Lehrstuhl für Oberflächen- und Werkstofftechnologie

The Investigation of Sputtered S(I)S Structures for SRF Cavities

10th TFSRF`22
(Jefferson Lab - USA)

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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).

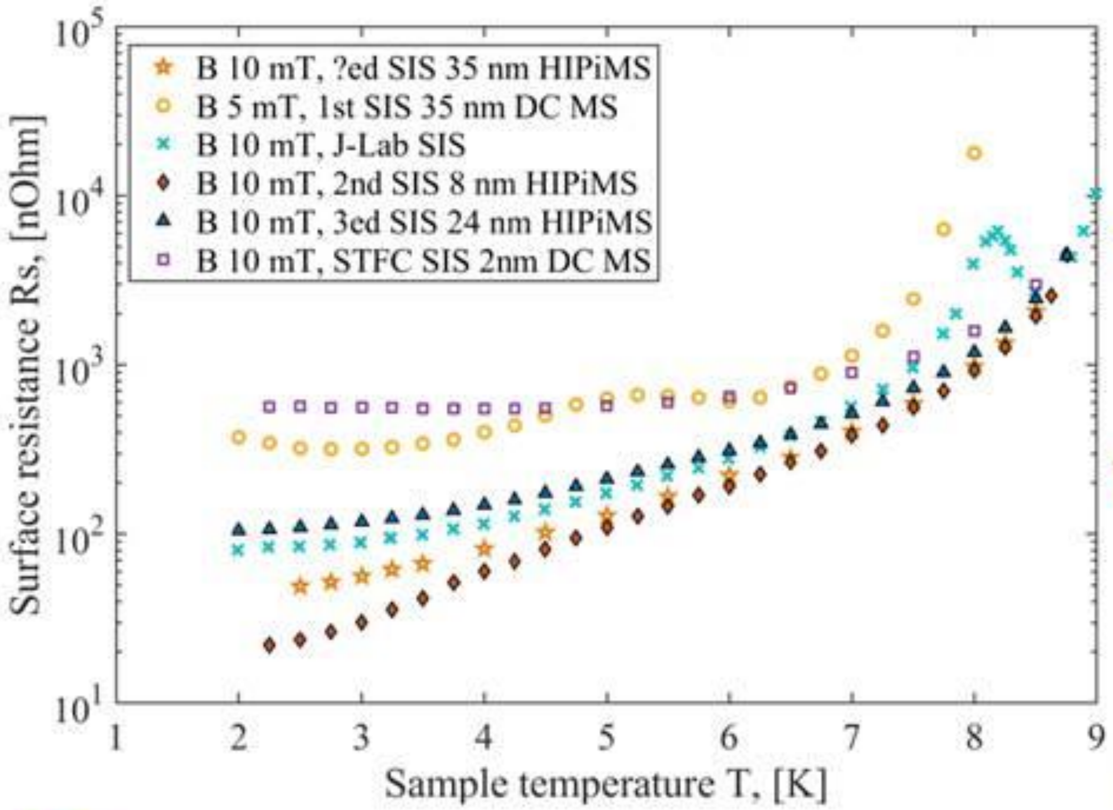
"Optimized multilayers of Nb_3Sn, NbN, some of the iron pnictides, or alloyed Nb deposited onto the surface of the Nb resonator cavities could potentially double ***the rf breakdown field****, pushing* ***the peak accelerating electric fields*** *above* ***100 MV/m*** *while protecting the cavity from* ***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

The current status in the multilayers research for SRF

Frequency fit (approx. data)

HZB Helmholtz Zentrum Berlin



AlN thickness	Method	R_{res} (Approx) (nOhm)
35 nm	DC MS	375
☆ 35 nm	HiPIMS	44
24 nm	HiPIMS	104
8 nm	HiPIMS	21
~2 nm	DC MS	567
☆ 0	HiPIMS	44

*All data with subtracted stainless-steel shift (~24 nOhm) or with Nb coated flange [3]

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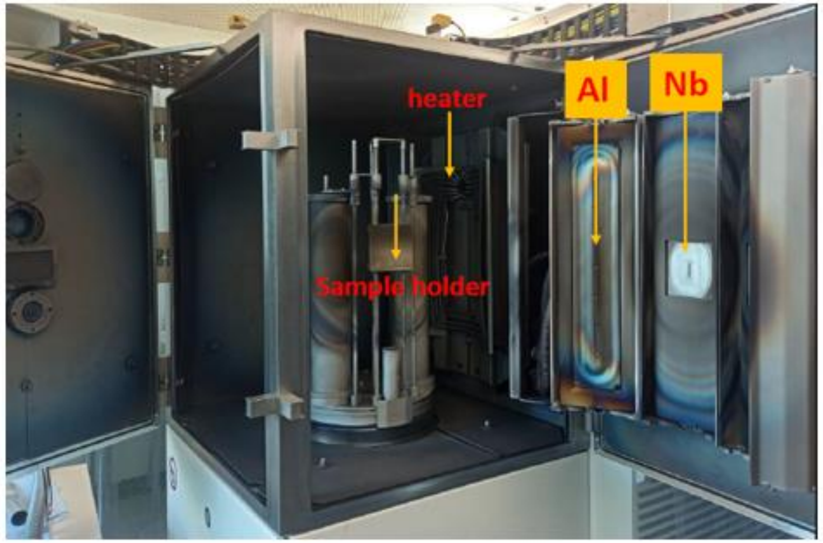
[4]

Experimental Design

CemeCon – CC800 at USI



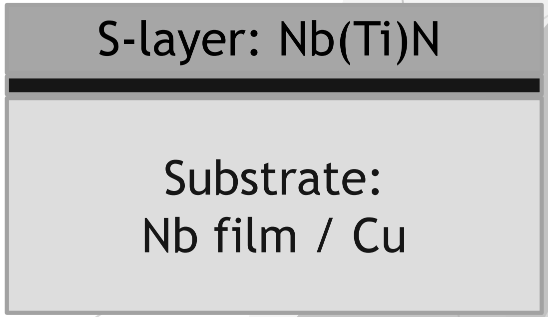
The deposition parameter window of HiPIMS-coated S(I)S structures for VSM* and QPR** tests **[5,6]**.

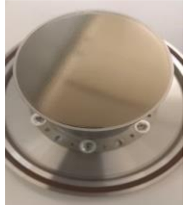
Material	Cathode Power [W]	Substrate Bias [V]	Deposition Pressure [mbar]	N_2 Content [vol%]	Process Temperature [°C]
Nb	**600*, 400****	**50*, 50****	**2.0×10^{-2}*, 8.0×10^{-3}****	**0* & ****	**400**
(AlN)	**3500* & ****	**0* & ****	**6.0×10^{-3}* & ****	**100* & ****	**400**
NbN	**600*, 400****	**50*, 50****	**2.7* x 10^{-2}*, 2.5×10^{-2}****	**8*, 10****	**400**

*corrected.

The uncoated Cu-QPR sample

((PVD / PE-ALD)-coated I-layer: AlN) →

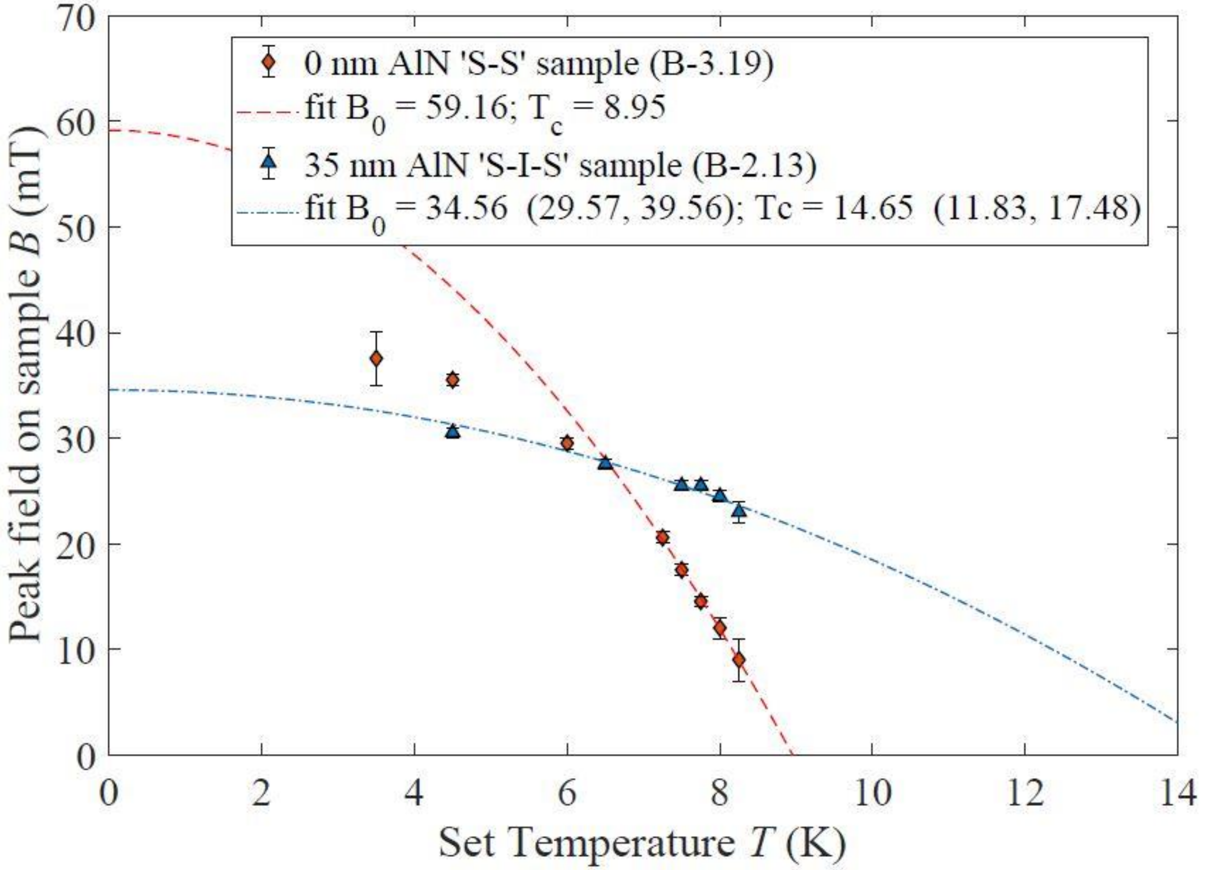


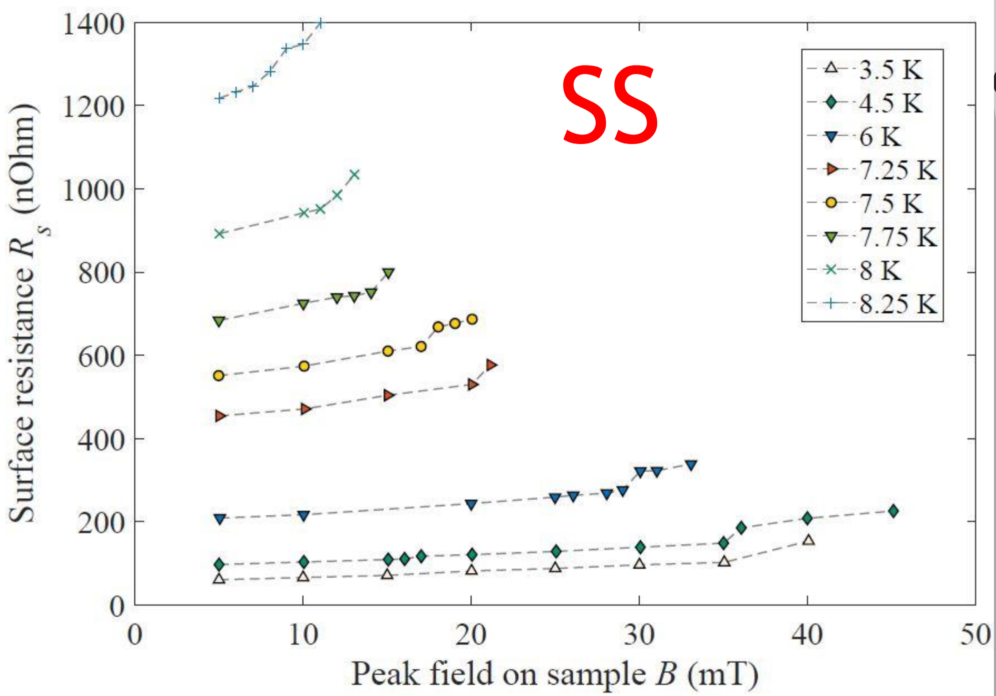


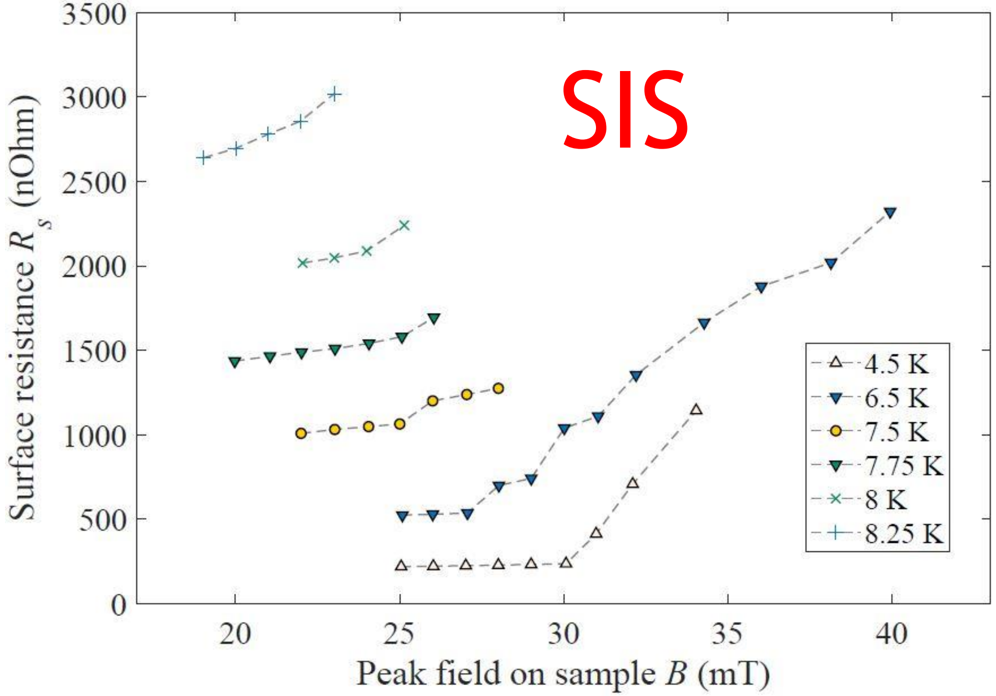
The HiPIMS-S(I)S (Nb/(AlN)/NbN)-coated Cu-QPR sample

QPR Results - HZB

Rs=(T, Bpeak) of S(I)S:



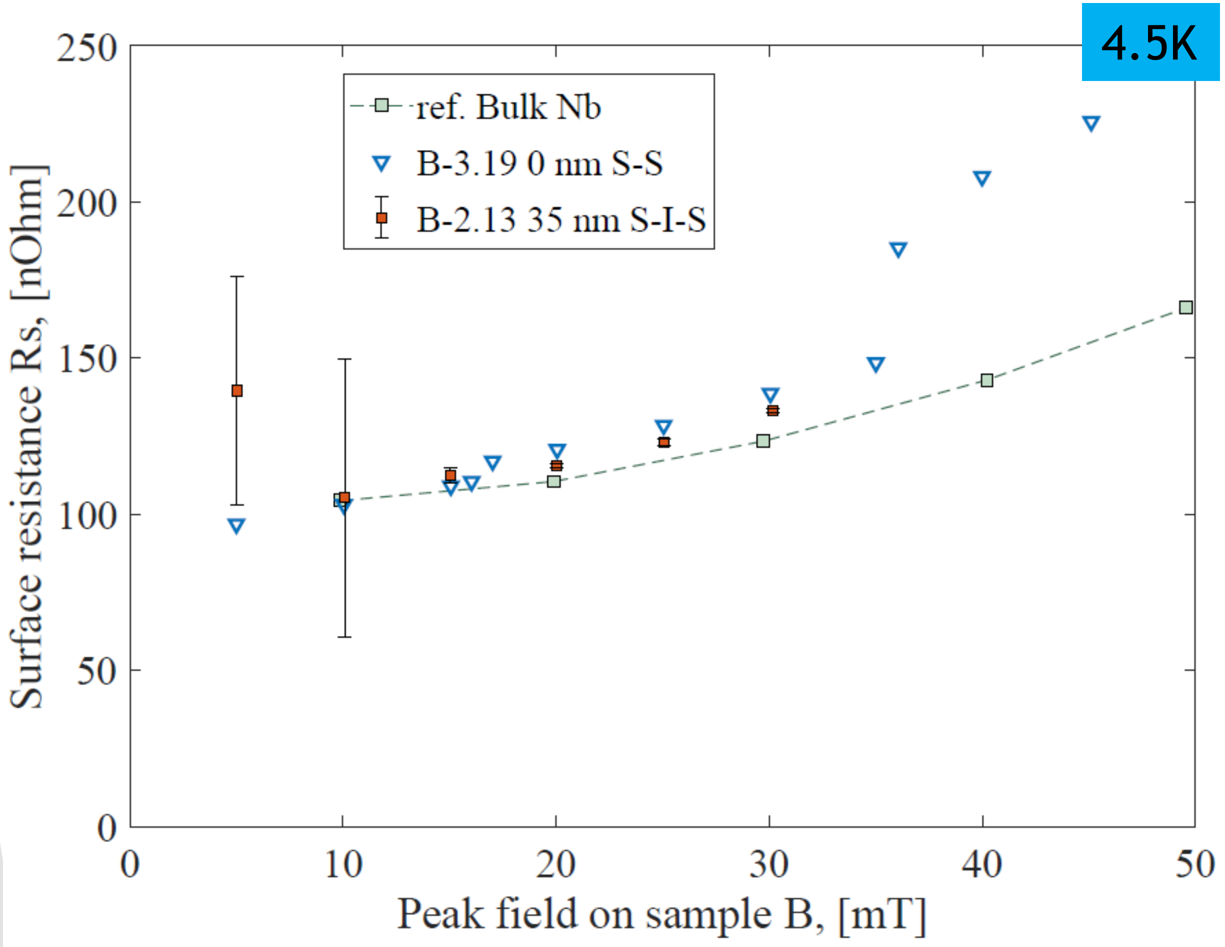


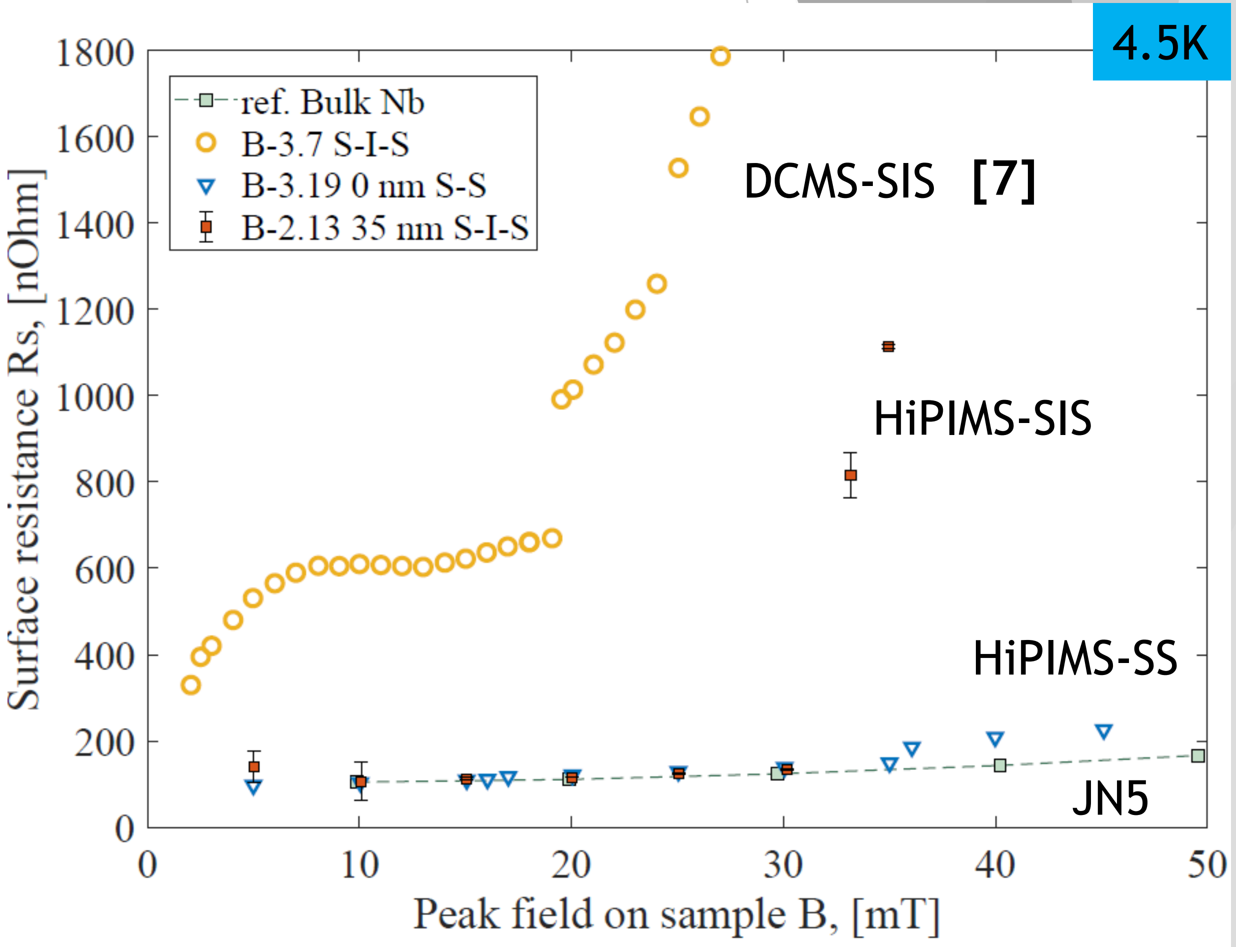


[6]

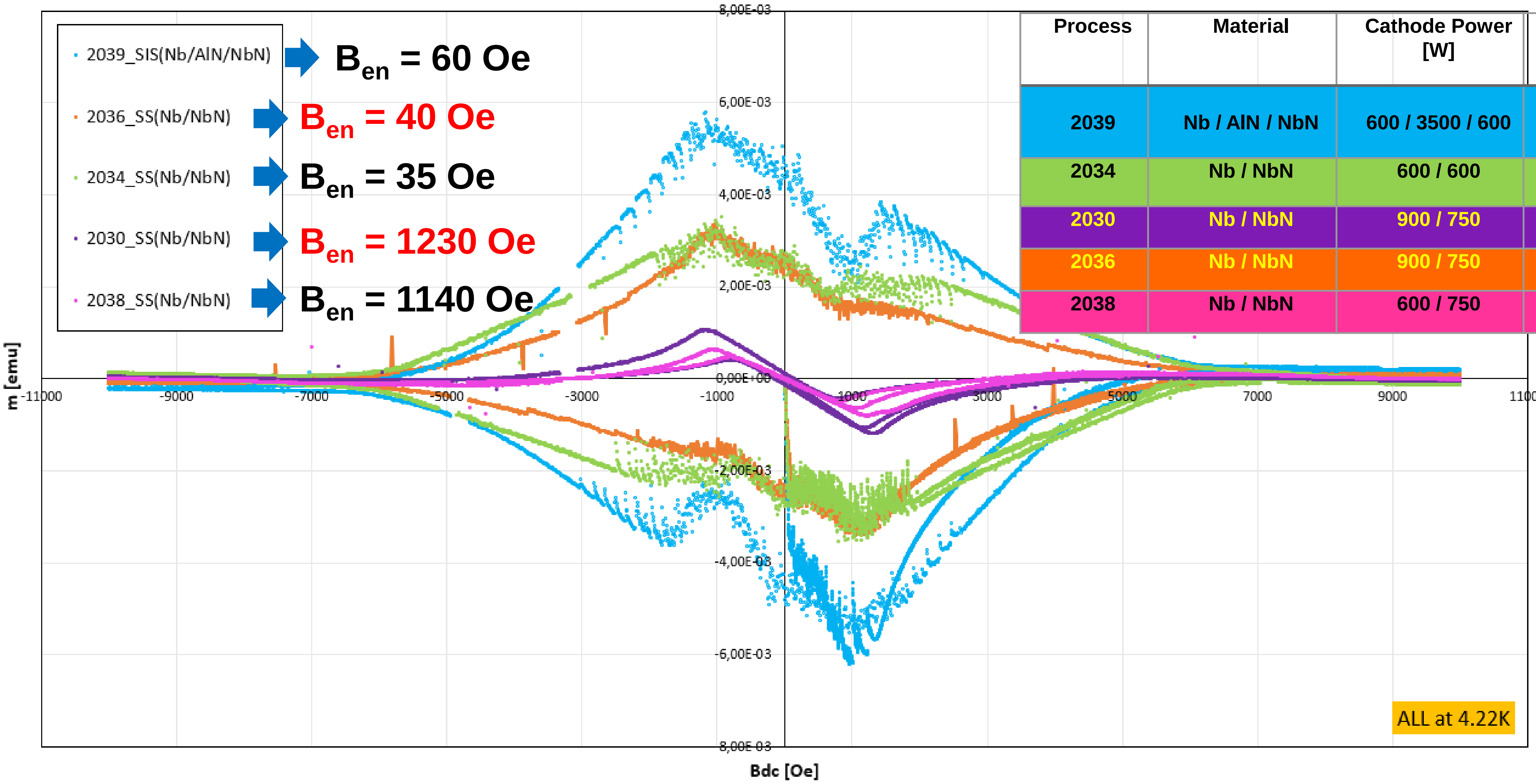
QPR Results – HZB

Rs=(Bpeak) for the S(I)S structures vs the Bulk Nb (JN5):



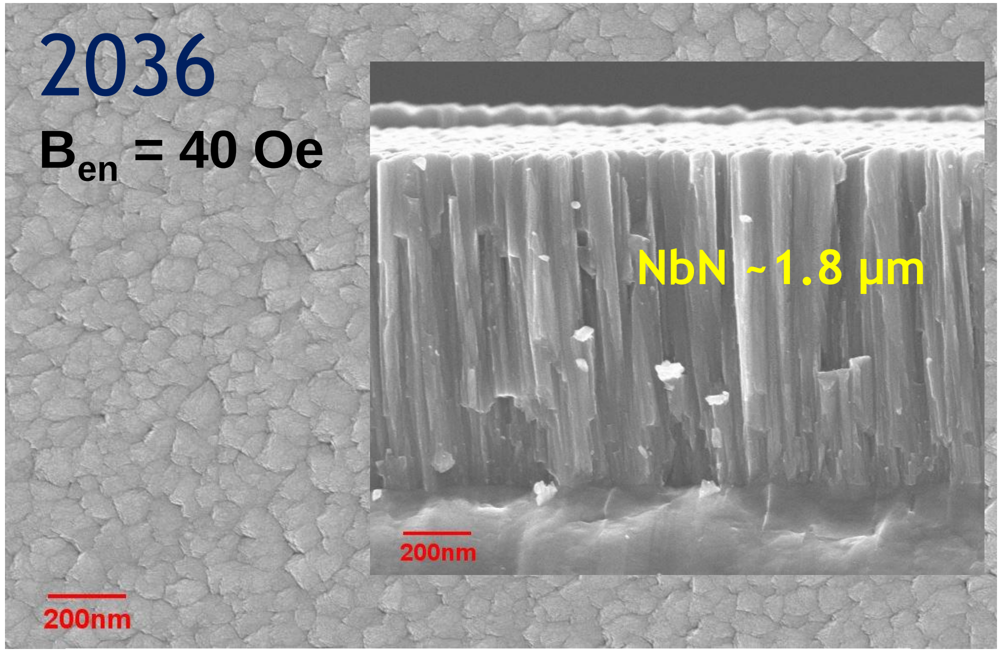


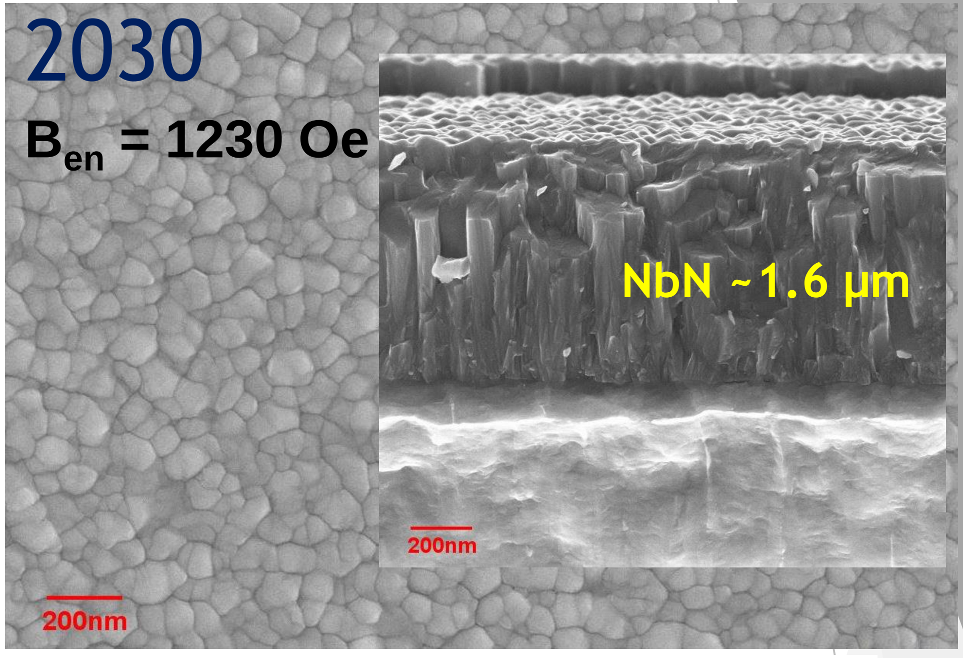
VSM Results (on Si) – IEE SAS

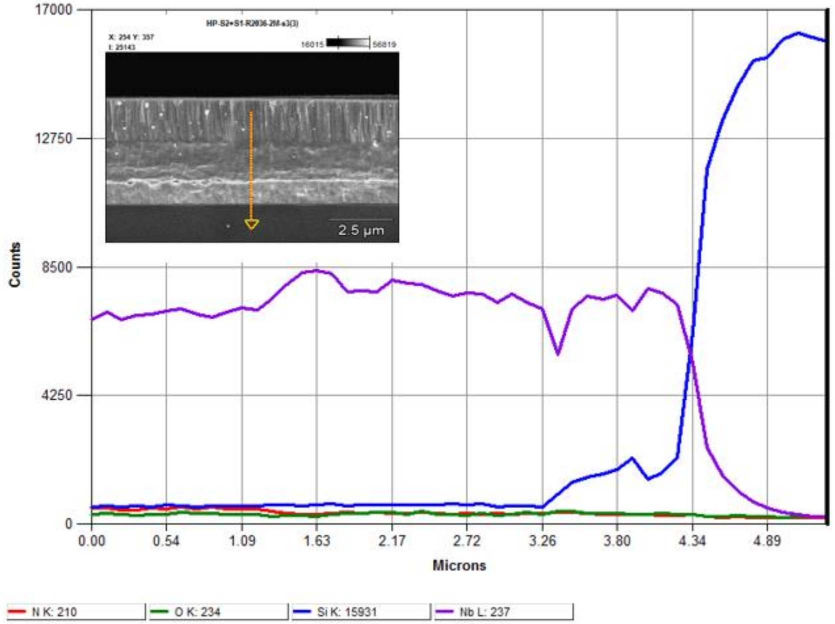


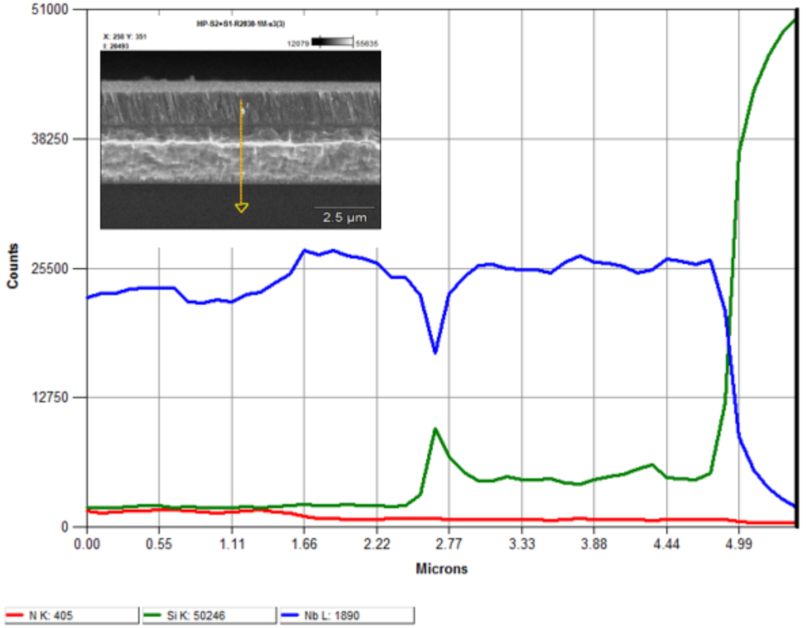
Process	Material	Cathode Power [W]	Substrate Bias [V]
2039	Nb / AlN / NbN	600 / 3500 / 600	50 / 0 / 50
2034	Nb / NbN	600 / 600	50 / 50
2030	Nb / NbN	900 / 750	50 / 50
2036	Nb / NbN	900 / 750	0 / 0
2038	Nb / NbN	600 / 750	50 / 50

Materials Characteristics (SEM / EDX) - USI

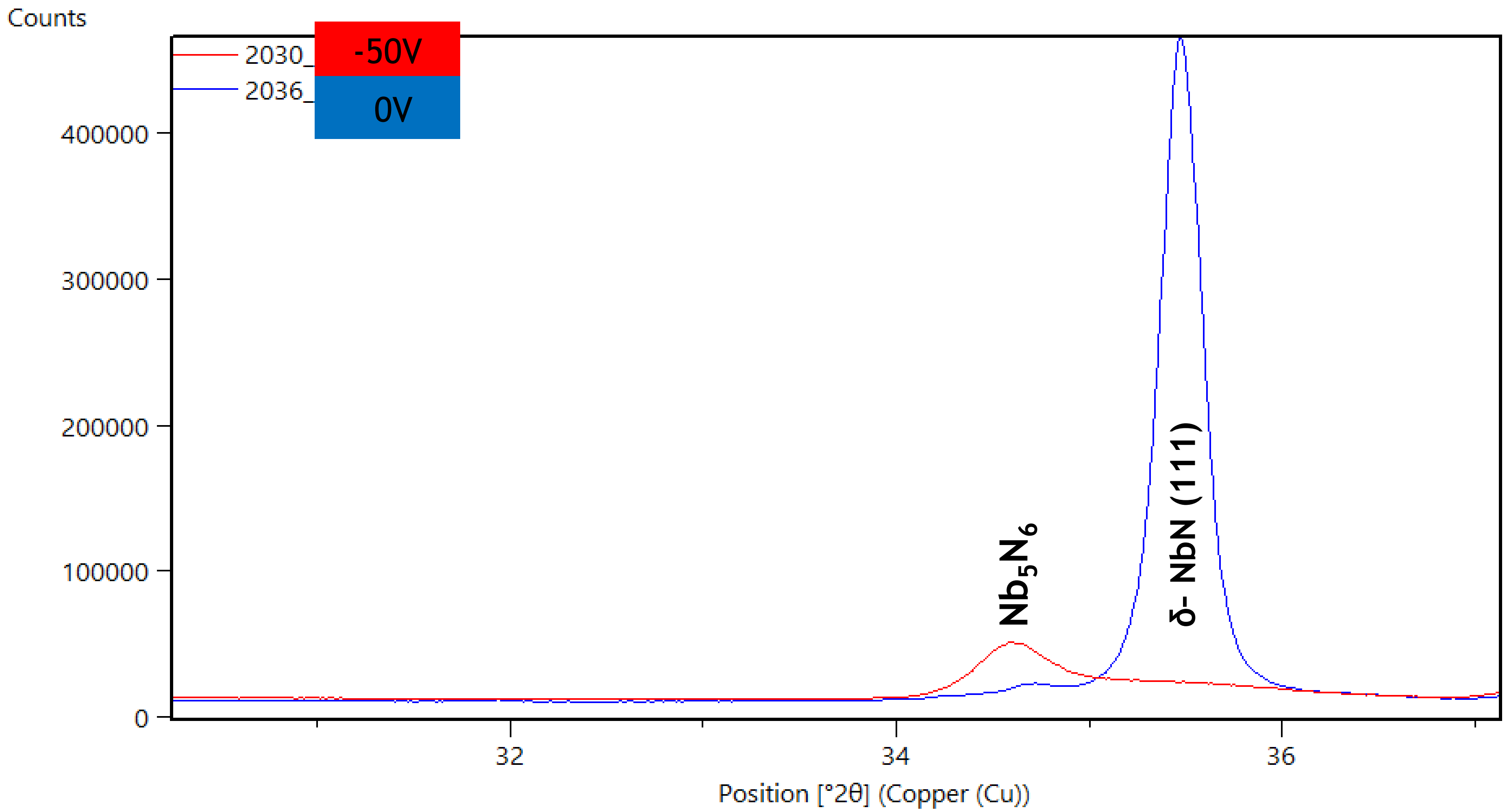








Materials Characteristics (XRD)- USI



Summary & Outlook

1. While it had been previously shown that **the HiPIMS-coated SIS structures perform better than the DCMS-coated SIS structures** [7]; in this recent study, we show that together with the right deposition parameter space, highly performing **HiPIMS-coated SS structures** could be obtained, and in some cases seemingly even **better than the HiPIMS-coated SIS structures under RF fields**.

2. **The HiPIMS-coated SS structure** attains lower R_s values up to higher B_{peak} field ranges **(>45mT)** compared to the HiPIMS-coated SIS structure, albeit having lower T_c.

3. **The previously observed non-monotonic R_s behaviour** seems to emerge particularly in the DCMS-coated SIS strucutures as compared to HiPIMS-coated S(I)S structures; drawing the attention more towards the quality of the superconducting layers rather than the insulating layer, per se.

4. These recent results require more detailed studies of not only the insulating layers within the alternating multilayers; but also, **the interfacial phenomena** between the insulating and superconducting layers with advanced material techniques such as **STM, PALS,** TEM, SIMS, etc. for fundamental understandings.

Acknowledgments

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For any further curiosity, please feel free to contact via

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