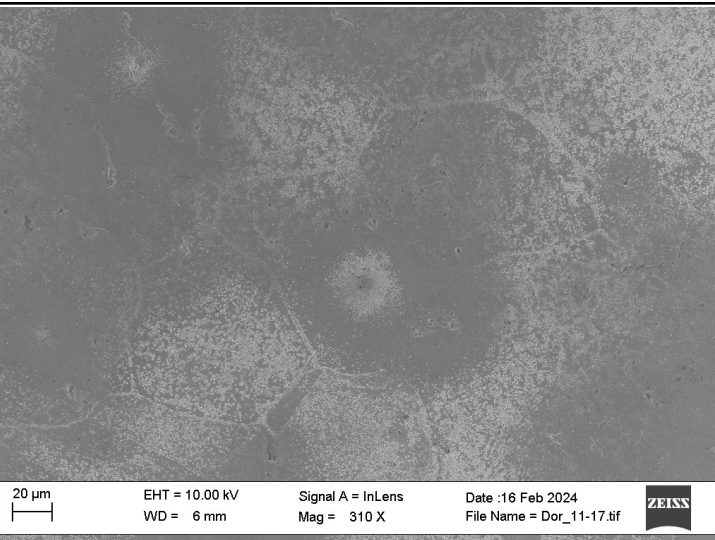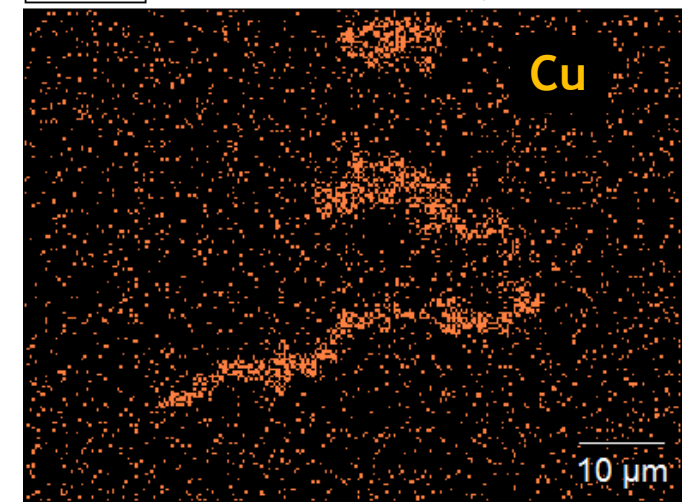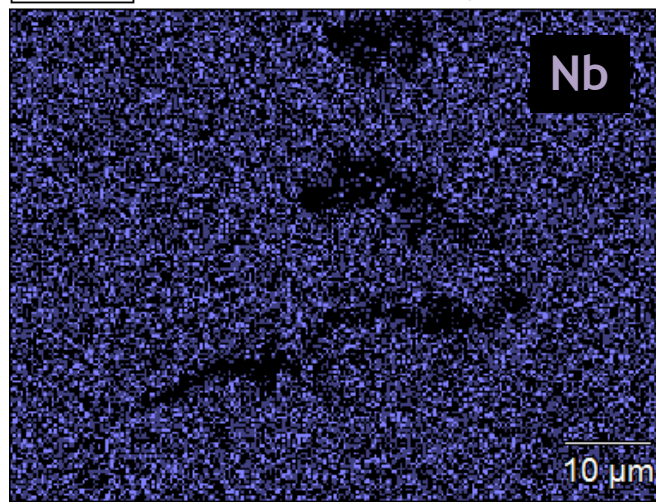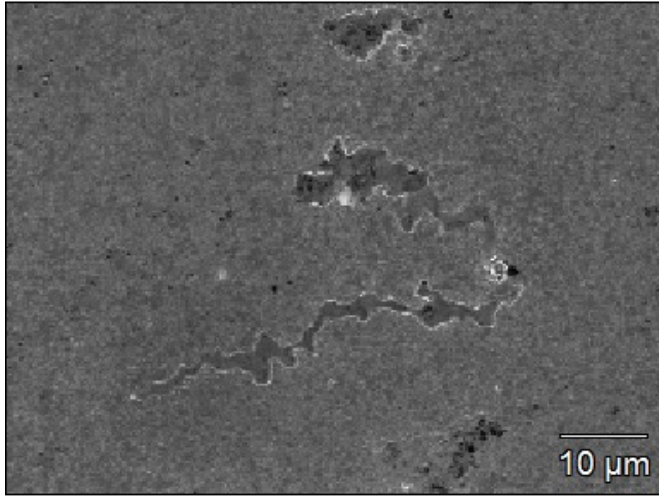
1µm Nb buffer layer: Nb_3Sn (1µm) / Nb (1µm) / Cu

600°C

500°C

A. Zubtsovskii