LOT

Lehrstuhl für Oberflächen- und Werkstofftechnologie

UNIVERSITÄT SIEGEN

NbN Thin Film-Based Multilayer (S-(I)-S) Structures for SRF Cavities

Bundesministerium für Bildung und Forschung

9th Thin Film SRF`21
(Virtual)

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ARIES

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SIS Multilayer Structures for Applications in SRF Technology (SMART)

Outline

1. General motivation.
2. Technological motivation & S-I-S structures.
3. The project SMART & LOT, USiegen
4. The experimental set-up & the deposition techniques (DCMS, HiPIMS, (PE)-ALD).
5. Results & Discussions.
6. Next steps.

General Motivation: Sci.&Tech. Advancement

…at cosmic scales: e.g., the study of dark matter in relation to the Standard Model.

…at atomic scales: e.g., the real-time imaging and measurement of structural and electronic dynamics at the quantum scale ➔ the workings of matter at the quantum scale.

…new possibilities and capabilities beyond those existing currently so as to allow us to address fundamental scientific questions while contributing to the technological advancement in favor of societies.

Technology-specific motivation

The Challenge

The technological bottleneck set by bulk niobium.

The possible solution(s)

Advanced material structures: mono- and/or multi-layer (S-(I)-S) structured superconducting thin films (TFs).

"Optimized multilayers of Nb_3Sn, NbN, some of the iron pnictides, or alloyed Nb deposited onto the surface of the Nb resonator cavities could potentially double ***the rf breakdown field****, pushing* ***the peak accelerating electric fields*** *above* ***100 MV/m*** *while protecting the cavity from* ***dendritic thermomagnetic avalanches*** *caused by* ***local penetration of vortices****." [1]*

[1] AIP Advances 5, 017112 (2015)
[2] https://doi.org/10.1088/1361-6668/30/2/023001

SIS Multilayer Structures for Applications in Superconducting Radio-Frequency Technology (SMART)

(P)VD (e.g., DCMS, HiPIMS, RFMS, etc.) & Material Characterizations

(PE)-ALD & Tc

Computational EM

QPRs

SRF

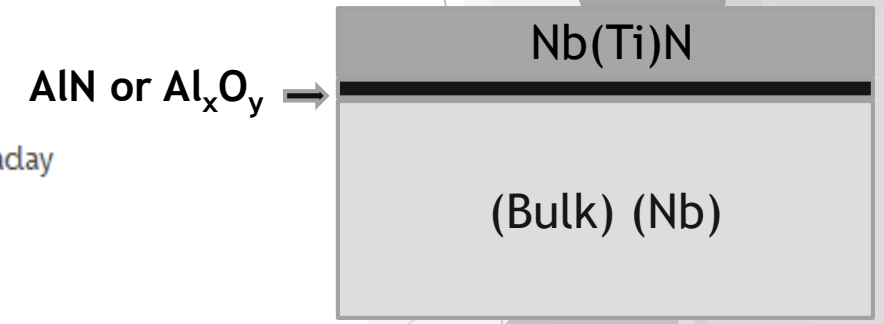
Additional expertise, in particular in QPRs

Additional expertise in (ALD)-based ML TFs

Bundesministerium für Bildung und Forschung

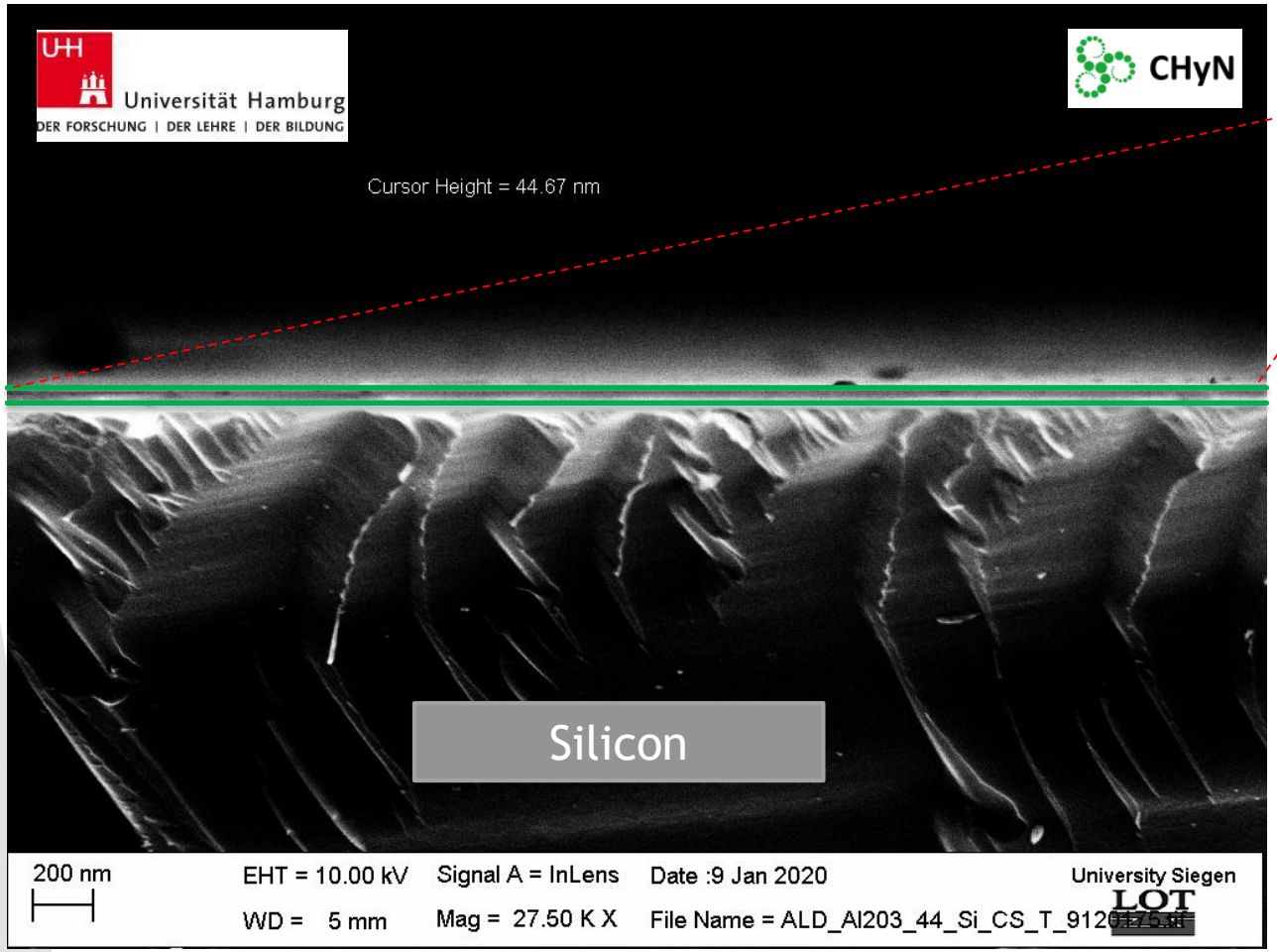
Verbundforschungsprojekt:

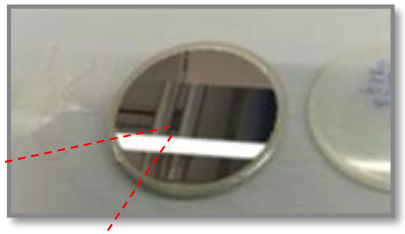
- Universität Hamburg
- Universität Siegen
- Technische Universität Darmstadt
- Helmholtz-Zentrum Berlin (HZB)
- Deutsches Elektronen-Synchrotron (DESY)
- European Organization for Nuclear Research (CERN)
- Commissariat à l'énergie atomique et aux énergies alternatives (CEA) Paris-Saclay



[https://www.mb.uni-siegen.de/lot/forschung/projekte/smart.html?lang=de]

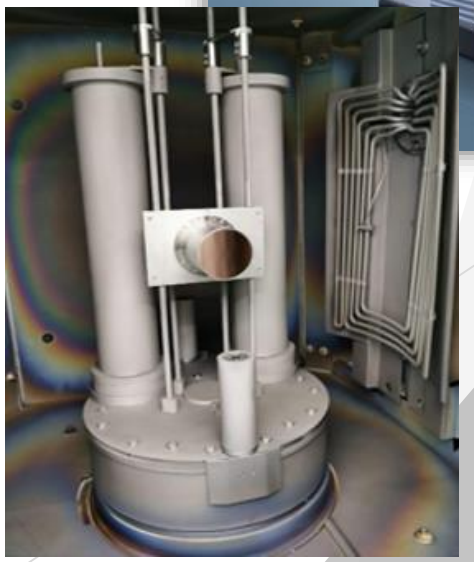
Experimental Set-up





ALD - Alumina

CemeCon – CC800



- MS: Magnetron Sputtering (e.g., DCMS, HiPIMS).
- (PE)-ALD: (Plasma Enhanced)-Atomic Layer Deposition.

Development of NbN TF-based Multilayer Structures

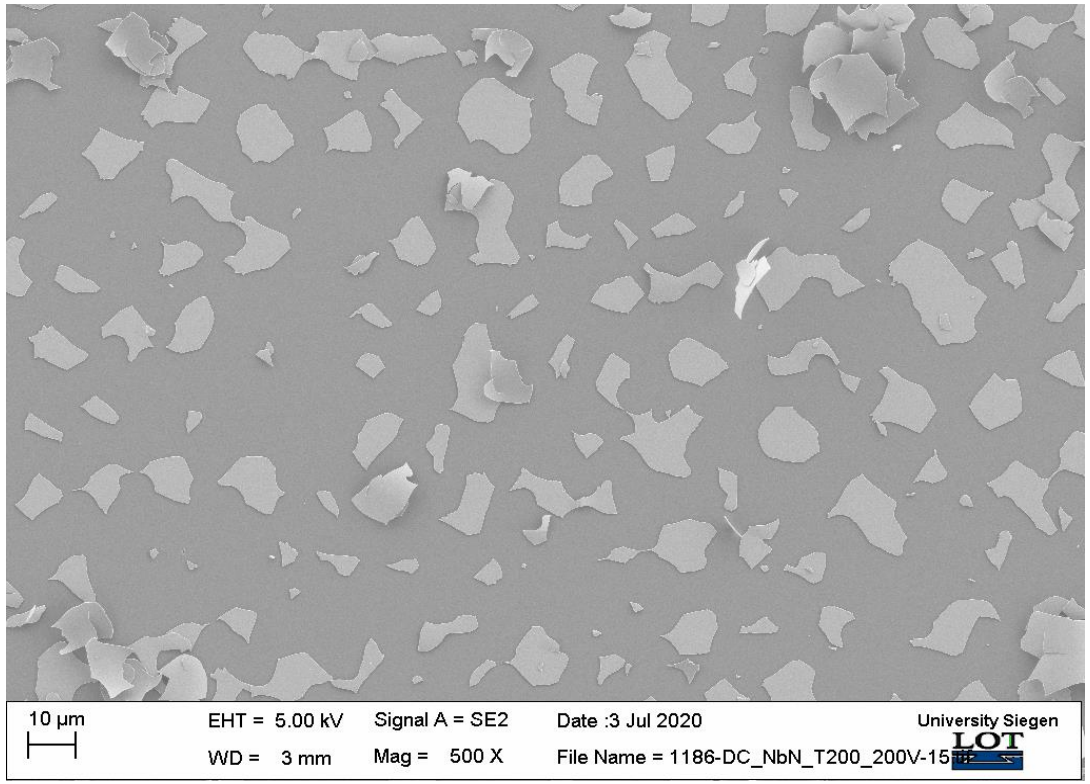
- The optimization studies of *the parameter window* for **DCMS-NbN** thin films (TFs) on **ALD-Alumina/Si, PEALD-AlN/Si**, and silicon.

- The parameter studies of **HiPIMS-NbN** mono-/multi-layer (S-I-S) structures on **(PEALD)-AlN/Si & (ALD)-Alumina/Si**, and silicon substrates.

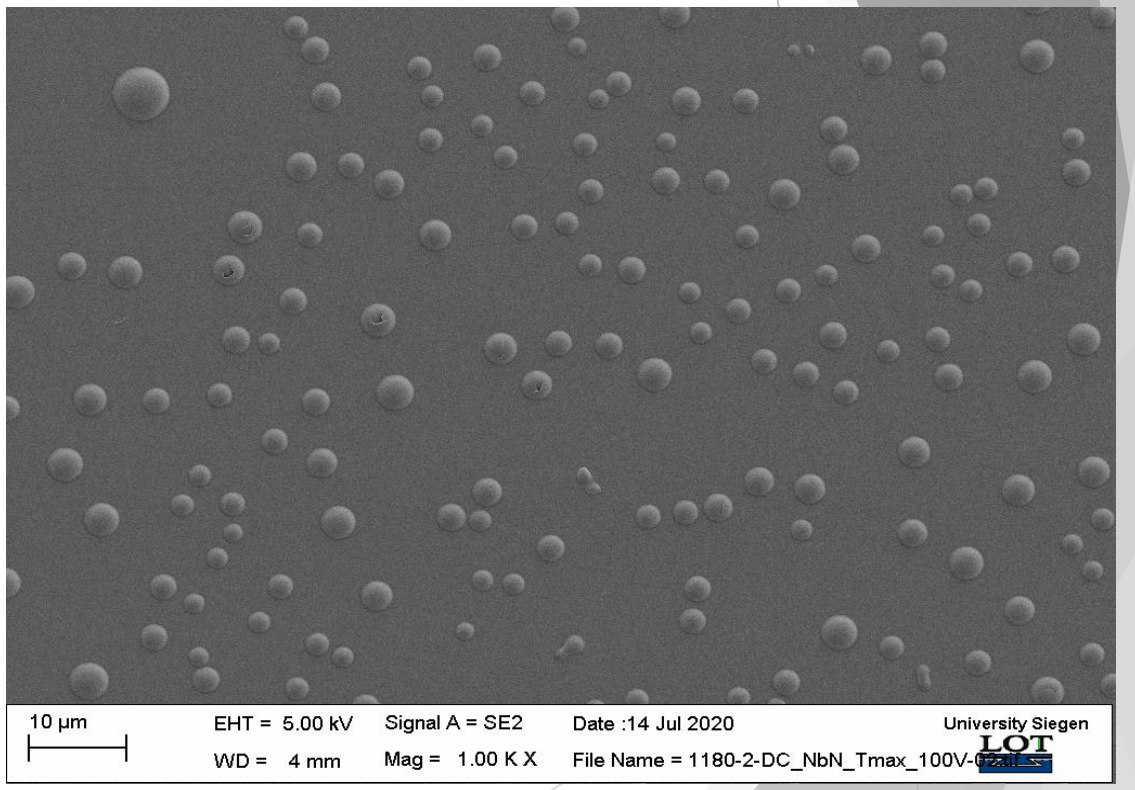
- The **thickness uniformity studies** of the coated-layers - after the development of the code for the rotation (rocking/pulsing) of the table.

Initial DCMS-NbN Parameter Studies

DC - P1

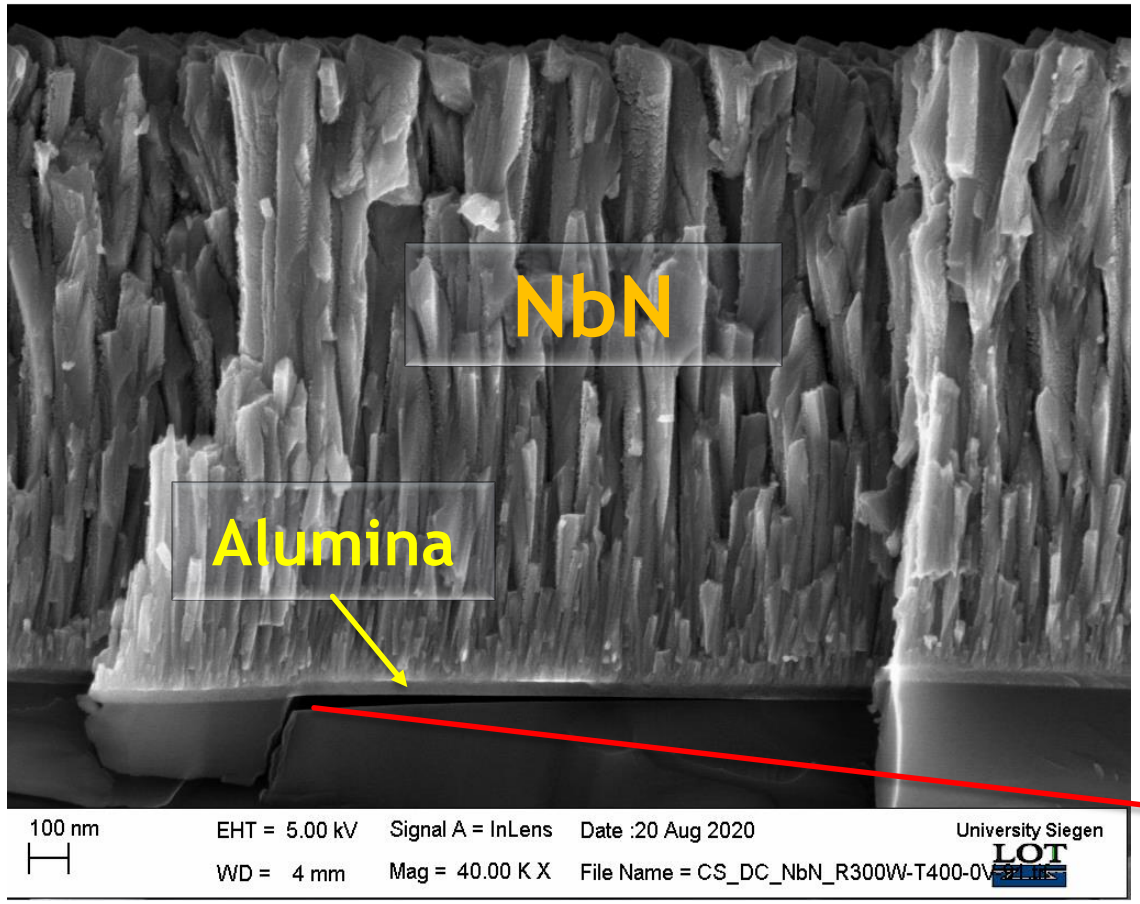


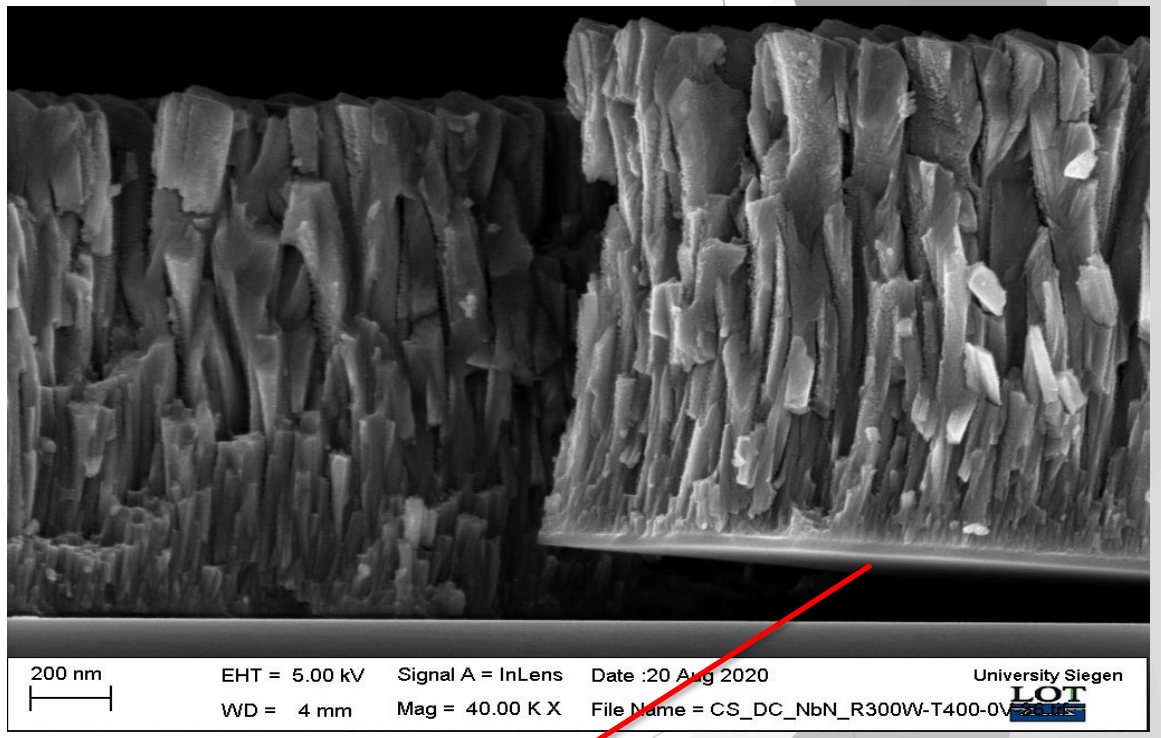
DC - P2



The Delamination of ALD-Alumina

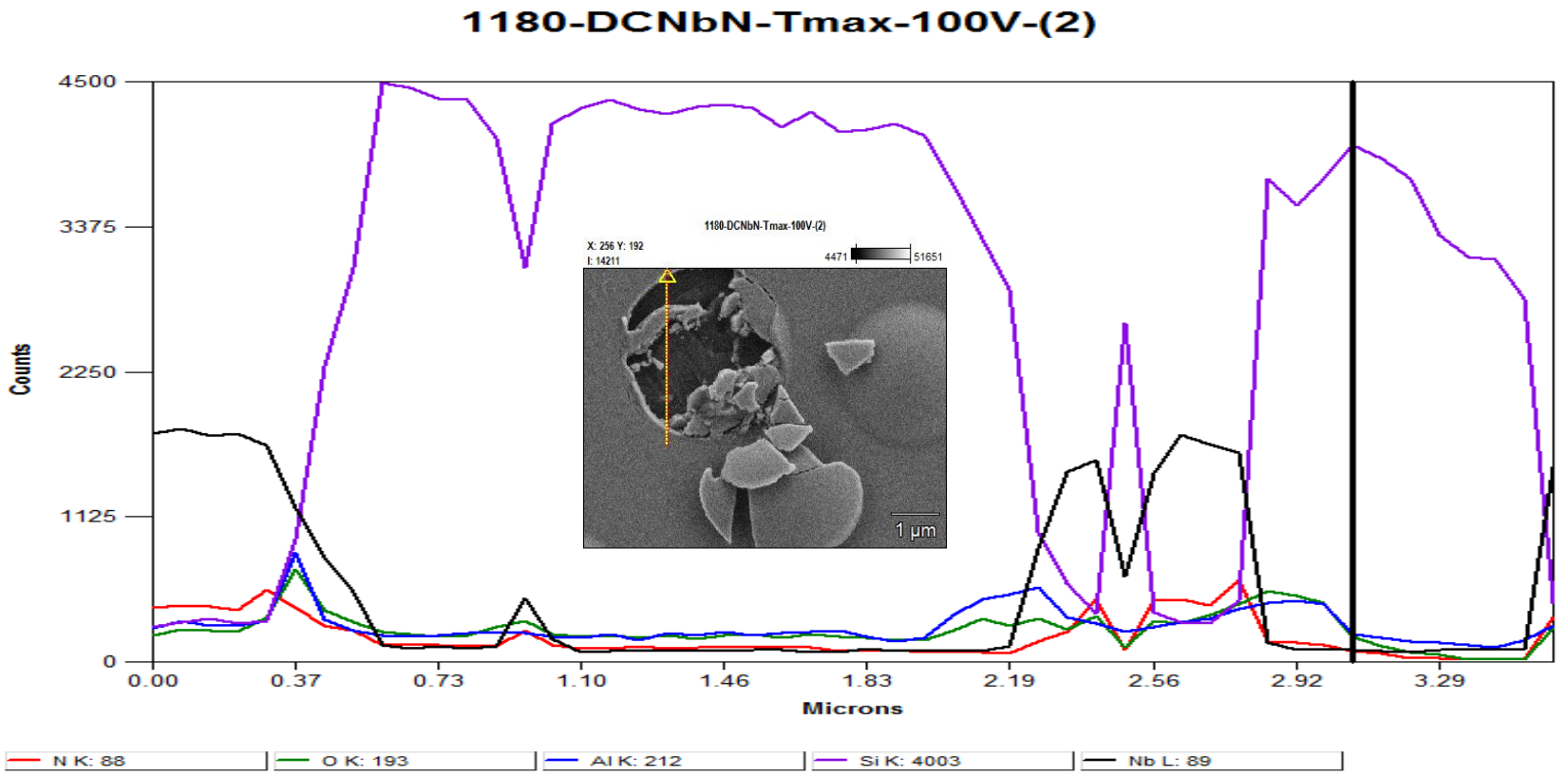
DC – P3

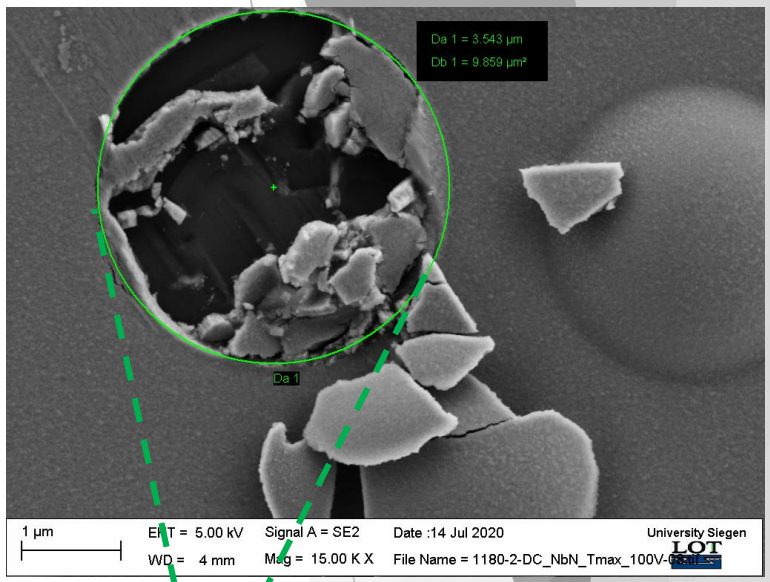


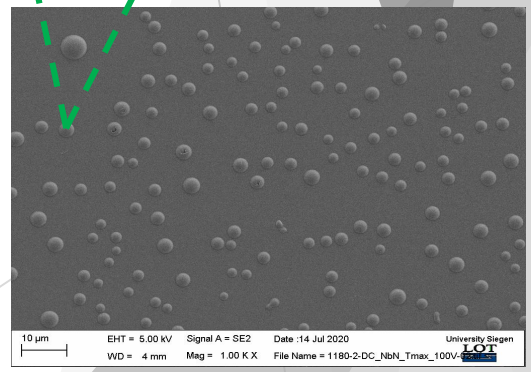


The <u>delamination issue</u> of the insulating layer (ALD-alumina).

The Delamination of ALD-Alumina







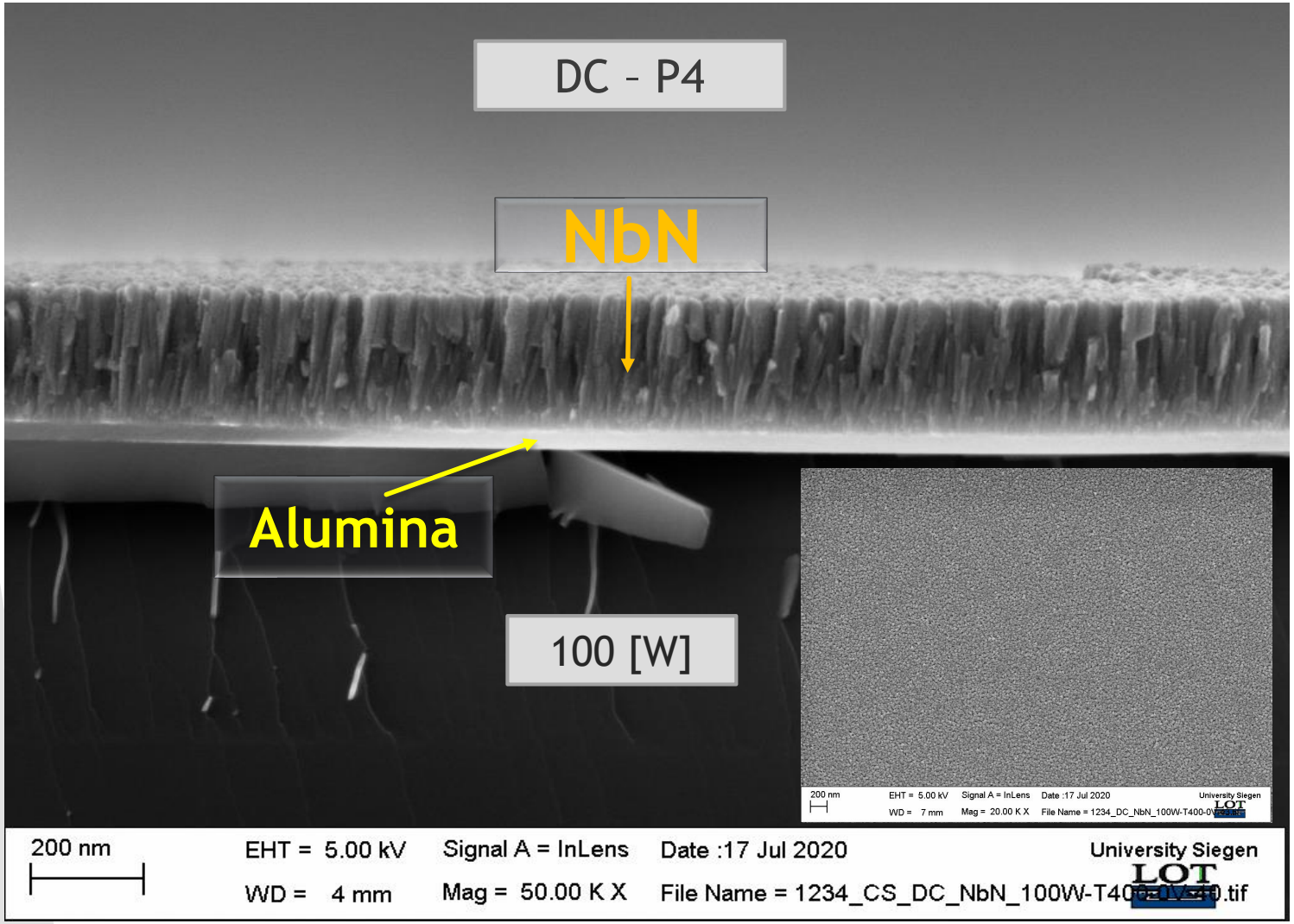
Insulating Deposition System	Thickness (nm)	Bubbles	Thickness (nm)	Bubbles
Al_2O_3 Thermal ALD	42,67	✓	16	✗
Al_2O_3 Thermal in PEALD	39,55	✓	10	✗
Al_2O_3 PEALD	-	-	12,55	✗
AlN PEALD	42,21	✓	18,94	✗

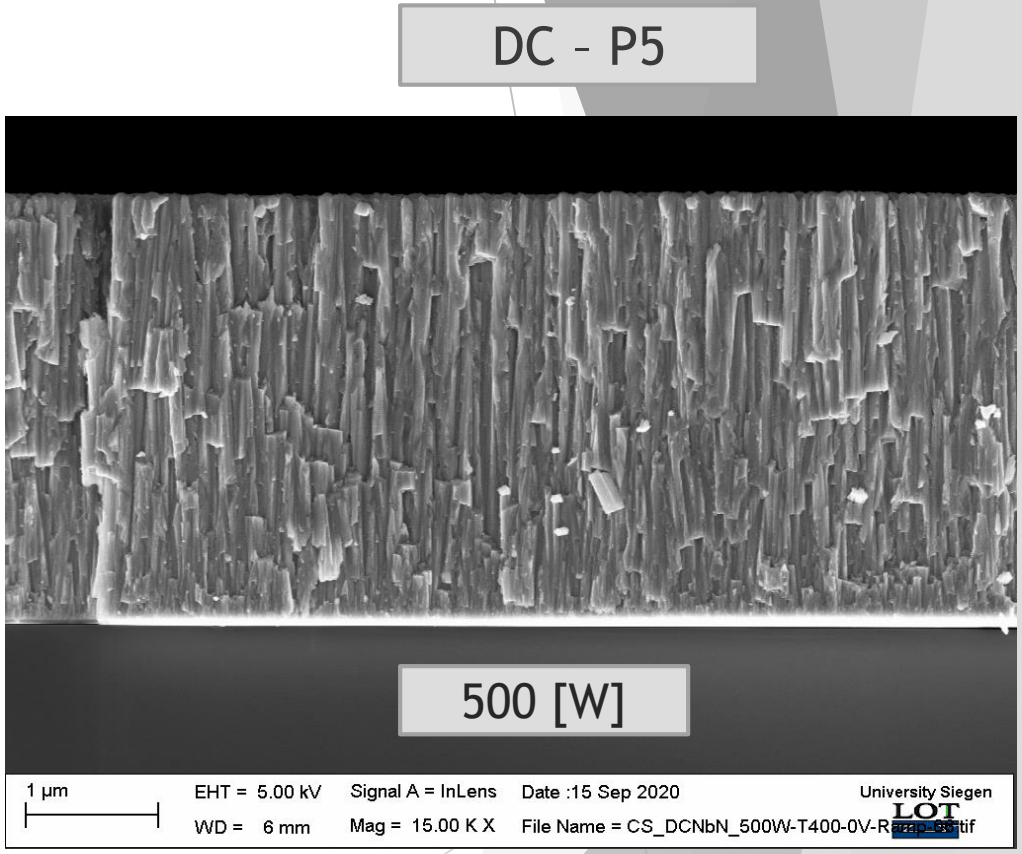
I. Gonzales Diaz-Palacio

(CHyN/UHH)

DC – P2

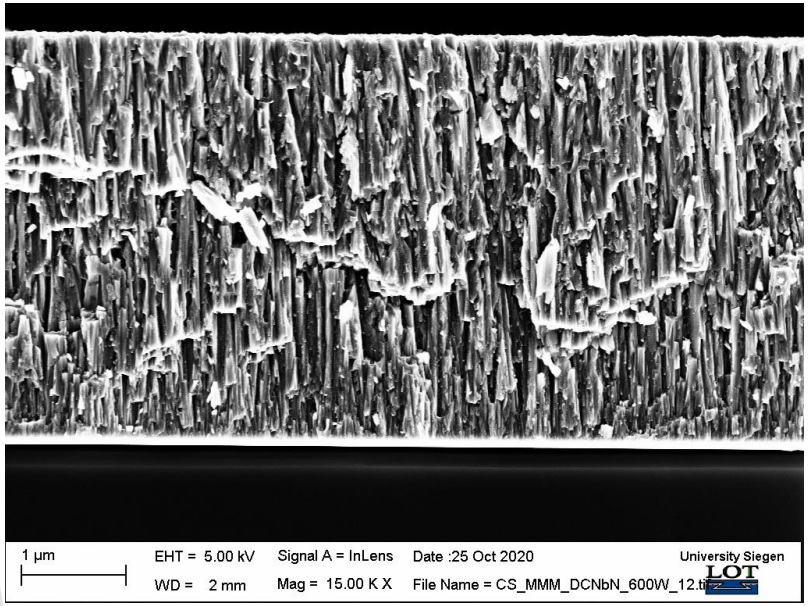
DCMS-NbN Optimizations - High P [W]

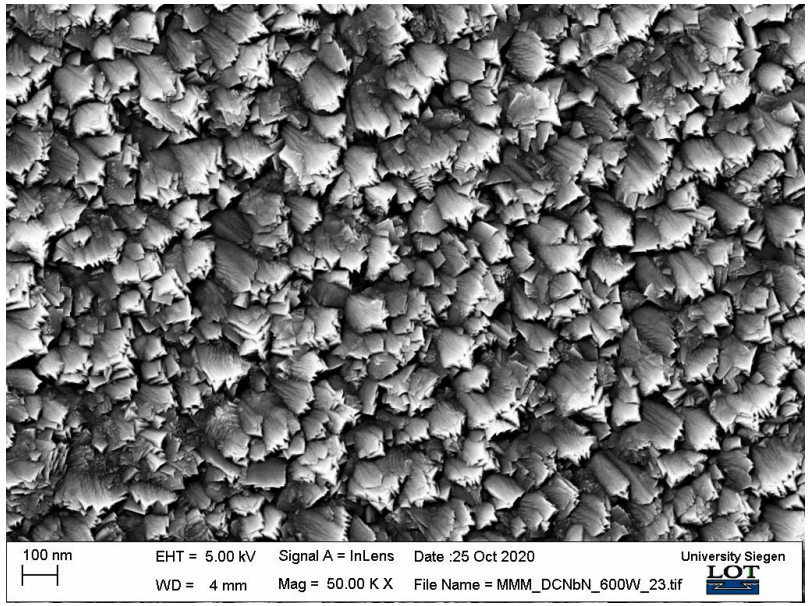


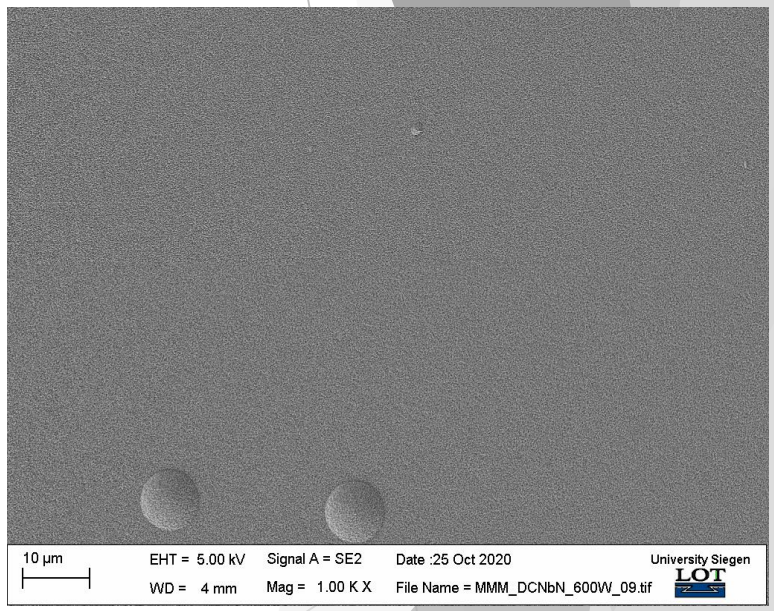


DCMS-NbN Optimizations - High P [W]

DC – P6

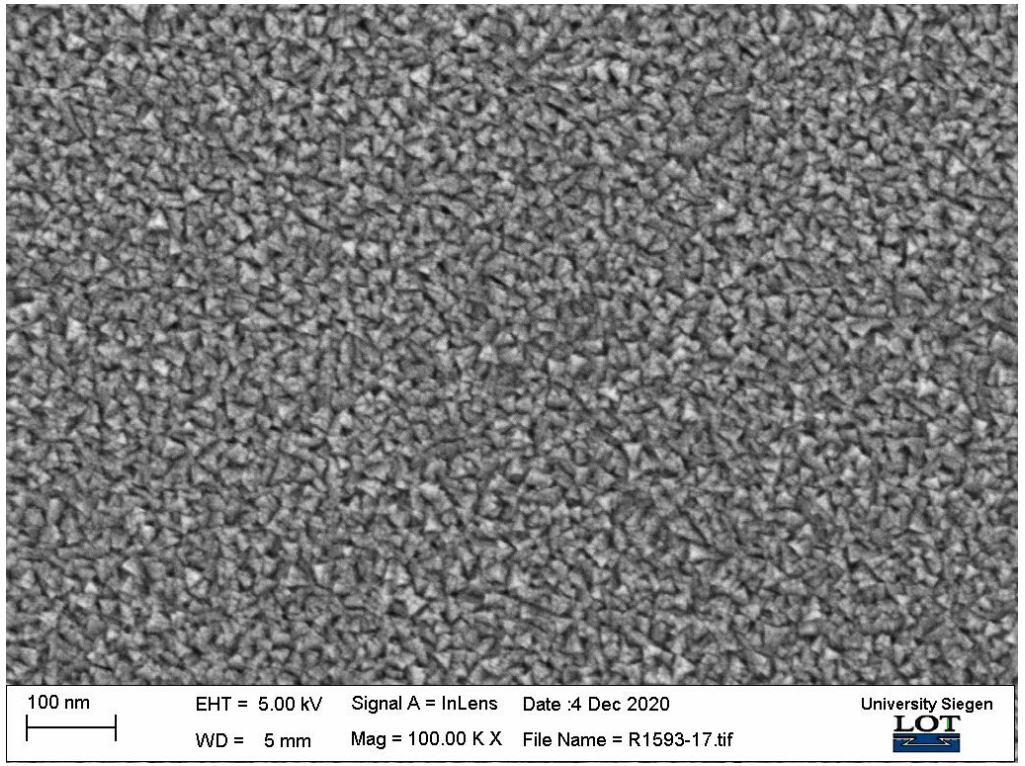




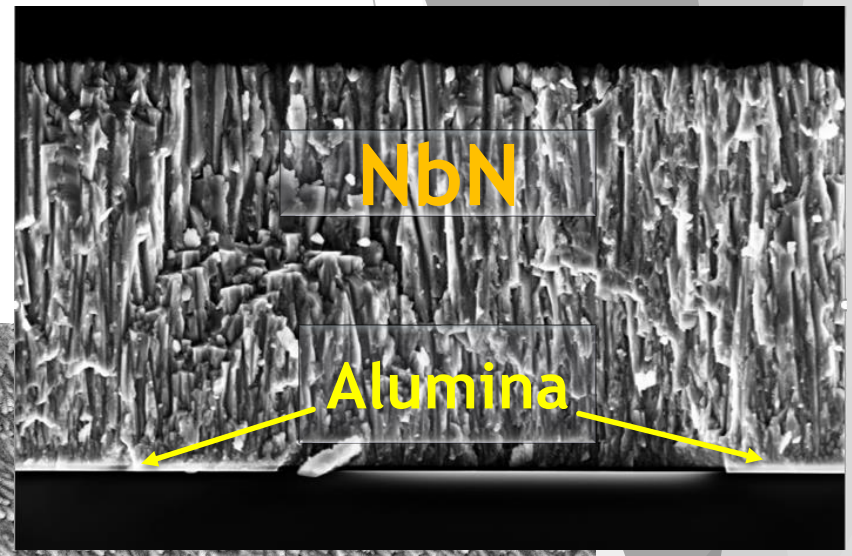


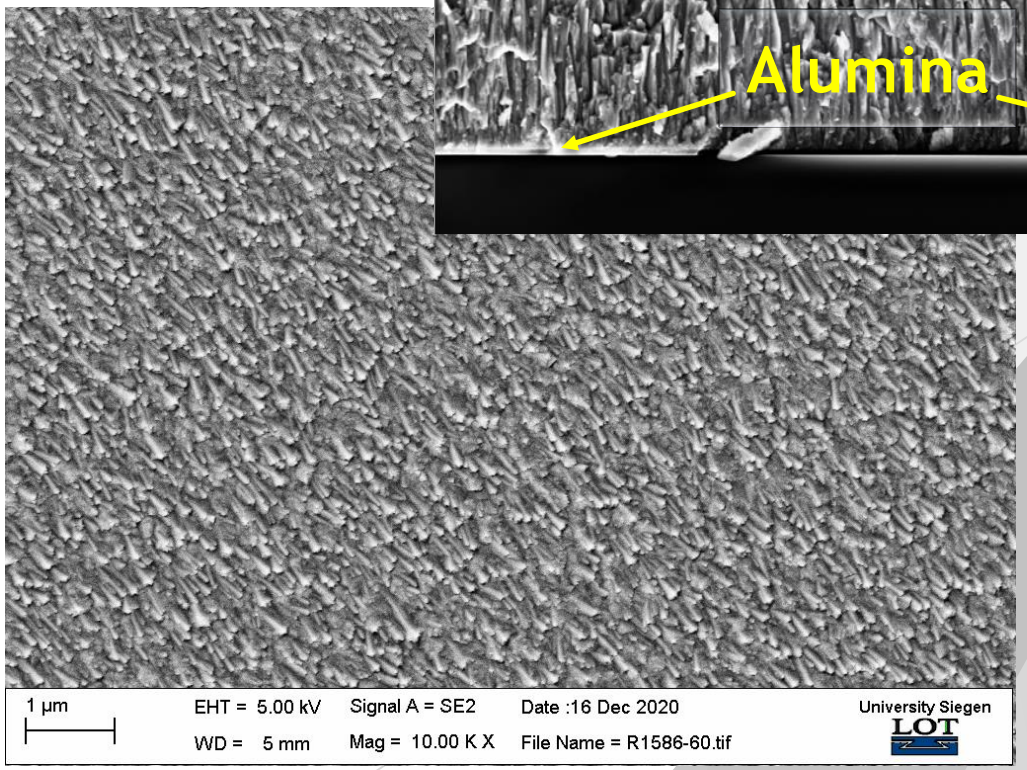
600 W

DCMS-NbN Optimization Studies



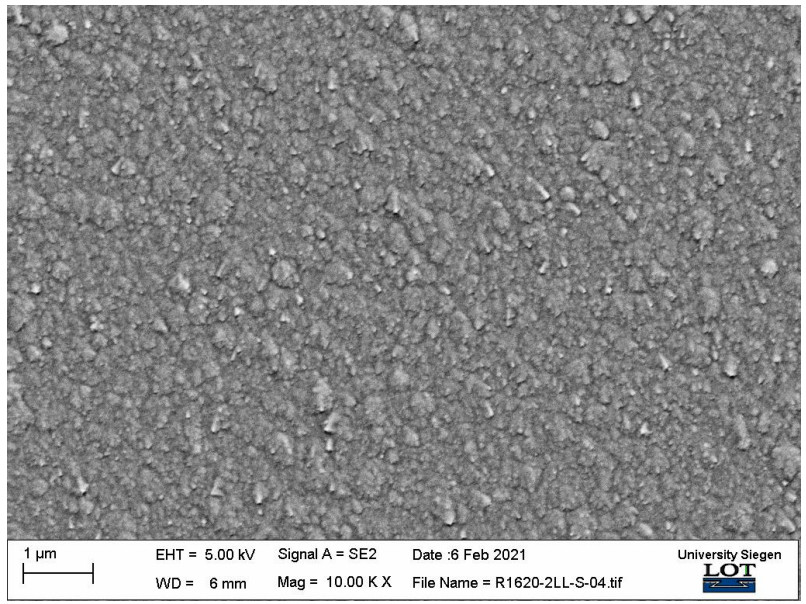
DC-OP1
100W-50V
2100mPa

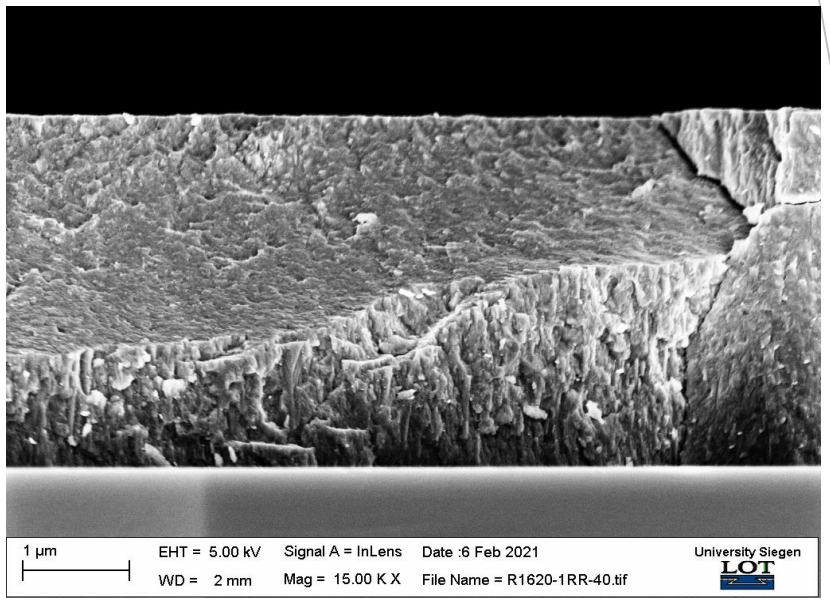




DC-OP2
950W-50V
2100mPa

DCMS-NbN Optimization Studies

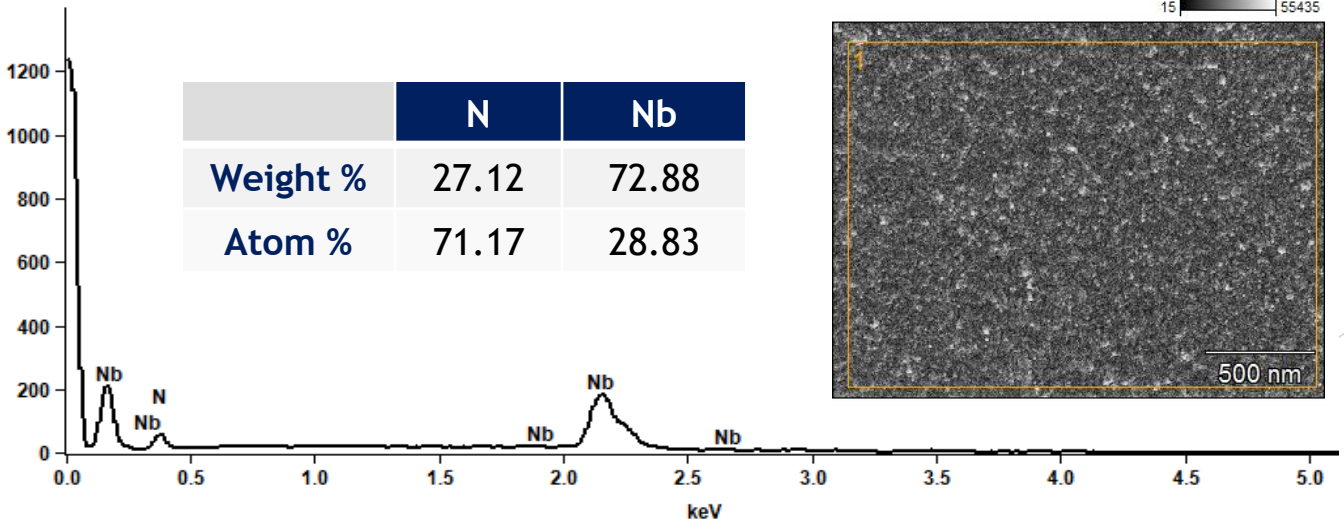




DC-OP3
1100W-50V
2100mPa

Full scale counts: 1234

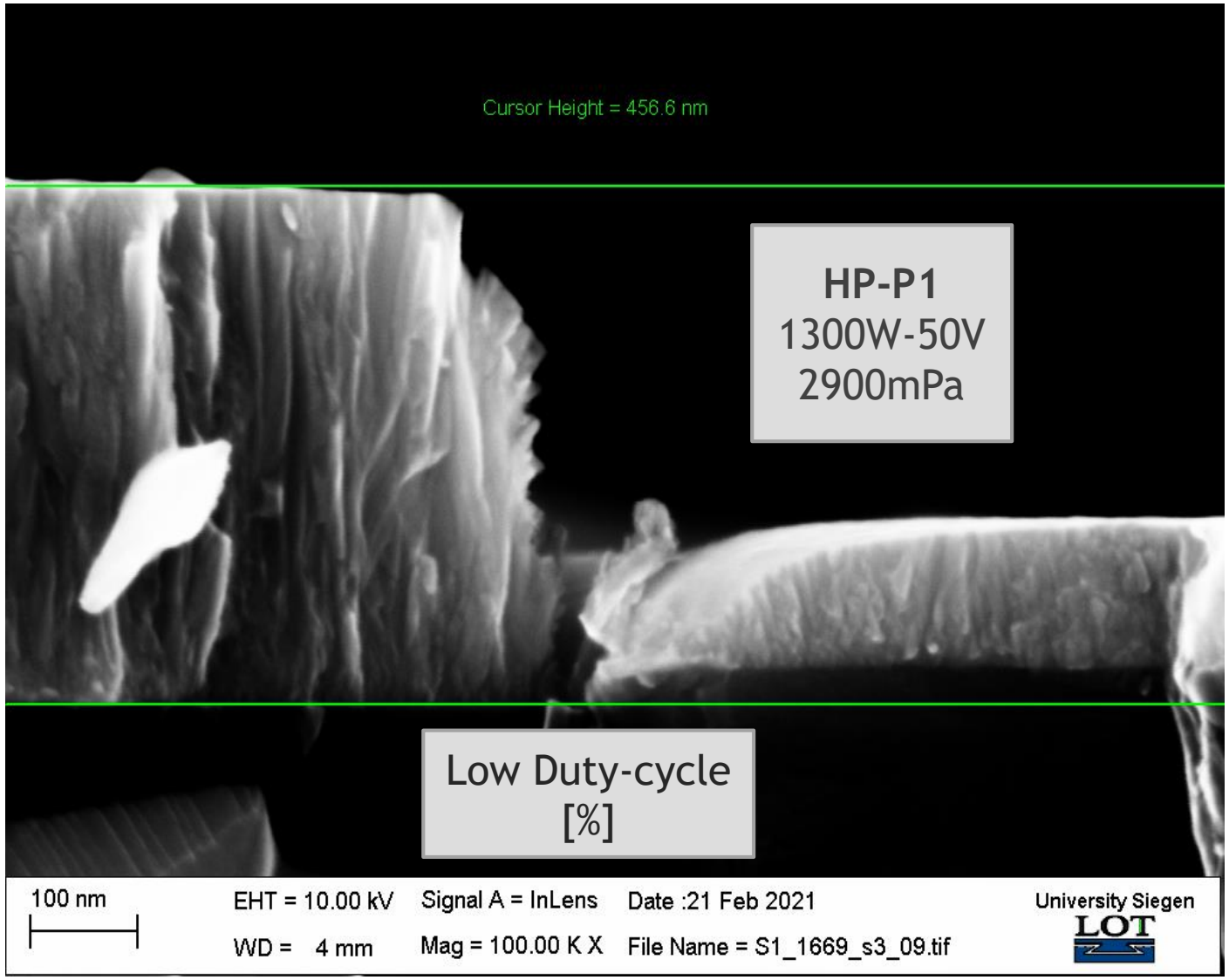
R1620-2LL-(2)_pt1

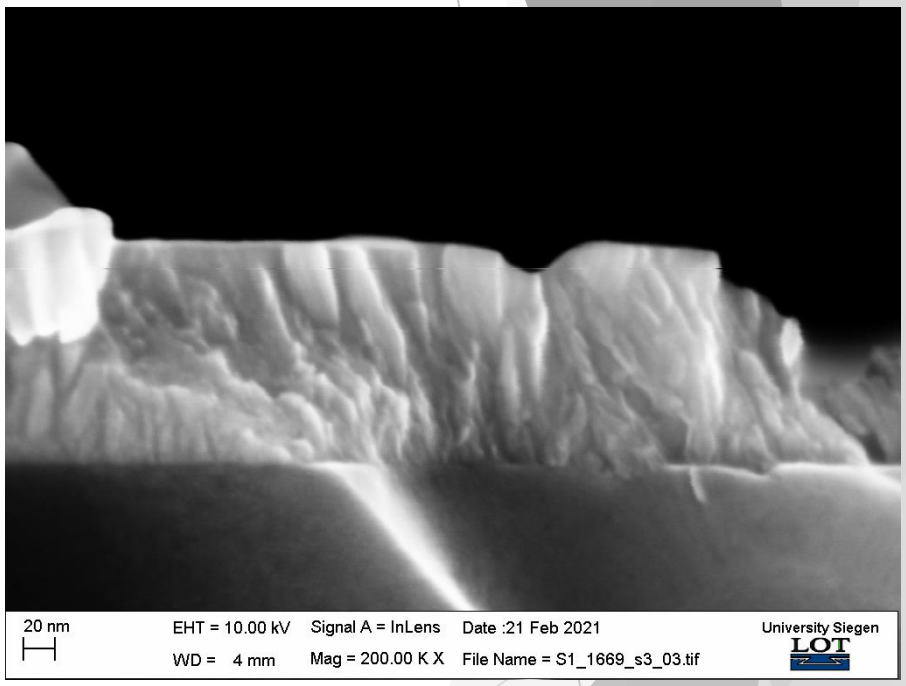


	N	Nb
Weight %	27.12	72.88
Atom %	71.17	28.83

R1620-2LL-(2)

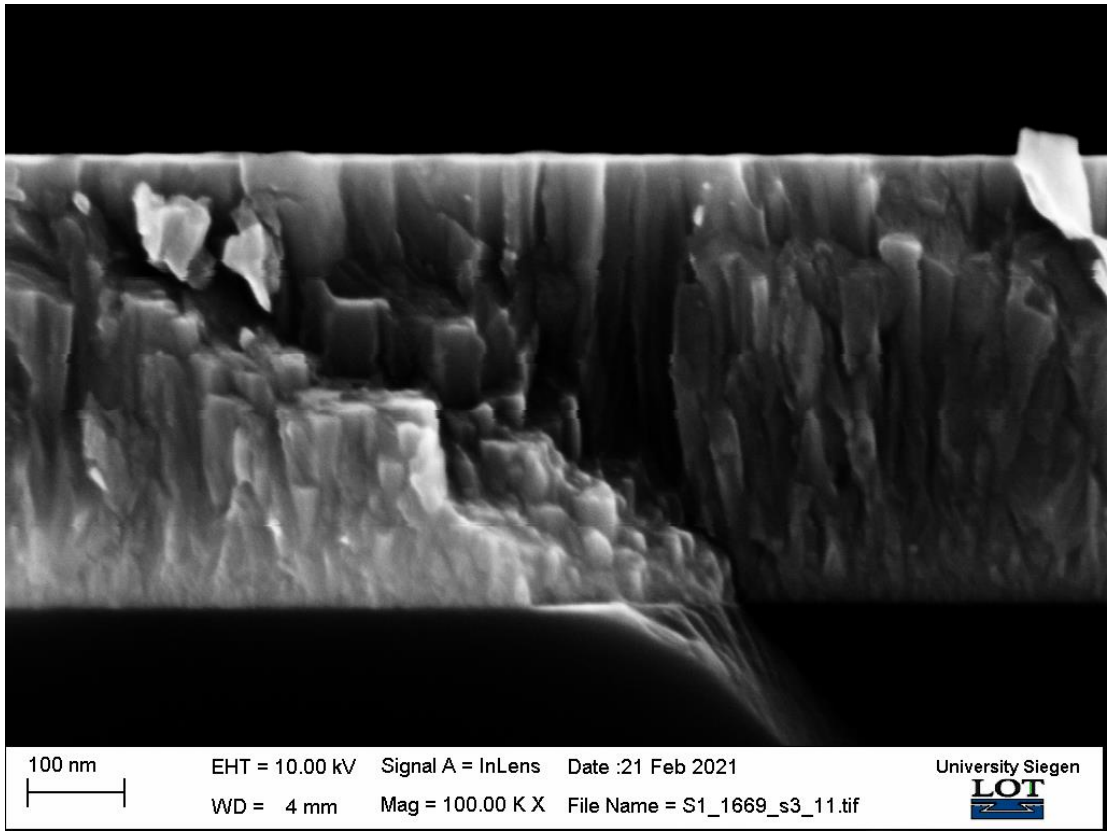
HiPIMS (HP) - NbN Parameter Studies

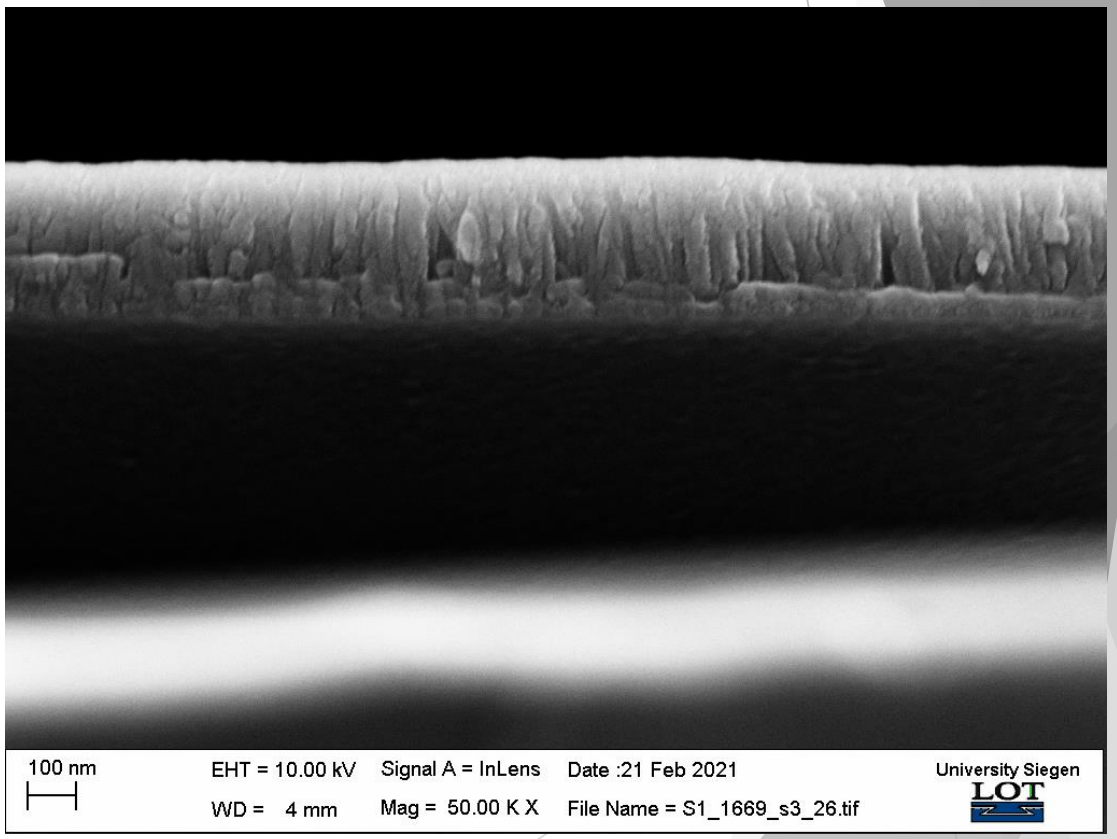




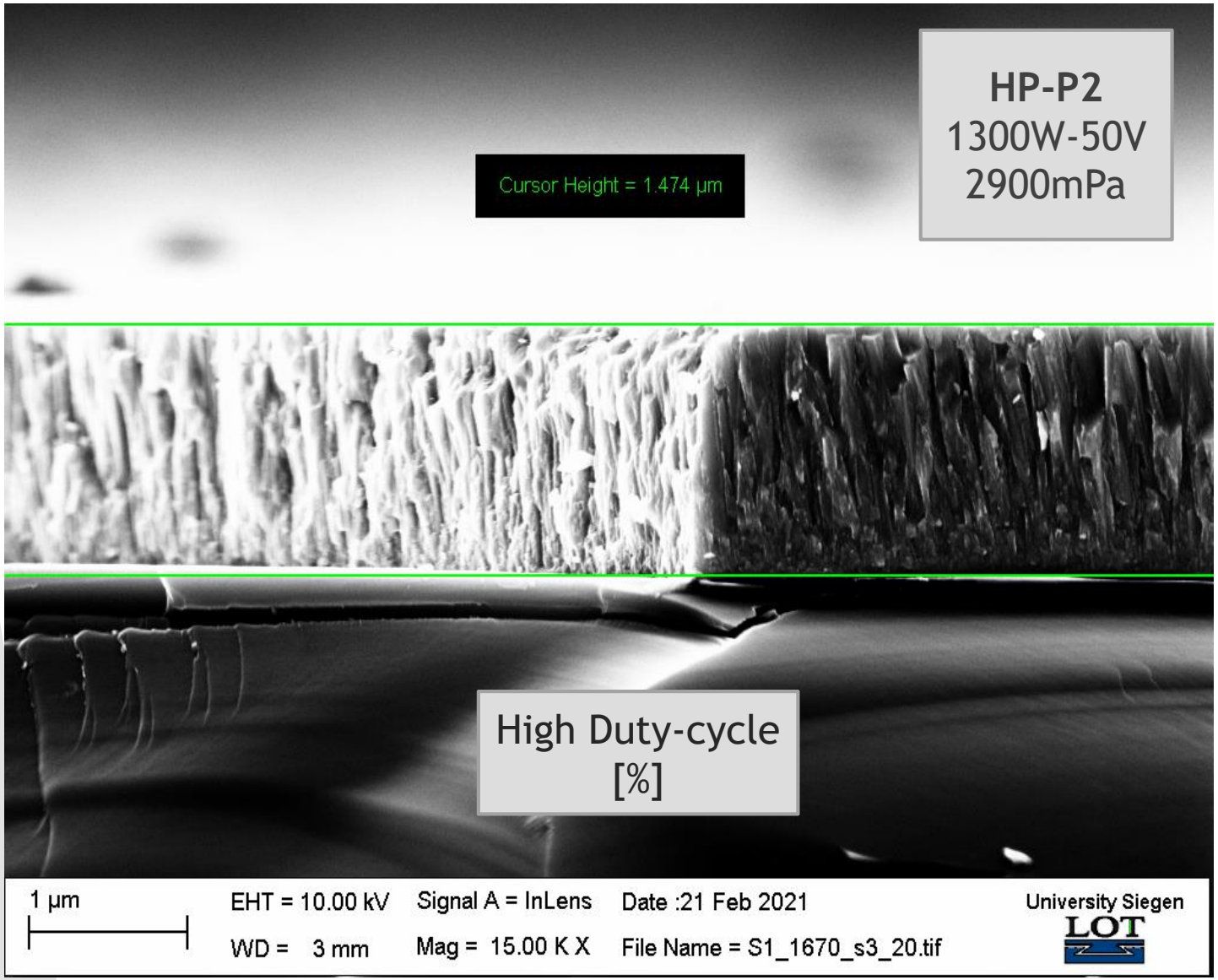
HiPIMS (HP) - NbN Parameter Studies

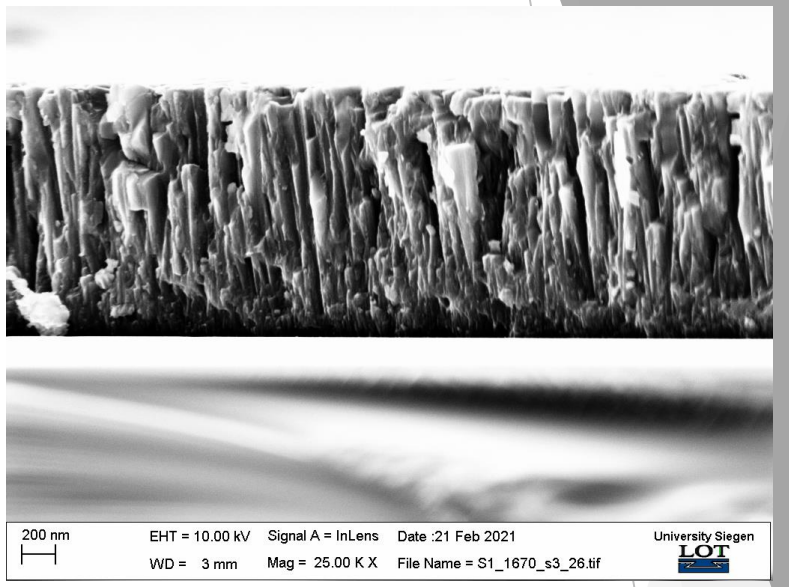
HP-P1

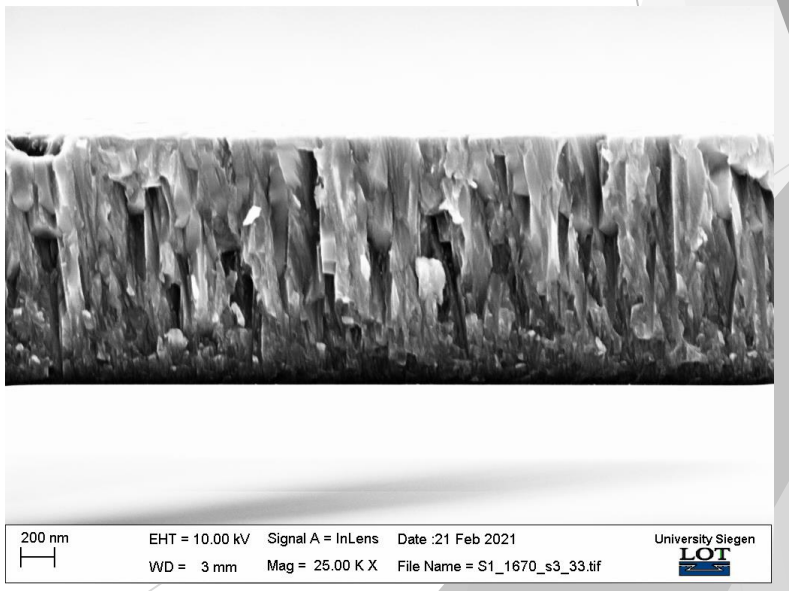




HiPIMS (HP) - NbN Parameter Studies

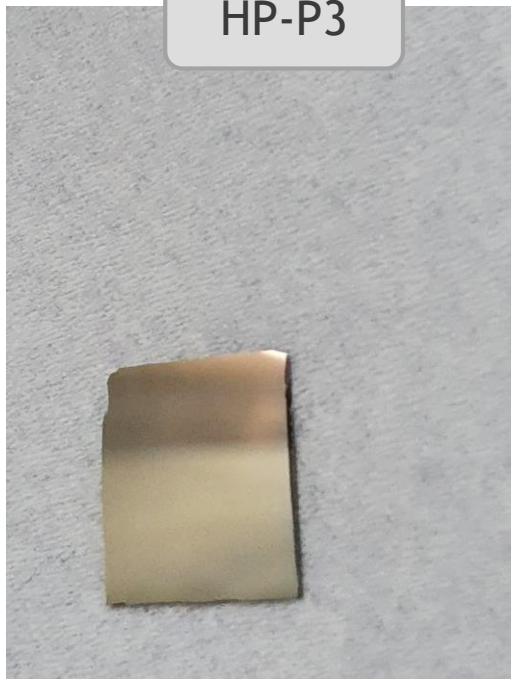




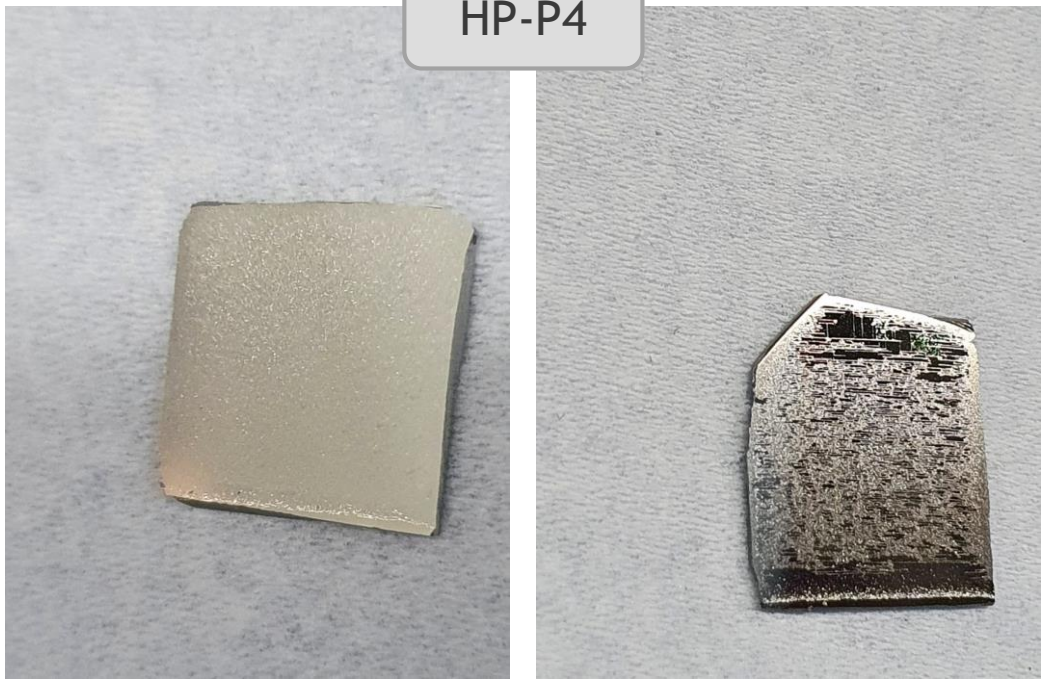


MMM – HiPIMS (HP)-NbN Parameter Studies

HP-P3



HP-P4



2000 Hz

1000 Hz

Rock-Angle:12°

Summary & Outlook

- Further recipe developments for optimized **etching, sputter cleaning, and coating** of **HiPIMS-NbN** thin films in S(I)S structures,
- Further **material (surface & interfacial) characterizations** (e.g., SEM/EDX, XRD, AFM, TEM, SIMS, EBSD etc.) of the **NbN-thin film based multilayer structures.**
- **Superconductivity and RF characterizations** of the optimized NbN thin film-based S(I)S structures.
- Studies of **PVD-Alumina** as well as investigations of the possibility of **NbxOy** as potential **insulating layers in SIS structures**.
- On going **experimental design** of **hybrid (DCMS+HiPIMS)-NbTiN thin films** (to be started soon) and **(RF)-MS-Nb_3Sn** (in the near future) coatings to be applied in SIS structures.
- Transition studies from **flat surfaces** to **more complex geometries** (e.g., **SRF cavities**).

Acknowledgments

- The Colleagues from LOT/USiegen, SMART, and ARIES for fruitful discussions.

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THANK YOU

FOR

YOUR ATTENTION !

For any further curiosity, please feel free to contact via

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