A_RD_20
Innovative superconducting surfaces applied to cavity scale

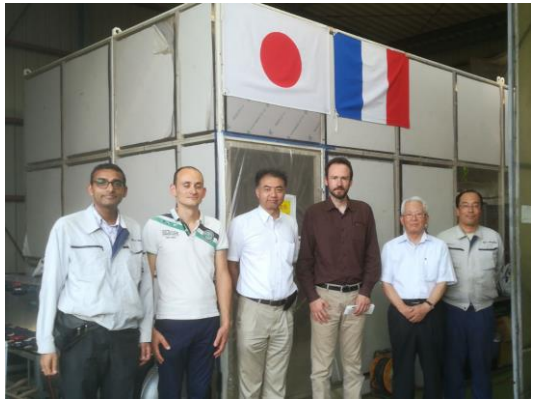
TYL/FJPPL

9th Joint Workshop of the France-Japan (TYL/FJPPL) and France-Korea (FKPPL)
International associated Particle Physics Laboratories

May 11th 2021

GOAL OF A_RD_20 PROGRAM

- Modelling multilayers/optimization
- Deposition and characterization of multilayer films (S-I-S; S-S')
- Apply results achieved within A_RD_9 to the cavity case
- Apply optimized Vertical Electro-Polishing (VEP) Technology to different cavity geometries (704MHz)
- Study the effect of doping for this kind of cavities

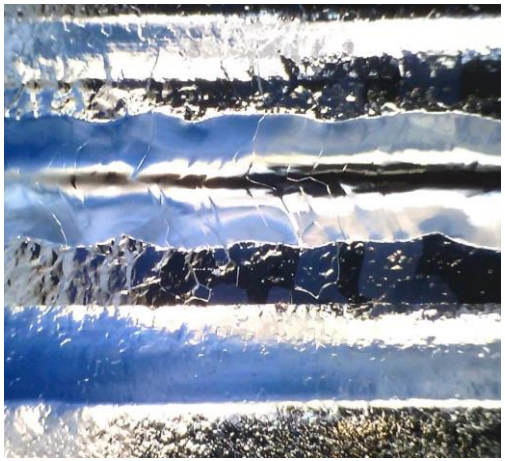


ID[1]:	Title: Innovative superconducting surfaces applied to cavity scale					
	French Group			Japanese Group		
	Name	Title	Lab./Organis.[2]	Name	Title	Lab/Organis.[3]
Leader	F. Eozénou		Irfu	Takayuki Saeki	Dr.	KEK
Members	T. Proslier	Dr.	Irfu	Hitoshi Hayano	Dr.	KEK
	C. Madec	Dr.	Irfu	Shigeki Kato	Dr.	KEK
	C. Antoine	Dr.	Irfu	Hideaki Monjushiro	Dr.	KEK
	S. Berry	Dr.	Irfu	Havato Ito	Dr.	KEK
	E. Cenni	Dr.	Irfu	Takeyoshi Goto	Dr.	KEK
	C. Servouin		Irfu			

T. Saeki is temporary new leader for KEK side

VEP 704MHZ: STATUS AT LAST WORKSHOP

ESS 1C cavity on VEP set-up

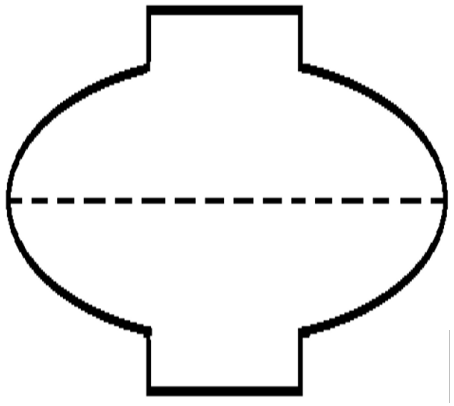


Equator surface (80µm average removal)

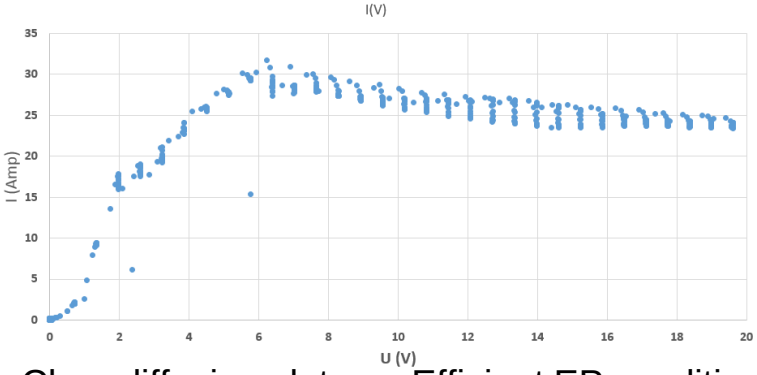
- VEP with rotating Ninja cathode
- Surface quality > BCP
- Symetric removal
- Excellent Rres:<4nOhm

Promising results. Waiting for the VT…

Delta total µm
44,5
49
50
75
83,5
86
84,5
84,5
75
79,5
97
128,5
92
88
86
87
85
76
72,5
52,5
44
56



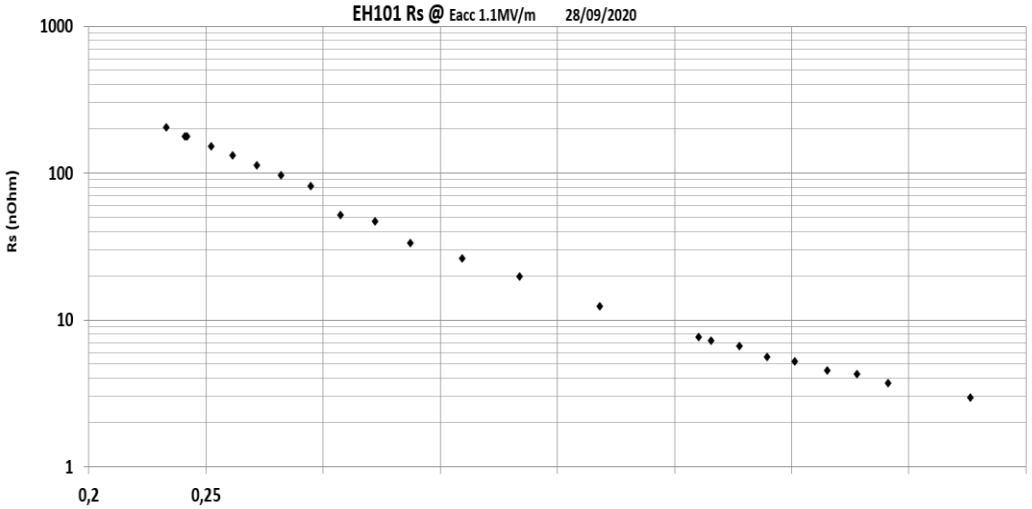
Uniform removal in the cell
(measurement after 80µm average)



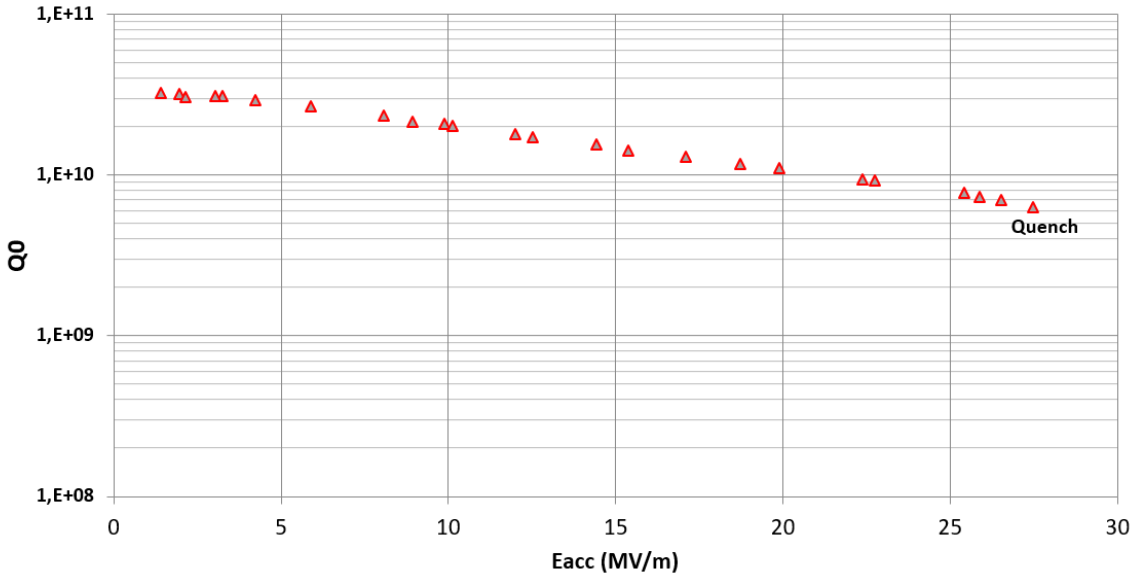
Clear diffusion plateau: Efficient EP conditions.
Working Parameters:

- U: 20V
- Acid flowrate: >15L/min
- T<15°C

EXCELLENT RF RESULTS AT THIS STAGE!



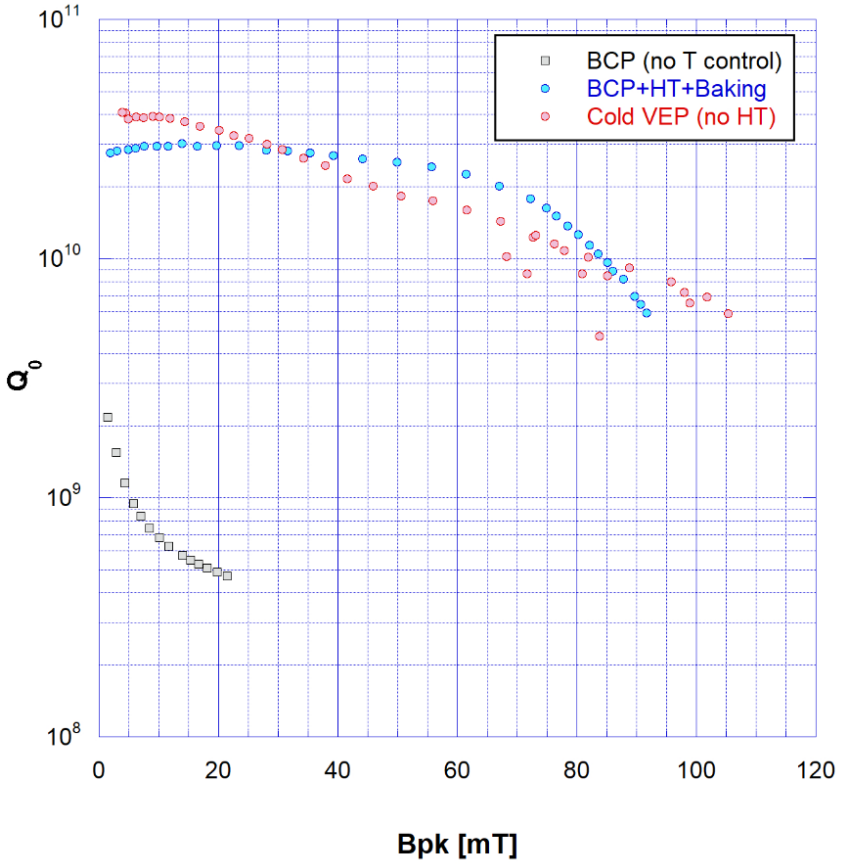
RESULTS WITHOUT HEAT TRATMENT!



Paper CEA-KEK-Marui at SRF 2021

COMPARISON VS BCP (5CELL CASE)

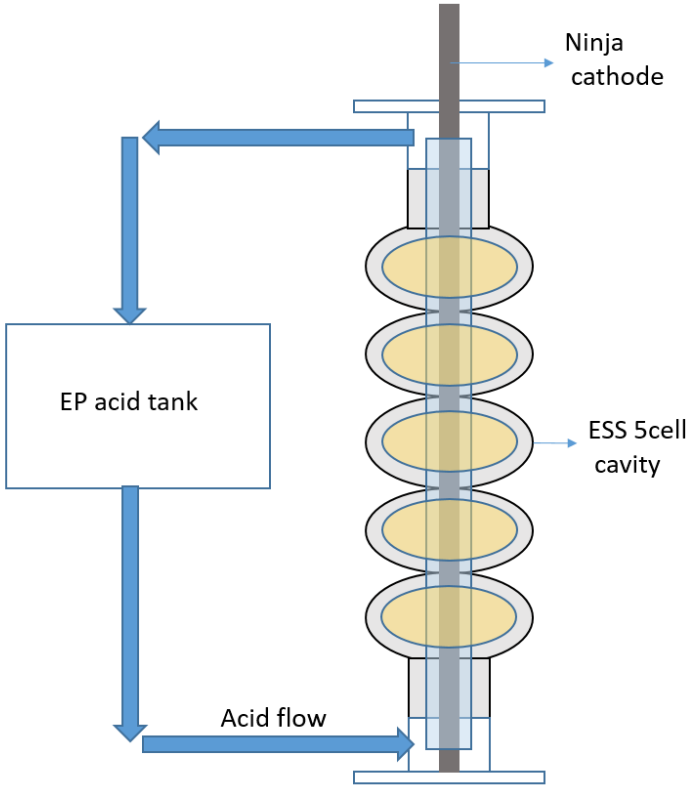
Potential for further significant improvement after Heat Treatment



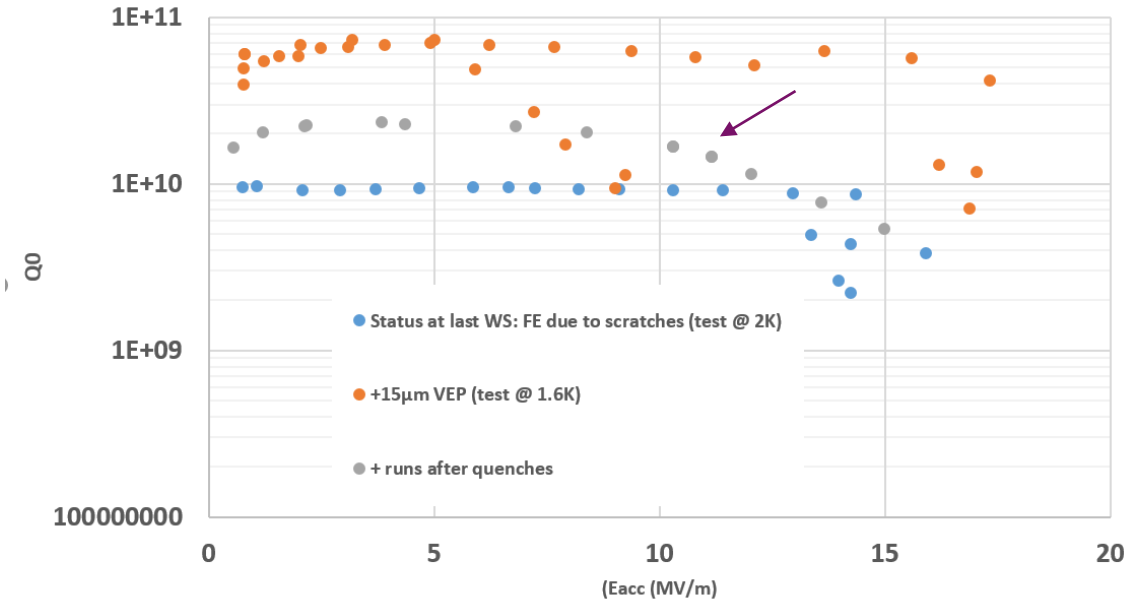
- Superiority Vs BCP should be confirmed
- Design of the Ninja Cathode for 5-Cell ready

FUTURE VEP ACTIVITIES (704MHZ)

- Heat Treatment of the1Cell ESS cavity
- VT after flash VEP
- Purchase of Ninja Cathode for 5-Cell cavity
- VEP of ESS 5Cell prototype cavity
- Comparison with BCP



VEP TREATMENT WITH TSB01 (ILC SHAPE) CAVITY AT SACLAY



Status at last Workshop:

- 30µm removed at Saclay on TSB01, previously VEP'ed at KEK/Marui.
- Strong Field emission measured during Vertical Test
- Scratches observed at irises

→Additional 15 µm VEP sequence and VT: Improved Q0 but still FE (remaining scratches)

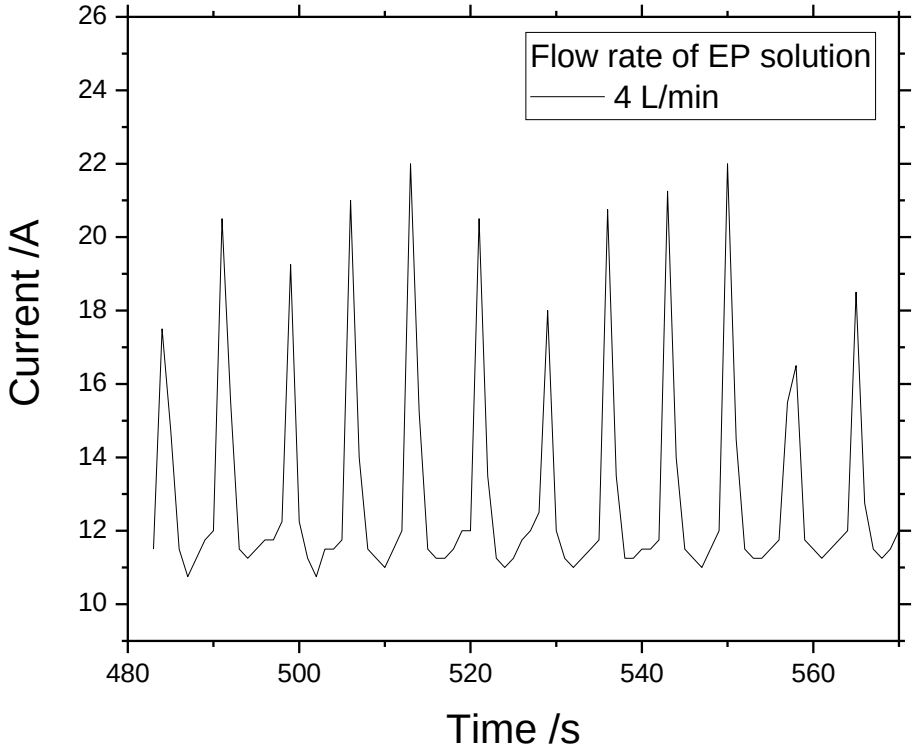
→Additional 15 µm VEP sequence and VT

But:

- Problem detected: Leak observed on the valve
- Additional HPR and assembly with new valve
- Waiting for VT

Horizontal cold EP system with cooling water at STF/KEK

Current-time profile (6 V)



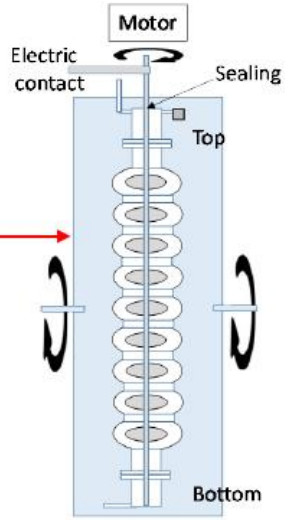
- The Nb surface can be polished more uniformly.
- The in-phase current-time profiles with a period of ~10 s were observed under the optimal condition.
- The effects of cold EP with cooling water on the SRF performance of the cavities are currently being examined.

Plan: Repeating cold-EP of 1.3GHz 9-cell cavities in FY2021.

VEP AT MARUI COMPANY

Improved flipping VEP system

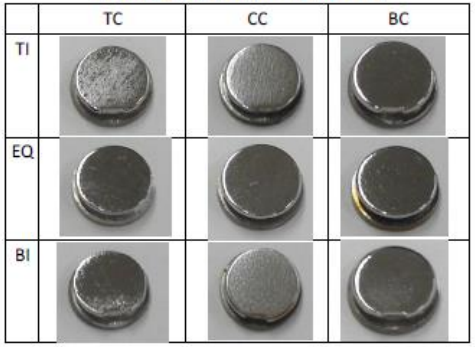
VEP setup



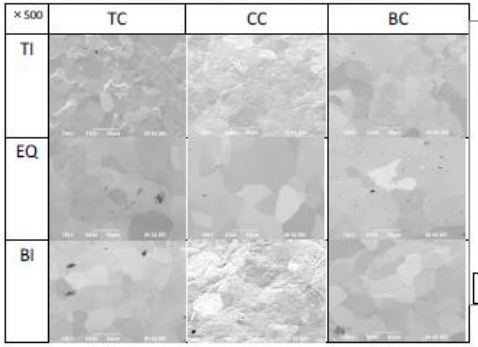
VEP conditions

Parameter	Condition
EP acid	H_2SO_4(98%):HF(55%)=9:1 120L
Voltage	17 – 18 V
Current density	~ 20 mA/cm^2
Cavity surface temperature	~ 15 °C
Cathode rotation speed	20 rpm (Both forward and reverse)
EP acid flow rate	5 – 10 L/min
Target removal	~ 30 μm
EP time	3minON(F) - OFF, flipping -3minON(R) - OFF, flipping 13 times repetition
Cathode type	Ninja cathode V6 (With metal wing and mesh cover)

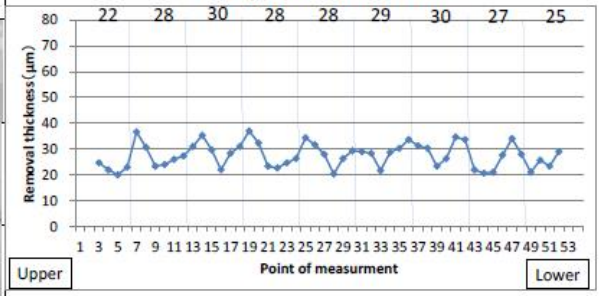
Coupon surface photos



Coupon surface SEM images



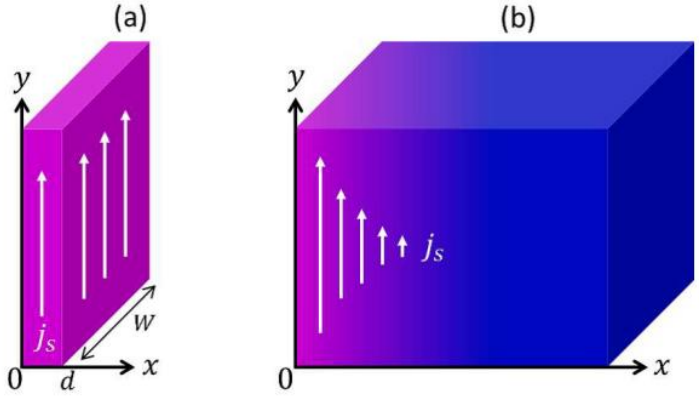
Cavity removal trend



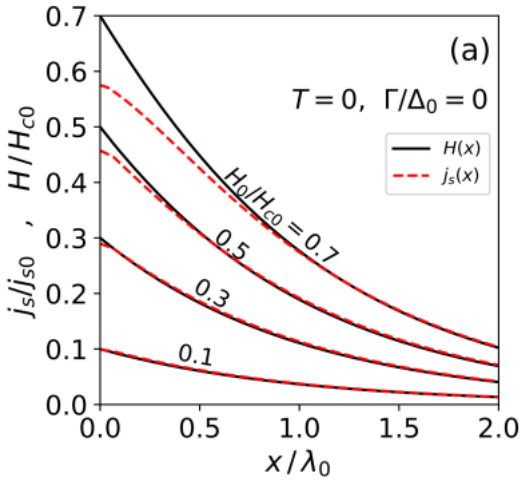
- Improved setup: Semi-automatic flipping and flow direction change
- Improved condition: Lower cavity surface temperature (around 15 C), increased EP acid amount (around 120 L)
- Nb surface after VEP is greatly improved overall, but some rough parts are remained.
- Cavity removal trend is very uniform.

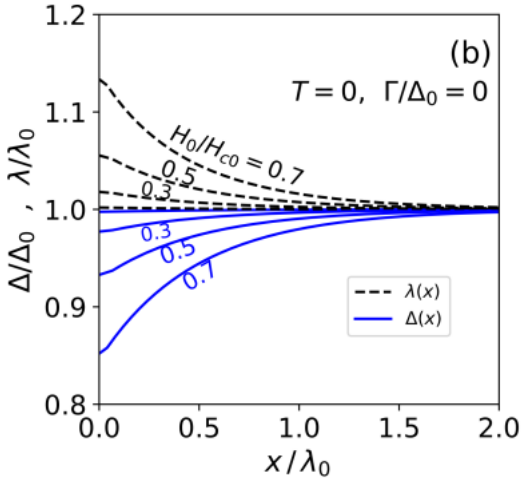
Progresses in SRF theory at KEK (FY2020-#1)

T. Kubo, Physical Review Research **2**, 033203 (2020)



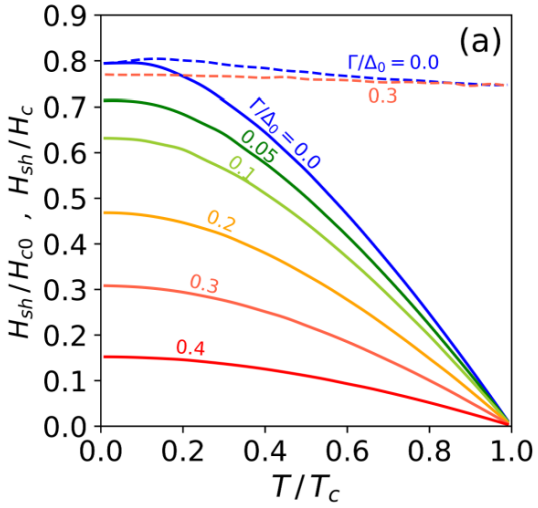
Current distribution

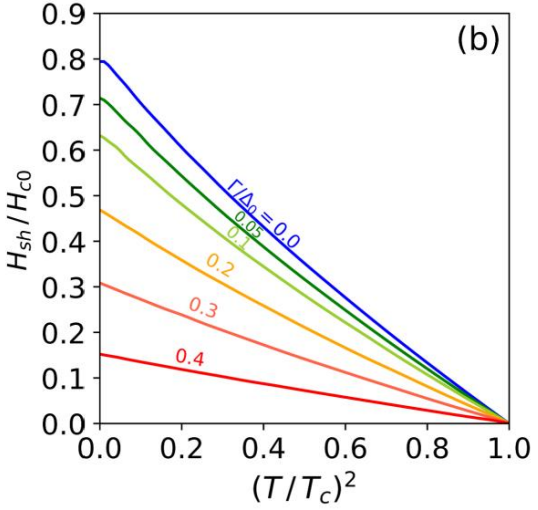




We investigate the effects of Dynes pair-breaking scattering rate Γ on the superfluid flow in a narrow thin-film superconductor and a semi-infinite superconductor by self-consistently solving the coupled Maxwell and Usadel equations for the BCS theory in the diffusive limit for all temperature T , all Γ, and all superfluid momentum.

Superheating field

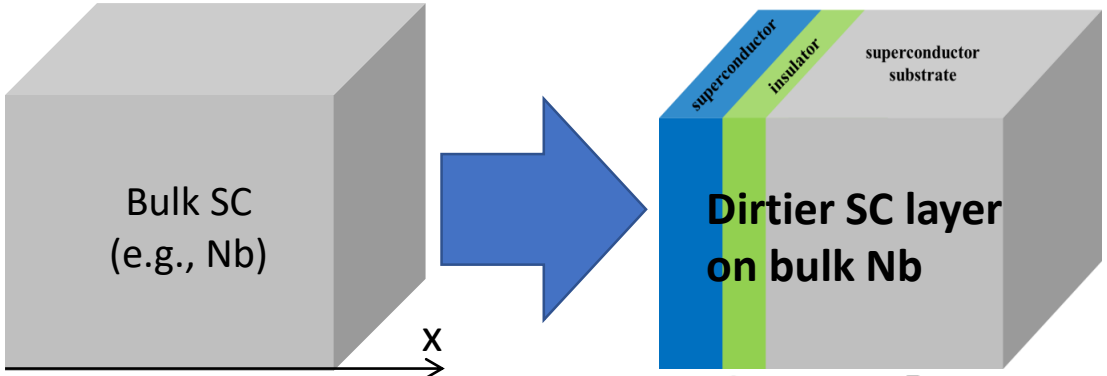


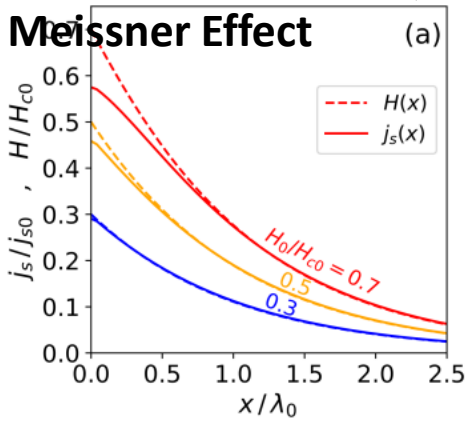


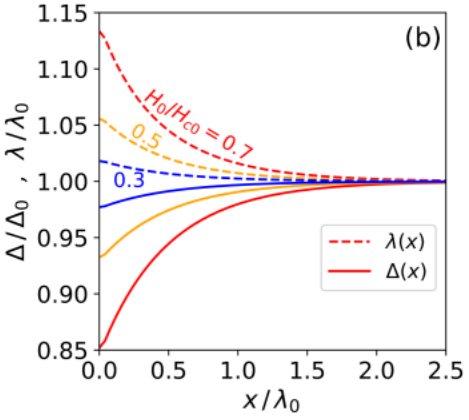
Progresses in SRF theory at KEK (FY2020-#2)

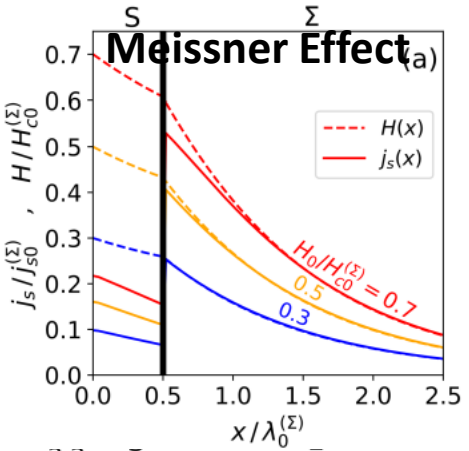
T. Kubo, Superconductor Science and Technology **34**, 045006 (2021)

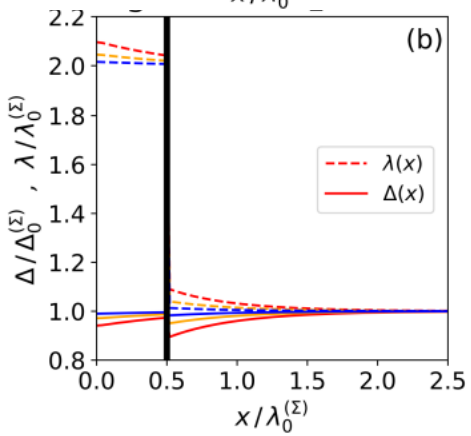
The first microscopic calculation of the dirty heterostructure

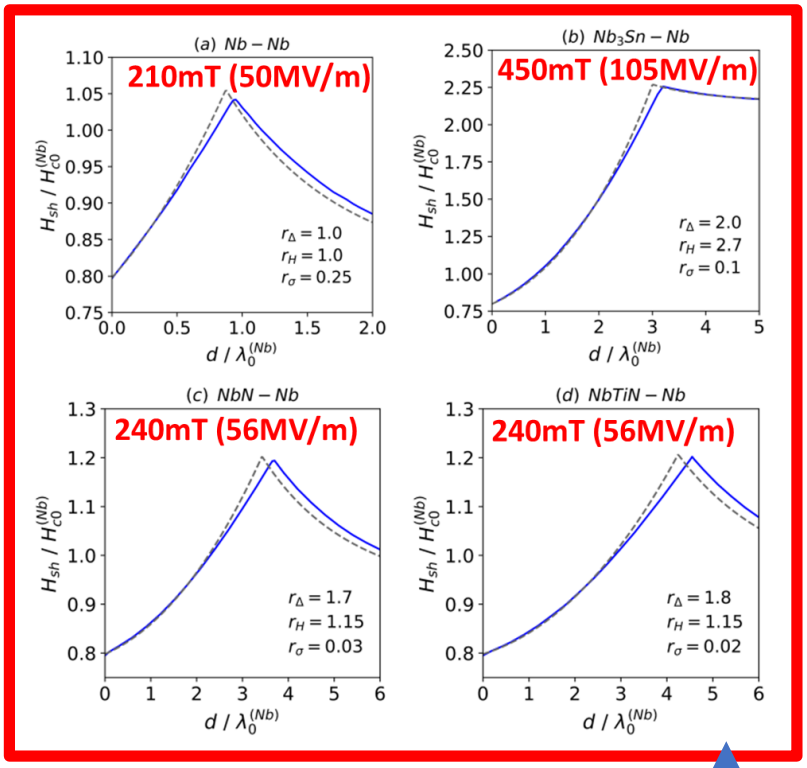










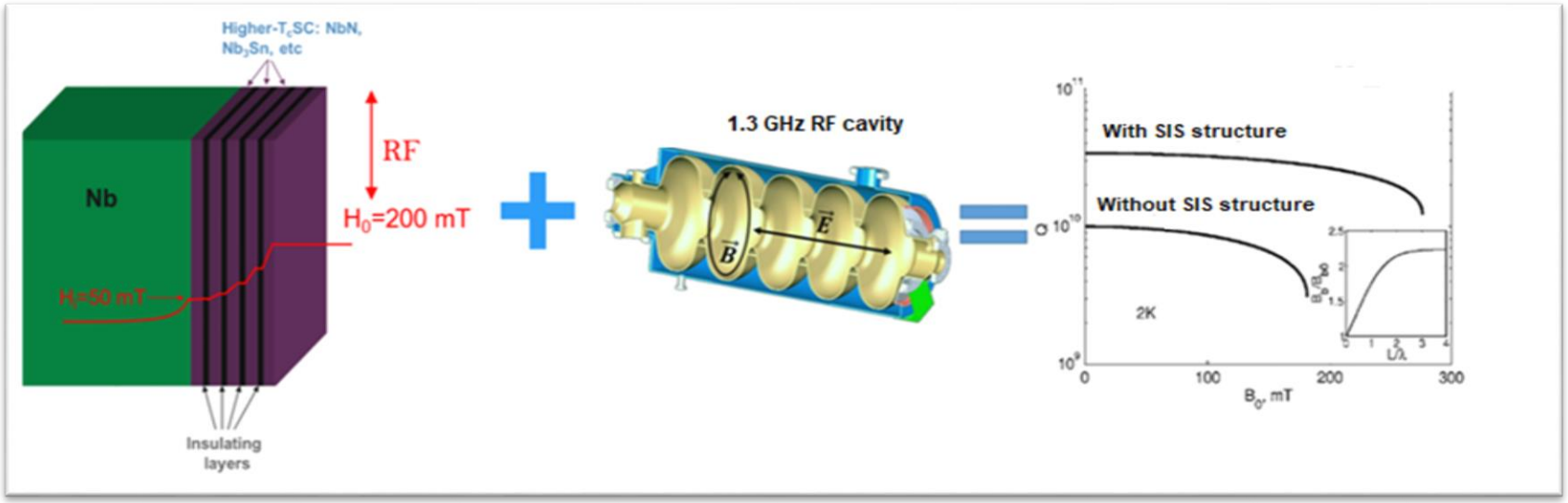


←The current distribution is much different from that of a simple bulk SC: The screening current density in the film is significantly suppressed.

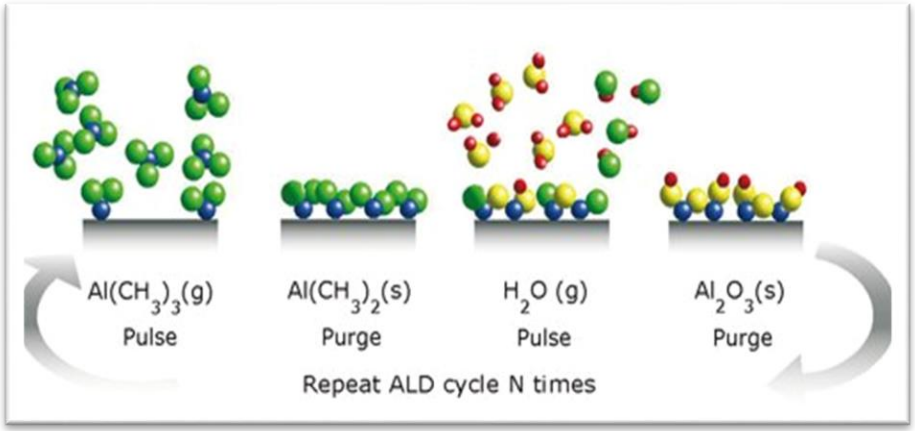
←As a result, the pair-breaking effect due to the RF magnetic field is suppressed (see Δ).

Can enhance the RF field limit

NANO-HETERO STRUCTURES FOR RF CAVITIES



- An original approach proposed by A. Gurevich [1] to improve RF cavities through depositing a superconducting multilayer capable of screening efficiently the magnetic field.

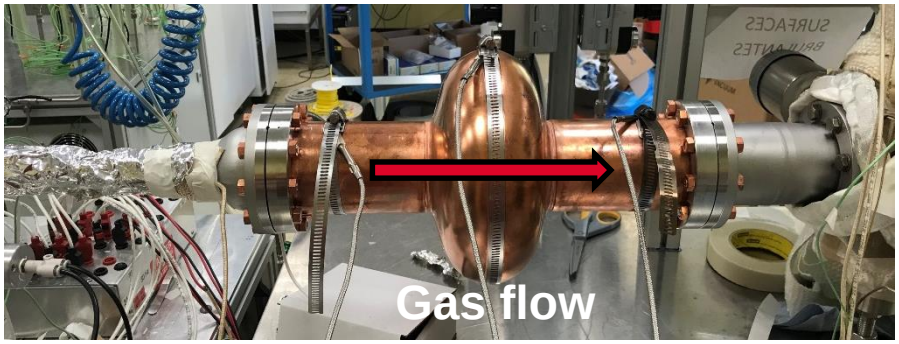


- The multilayer is composed of a compilation of nanometric films of insulators and high T_c superconductors (NbTiN ,MoN).
- Atomic layer deposition (ALD) is the only deposition technique able of providing such high quality Nano-films over large surfaces with complex shapes such RF cavities.

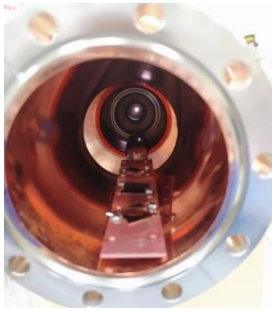
[1] A.Gurevich,Enhancement of RF breakdown field of SC by multilayer coating".Appl. Phys.Lett, 2006.

MULTILAYERS ON 1.3 GHZ CAVITIES

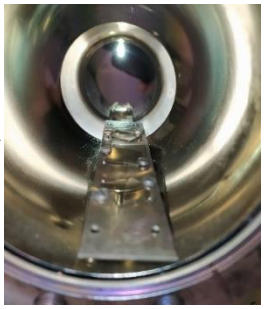
- Deposition test on a Cu cavity :
  NbTiN (50 nm) /AlN (7 nm)



Before

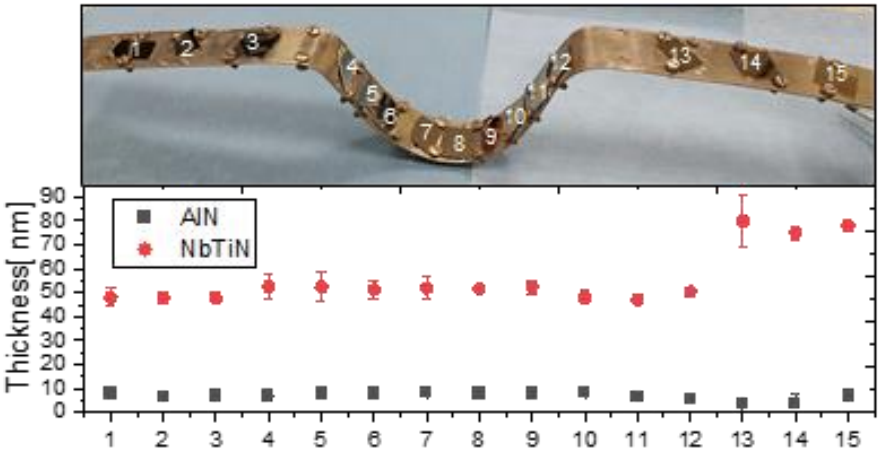


ALD



After

- Thickness, density and roughness and structure variations measured by XRR



- Film homogeneous in structure, thickness and composition (Tc under way) on 1.3 GHz tesla shape cavity

Future:

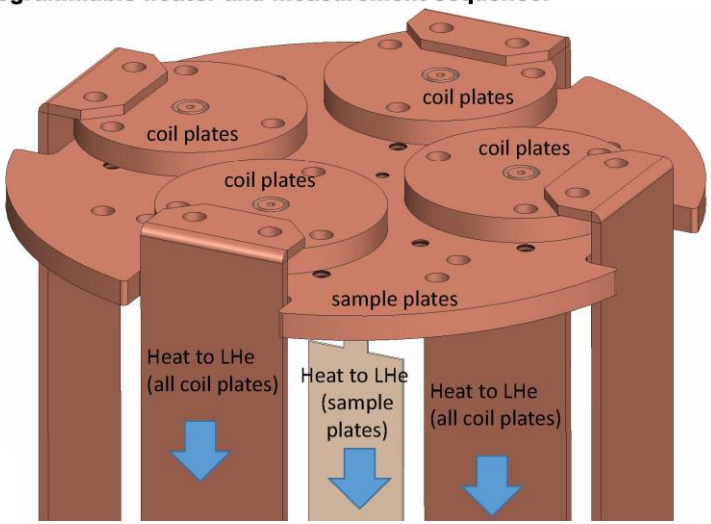
- ALD of Al_2O_3 and multilayers NbTiN/AlN on 1.3 GHz shape cavities homogeneous.
- Tc of NbTiN up to 10 K without post annealing.
- Future: increase Tc of NbTiN, and deposit on Nb cavities.

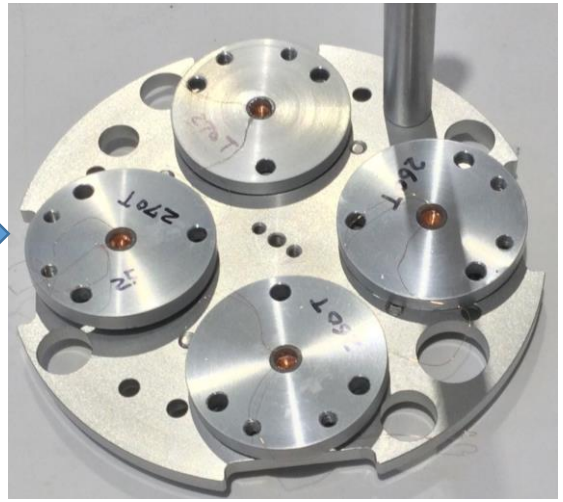
Development of Quad THD system @ KEK

Third Harmonic Detector (THD) System to measure Hc1-effective of thin-film super-conductor samples.

Test setup under preparation:

- **Four samples can be measured at one LHe charge (~one day).**
- **Programmable heater and measurement sequence.**

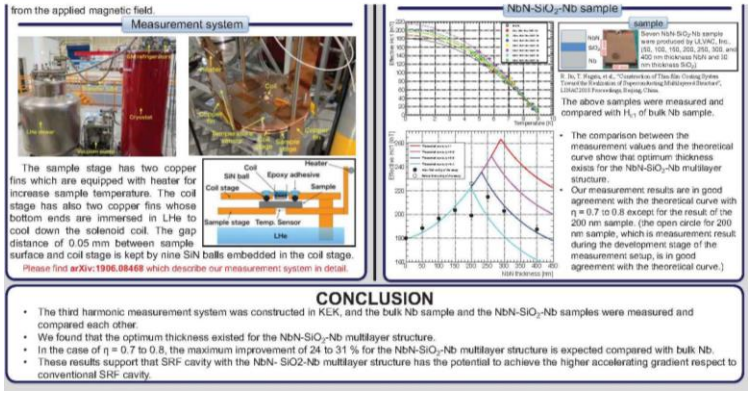




SRF2019 Conf. SUSP013 TUP078

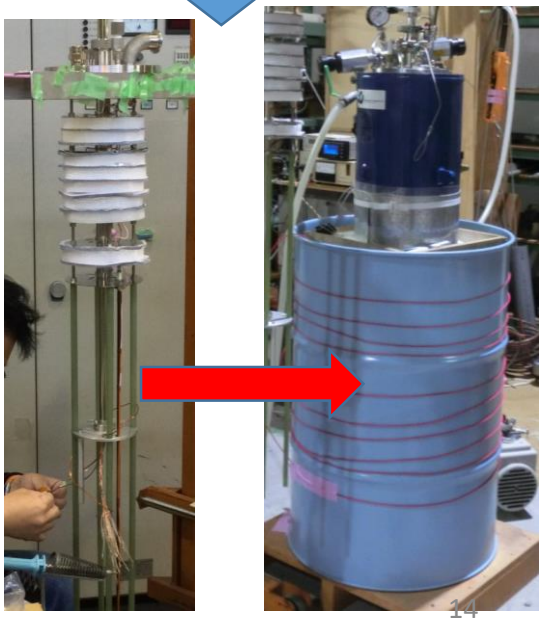
LOWER CRITICAL FIELD MEASUREMENT OF NbN MULTILAYER THIN FILM SUPERCONDUCTOR AT KEK

H. Ito[A,A], H. Hayano[B], T. Kubo[B], T. Saeki[B], R. Katayama[B], Y. Iwashita[C], H. Tongu[C], R. Ito[D], T. Nagata[E], C. Z. Antoine[E]
[A]SOKENDAI (The Graduate University for Advanced Studies), [B]KEK, [C]Kyoto University, ICR, [D]ULVAC, Inc., [E]CEA, Irfu
*hayasei@post.kek.jp



Speed up the measurement cycle by Quad system.

Fast search of wide parameter space !
Both thin-film creation parameter space and film-thickness / material parameter space.



THANK YOU FOR YOUR ATTENTION